Conservation Advice for *Mastacomys fuscus mordicus* (broad-toothed rat (mainland))

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 15 November 2023.

This document combines the draft conservation advice and listing assessment for the *Mastacomys fuscus mordicus* (broad-toothed rat (mainland)). It provides a foundation for conservation actions and further planning.

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Conservation status

Mastacomys fuscus mordicus (broad-toothed rat (mainland)) was listed in the Vulnerable category of the threatened species list under the EPBC Act, effective from 5 May 2016 and transferred to the Endangered category effective from 15 November 2023.

The broad-toothed rat (mainland) was reassessed by the Threatened Species Scientific Committee to be eligible for transfer from the Vulnerable to the Endangered category under Criterion 1. The Committee's assessment is at Attachment A. The Committee's assessment of the species' eligibility against each of the listing criteria is:

- Criterion 1: A2bce+3bce+4bce: Endangered
- Criterion 2: B2ab(i,ii,iii,iv,v): Vulnerable
- Criterion 3: ineligible.

- Criterion 4: ineligible.
- Criterion 5: ineligible.

The main factors making the subspecies eligible for listing in the Endangered category are an overall population decline exceeding 50% over 10 years, from population reduction and habitat destruction caused by the 2019/2020 bushfires, and a continuing decline in extent of occurrence (EOO), area of occupancy (AOO), number of individuals and populations and increased fragmentation of an already fragmented distribution.

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

Species information

Taxonomy

Two subspecies of broad-toothed rat are recognised. The mainland subspecies is conventionally accepted as *Mastacomys fuscus mordicus* Thomas (1922). The Tasmanian subspecies is known as *Mastacomys fuscus fuscus*.

Description

The broad-toothed rat (mainland) has a broad face, short tail and stocky body. It has fine, dense fur, which is brown tinged with rufous above, merging to a paler grey underneath. The fur may have a green tinge due to the presence of algae. The ears are small and round with tufts of hair inside. The feet are brown above and below. The tail is lightly haired, dark above and becoming slightly lighter underneath. It has characteristically large molars in a rounded head, with well-developed cheeks and large jaw muscles. It has a head and body length of 14-17 cm and a tail length of 10-13 cm (Happold 2008, Australian Museum 2014). Its large cream molars, dark brown feet and distinctive scats help to distinguish it from other small mammals in the Alps (Green and Osborne 2012, DPIE 2019). The scats of the broad-toothed rat are easily distinguished from other sympatric species as fresh scats are a distinctive olive-green, fibrous with small fragments of undigested grass and are abundant when present (Milner et al. 2015). However, caution should be used when identifying scats as swamp rats (*Rattus lutreolus*) have similarly grassy/fibrous scats but with a dark outer coating and look somewhat different when dry (Burns 2023. pers comm 23 March). The scats can persist in some environments for up to 5 years so detection of populations for up to 5 years post-occupancy is sometimes possible (Milner et al. 2015).

Distribution

Historical distribution

The historical distribution of the broad-toothed rat (mainland) is known from New South Wales, the Australian Capital Territory, Victoria and South Australia, with numerous sub-fossil deposits found that lie well outside its current recognised distribution and habitat (Bilney 2022. pers comm 13 April, Bilney 2014, VSAC 2012, VSAC 2015, Fusco et al. 2016, McDowell et al. 2023).

The mainland subspecies historically occupied a much wider range of drier habitat types (<700mm rainfall) at lower elevations (<100m), but it is now considered locally extinct in most of these habitats (Menkhorst 1995, Bilney et al. 2010, Fusco et al. 2016, McDowell et al. 2023). It is now locally abundant only in a few alpine regions (Menkhorst 1995, Seebeck & Menkhorst 2000, Green & Osborne 2003, Menkhorst et al. 2008) but also occupies coastal heath. Shipway et al. (2020) conducted surveys in 2014 and 2015 and found a 52% decline in sites occupied pre-1990 across Victoria with site persistence more likely at sites of higher elevation and precipitation and less likely at sites with a higher temperature. Evidence shows declines prior to 1990 were not driven by climate, but rather the pattern of decline was associated with elevation and climate, and occurred rapidly and recently (McDowell et al. 2022, Liddle et al. 2018). Suitable habitat may still exist in the central Tablelands/Blue Mountains and coastal Victoria areas (McDowell et al. 2023).

The subspecies has also declined significantly since European settlement (Seebeck 1971, Menkhorst 1995, Hocking & Driessen 2000, Bilney et al. 2010, Fusco et al. 2016, Shipway et al. 2020). Radiocarbon-dated fossils show that the subspecies occupied such regions as the Fleurieu Peninsula, Kangaroo Island and South Eastern Australia within the last few hundred years (Liddle et al. 2018 and references therein).

Current distribution

The broad-toothed rat (mainland) has a highly fragmented distribution mainly within the alpine and sub-alpine regions of south-eastern Australia (Green & Osborne 2003). The subspecies is known from scattered records from the Otways in Victoria and extending across the Great Dividing Range from near Healesville, Victoria to Kosciuszko National Park in New South Wales and the Brindabella Range in the Australian Capital Territory. There are also two disjunct subpopulations at Barrington Tops and Gloucester Tops in New South Wales (Seebeck & Menkhorst 2000, Green & Osborne 2003, Woinarski et al. 2014, Shipway et al. 2020, Kazi 2022. pers comm 12 May). The subspecies is also known from one 2021 record from the Korumburra area in Victoria, one site in far East Gippsland in Victoria which was most recently detected in 2014 (Shipway et al. 2020) and one in a predator scat record from south-eastern New South Wales from 1996 (VBA 2022). See Map 1 and Table 1 for descriptions of key areas throughout the subspecies range.

The EOO and AOO for the broad-toothed rat (mainland) are continuing to decline. Based on records from 2017-2022 (5 years of surveys within the most recent known range of the subspecies), the EOO is estimated as 52 290 km^2, while the AOO is estimated as 912 km^2. In New South Wales, broad-toothed rats (mainland) have not been detected north of Forest Way in the Barrington Tops since 2002. In Victoria, the subspecies has not been detected in the Dandenong Ranges since 1992 (Wallis 1992, Wallis 2023), in west Gippsland since prior to 1950, and in the Victorian Western District Plains since prior to 1900 (Seebeck & Menkhorst 2000, Green & Osborne 2003, Green et al. 2008, Menkhorst et al. 2008, Happold 2008, Shipway et al. 2020). More recently, the 2019/2020 bushfires have had a significant impact on the subspecies across Victoria, New South Wales and the Australian Capital Territory, with declines in AOO due to loss of areas that burned (Macak & Rowe 2020, Walker et al. 2021, NSW DPE unpublished data). At some sites in New South Wales and eastern Victoria that were severely burnt in the fires, broad-toothed rats (mainland) have yet to return as of 2022 (Rowe 2022. pers comm 17 May, NSW DPE unpublished data). For broad-toothed rats not immediately impacted by the fires, the

wetter weather of La Niña may have benefited subpopulations in some locations during 2021-2022 (Rowe 2022. pers comm 17 May), whilst others would have been impacted by flooding (Parrott 2022. pers comm 8 April). Further, a large proportion of its distribution occurs across Regional Forest Agreement areas in Victoria and NSW (DEWLP 2020) and is exposed to impacts from forestry operations (noting that harvesting of native timber in state forests in Victoria will cease on 1 January 2024).

In Victoria, subpopulations are poorly defined as of 2022. However, 5 geographically distinct regions could be considered: (1) Alpine Victoria – from the Yarra Ranges to the New South Wales border, (2) Western Coastal Victoria – The Otway Ranges to Port Campbell National Park, (3) Central Coastal Victoria – Leongatha to Wilsons Promontory, (4) Eastern Coastal Victoria – Far East Gippsland (1 site, limited evidence), (5) Melbourne Metropolitan – Dandenong Ranges (Rowe 2022. pers comm 17 May). The number of subpopulations within each geographic region has not yet been formally established. There are several genetics initiatives planned and underway that aim to derive a greater understanding of dispersal patterns of the subspecies and delineate subpopulations. Although it is not yet clear that the above regions are evolutionary or management units in the classic sense, they help group localities into regions of practical scope thus aiding management. See Table 1 for further subpopulation details.

In Victoria, resident subpopulations are still found across all elevations surveyed (3–1731 m) however, fewer than half the historical sites that were occupied prior to 1990 were still occupied in 2014/15 (32 of 68 sites) suggesting that the subspecies' AOO in Victoria has decreased markedly (Shipway et al. 2020). Given that scats can remain in some environments for up to 5 years (Happold 1989, Green et al. 2014), estimates of sites currently occupied could be inflated and the decline in broad-toothed rat (mainland) occupied sites across Victoria might be more substantial (Shipway et al. 2020). Post-fire surveys in Alpine National Park revealed declines at surveyed sites. Surveys from 2019-2022 by Zoos Victoria found many lower elevation subpopulations within the Yarra Ranges were in marginal or road-side habitat and were highly fragmented and susceptible to disturbance (Parrott 2022. pers comm 8 April). Recent declines in the Dandenong Ranges could mean the subpopulation is locally extirpated but further surveys are required to validate this possibility.

In the Australian Capital Territory, the broad-toothed rat (mainland) is known from 23 sites in Namadgi National Park (Milner et al 2015). The high occupancy across most sites surveyed in the Australian Capital Territory subalpine region in 2013 was within a small and patchy distribution. On-going monitoring is required to determine whether subpopulations in the Australian Capital Territory are experiencing longer-term declines like those that appear to have occurred in Victoria and Barrington Tops in New South Wales (Milner et al. 2016). However, post fire surveys in 2020 suggest decline in occupancy of more than 80% due to fire (ACT Government 2022).

In New South Wales, the broad-toothed rat (mainland) was known from 5 disjunct subpopulations (NSW SC 2001). As of 2022, Kosciuszko National Park holds the largest subpopulation, followed by the Barrington Tops subpopulation.

Within Barrington Tops National Park, the subspecies is managed at 2 NSW Department of Planning and Environment Saving our Species (SoS) sites, Barrington Tops and Gloucester Tops. The extent to which occupancy extends within and beyond these areas is unknown. The

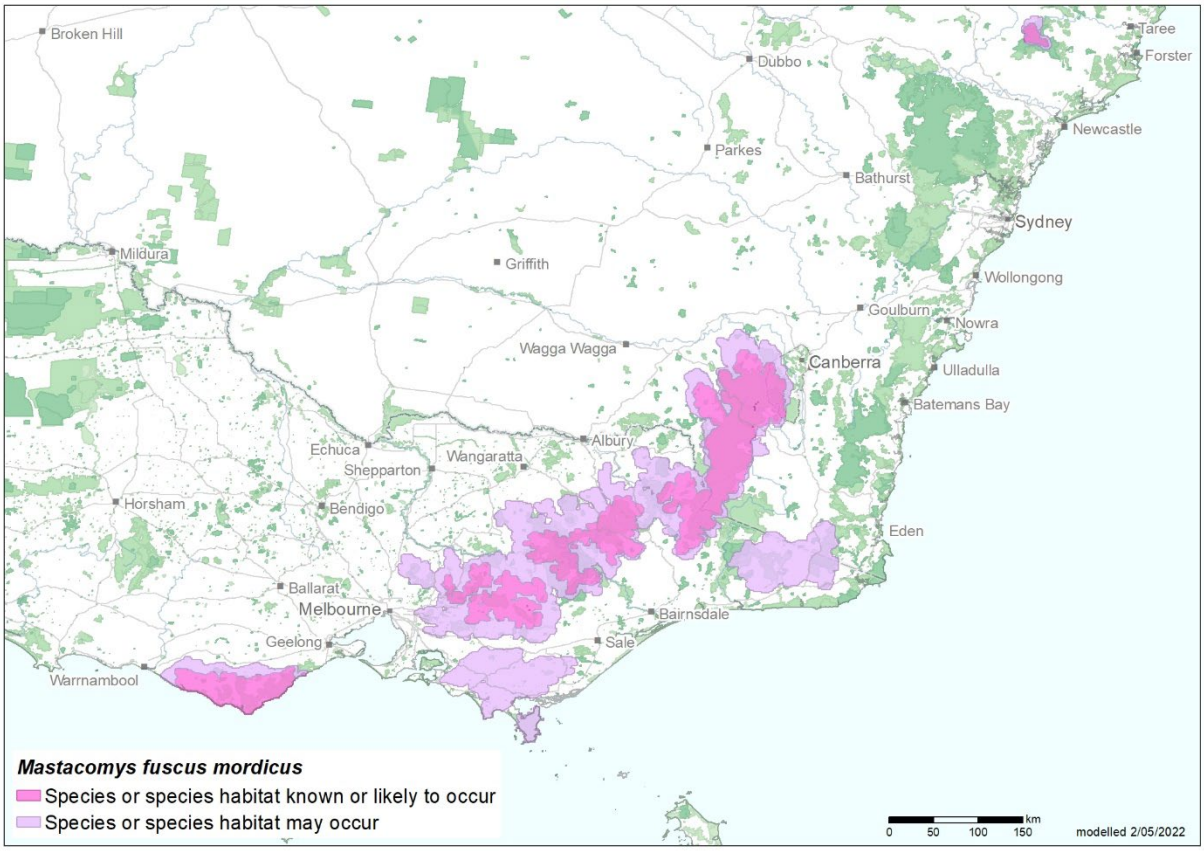
subpopulation has suffered continuing declines due to the pervasive impacts of threats, especially the impact of feral horses (*Equus caballus*). The status of the subpopulation(s) is unable to be established as of 2022 due to monitoring data collected since 1999 lacking sufficient rigour to detect change over time (Alley et al. 2022 in review, NSW DPE 2022b. pers comm 2 May).

Kosciuszko National Park is the stronghold of the species within New South Wales (DPIE 2019). Following on from the New South Wales Bushfire Inquiry in January 2020, broad-toothed rat (mainland) sites in Kosciuszko National Park have been identified as Assets of Intergenerational Significance (AIS), meaning special provision will be made for their conservation (NPWS 2022). The subpopulation is currently 'not on track' due to the impacts of the 2019/2020 fires and delays in feral herbivore management (NSW DPE 2022a. pers comm 31 May, DPIE 2020).

In recent decades several records of the subspecies have been derived via presence in the scats of its predators in coastal East Gippsland and Far South Coast of NSW, suggesting that the species may persist in these areas (Bilney 2022. pers comm 13 April). An example is the 1996 in-scat record located in south-eastern New South Wales (VBA 2022).

Within State Forests in New South Wales, there have been no concerted surveys completed for the broad-toothed rat (mainland) since 2004 when a strategic survey for threatened species within State Forests was conducted (Bilney 2022. pers comm 13 April, Belcher & Leslie 2011).

Map 1. Modelled distribution of broad-toothed rat (mainland)



Source: Base map Geoscience Australia; species distribution data Species of National Environmental Significance database.
Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for

errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything contained herein.

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

Table 1 Subpopulations of the broad-toothed rat (mainland)

State/ Territory	Region	Location	Occupancy (number of sites) trend. Subpopulation size is unknown for all locations
Victoria	Alpine Victoria	Coranderrk Nature Conservation Reserve adjacent to Healesville Sanctuary	In July 2023, detection of scats by Zoos Victoria Detection Dog team, followed by trapping of 3 individuals in the Coranderrk Nature Conservation Reserve, has confirmed the presence of a population of broad-toothed rat (mainland). The population is the only one contained within a predator-proof fence (Zoos Victoria 2023).
Victoria	Alpine Victoria	Yarra Ranges National Park	28% decline; absent in 5 of 19 sites surveyed in 2015 that were historically occupied pre 1990 (Shipway et al. 2020). Presence detected at 14 of 17 new sites surveyed in 2022 (Zoos Victoria unpublished). Often in marginal and roadside habitat and are susceptible to disturbance. Survey in 2023 confirmed presence via scat detection at Lake Mountain (Hutcheson 2023. pers comm 15 February).
Victoria	Alpine Victoria	Alpine National Park	In eastern Alpine National Park, following the 2019/2020 fires, broad-toothed rat occupancy declined 75% as they were absent from 12 of 16 burnt sites surveyed (within the study area) where they had occurred in the last decade with suitable habitat. Occupancy declined by 34% at unburnt sites as they were absent from 8 of 24 unburnt sites surveyed where they had occurred in the last decade with suitable habitats (Macak & Rowe 2022). In eastern Alpine National Park there has been an overall 50% reduction across 40 surveyed sites between 2017 and 2020 (Macak & Rowe 2022). In Mount Hotham and surrounds, broad-toothed rat (mainland) scats were found during targeted searches in 9 of 13 (69%) unburnt sub-alpine woodland and treeless alpine grassland/heathland sites within the study area. None were found at the 8 burnt sites searched (Macak & Rowe 2022).
Victoria	Alpine Victoria	Mt Buller Conservation Reserve	As of 2008-2010 there was a healthy subpopulation mostly on the south side of Mt Buller Alpine Resort. Presence was detected at 17 of 52 sites in a patchy distribution, likely due to ski run maintenance promoting ideal habitat (Whisson et al. 2015, Whisson 2022. pers comm 26 April).
Victoria	Alpine Victoria	Mt Buffalo National Park	Unknown.
Victoria	Alpine Victoria	Baw Baw National Park	100% decline (1 of 1 historically occupied site) (Shipway et al. 2020). As of 2012-2015 there was a significant subpopulation within the Alpine Resort, likely due to ski run maintenance promoting ideal habitat (Beilharz & Whisson 2016). As of 2022 some of the previously occupied heathlands at the resort have degraded or been lost over time. One area was surveyed and detected evidence of presence, although much of the sign was old. More survey effort is needed (Whisson 2022. pers comm 26 April). Outside of the resort, random surveys in 2022 detected signs of the broad-toothed rat (mainland) on Mt St Phillack and Mt St Gwinear and in suitable habitat along the Alpine Walking Track between Mt St Phillack and Mt Erica, suggesting that the subpopulation is doing well. This subpopulation has not been impacted by any fires possibly since 1939 (Whisson 2022. pers comm 26 April). Detection dog surveys in November 2022 have detected aged and new scats at 8 of 16 sites at Mt St Gwinear and at limited

State/ Territory	Region	Location	Occupancy (number of sites) trend. Subpopulation size is unknown for all locations
			sites in Baw Baw Village. No scats were detected near a historical site (Jamieson 2023. pers comm 17 January).
Victoria	Alpine Victoria	Bunyip State Park	50% decline; most recently detected in 2014 at 2 of 4 historically occupied sites (Shipway et al. 2020). Previously detected in 1998 and 2008 (Macreadie et al. 1998, Clarke & White 2008).
Victoria	Alpine Victoria	Moondarra State Park and surrounds	100% decline; no surveys within Moondarra State Park, however surveys in 2014 to the east and west of the park at 2 historically occupied sites, failed to detect broad-toothed rats (mainland) (Shipway et al. 2020). Last detected in 1982 (VBA 2022).
Victoria	Alpine Victoria	Tarra-Bulga National Park	Unknown. One record in the VBA of in-predator scat 18km east of Tarra-Bulga National Park thus exact location of source subpopulation is unknown.
Victoria	Western Coastal Victoria	The Otways	75% decline; no scats detected in 9 of 12 sites surveyed in 2015, historically occupied pre 1990 (Shipway et al. 2020). Presence detected at 31 of 52 sites surveyed in 2022. Absent from 2 historically occupied sites (Burns & Kazi (2022)).
Victoria	Western Coastal Victoria	Port Campbell National Park	Presence detected at all 8 sites via scat surveys in 2022. Some older tunnels/scat detected suggest a decline, but active tunnels and fresher scat nearby indicate the species is not locally extirpated (Burns 2022. pers comm 12 May).
Victoria	Central Coastal Victoria	Lowland areas north of Wilsons Promontory National Park to Leongatha and Korumburra	100% decline; absent in 3 of 3 sites surveyed in 2015, historically occupied pre 1990 (Shipway et al. 2020). Last detected in 1979 (VBA). One confirmed record in 2021 from Korumburra. This is the first record from Central Coastal Victoria since 1979 (Rowe 2022. pers comm 17 May).
Victoria	Central Coastal Victoria	Wilsons Promontory National Park	Absent in 3 of 3 sites surveyed pre-1990 and again in 2015 (Shipway et al. 2020). Last detected in 1979 (Wallis et al. 1982) and one individual trapped in 2022 (Burns 2022. pers comm 5 September, Perkins 2022).
Victoria	Eastern Coastal Victoria	Far east Gippsland (1 site)	Presence detected at one site in 2014, previously detected in 1980 (Shipway et al. 2020). The area has not been extensively surveyed (Rowe 2022. pers comm 17 May).
Victoria	Melbourne Metropolitan	Dandenong Ranges National Park	100% decline; 6 of 6 sites historically occupied pre 1990 (Shipway et al. 2020). One individual trapped in Sherbrooke Forest in 1992 (Wallis 1992, Wallis 2023). Absent from surveys in 2019, 2018 (Rowe 2022. pers comm 17 May) and 2014 (Shipway et al. 2020). Possibly locally extirpated.
Victoria	Melbourne Metropolitan	Victorian State forest estate east of the Hume Highway	12 observations of scats in 2020/2021 in estate forests east of the Hume Highway.
New South Wales	Kosciuszko National Park, Bimberi Nature Reserve and Scabby Range Nature Reserve	Kosciuszko site	Summary: Between 2017 and 2022 (5 years): 57% decline 2 years post-fire based on occupancy decline from 61 to 26 historically occupied fire-effected sites and a 92% decline 1-year post-fire. Evidence: In 2022 broad-toothed rats were recorded at 26 of the 69 sites (37.7%) resurveyed. This number is much higher than the 5 sites out of the same sites in 2021 (7.2%, n=69 sites) i.e., 92% decline 1-year post-fire. The number of sites with broad-toothed rats was still much lower than the original pre-fire survey in 2017, of the 69 sites 61 had presence detected (NSW DPE 2022).

State/ Territory	Region	Location	Occupancy (number of sites) trend. Subpopulation size is unknown for all locations
			Trapping survey in Northern Kosciuszko National Park between Tooma Dam and Coolamine Homestead confirmed presence of over 30 individuals (Fuik-Burgemeestre 2023. pers comm 16 February).
New South Wales	Buccleuch and Bondo State Forests	Buccleuch and Bondo State Forests	As of 2003 and 2004, presence in 15 of 50 sites in Buccleuch State Forest (Belcher & Leslie 2011). There were 2 incidental records obtained during northern corroboree frog surveys in Bondo and Buccleuch State Forests (Bilney 2022. pers comm 13 April).
New South Wales	Bago State Forest	Bago State Forest	As of 2003 and 2004, presence in 9 of 34 sites in Bago State Forest (Belcher & Leslie 2011).
New South Wales	Maragle State Forest	Maragle State Forest	As of 2003 and 2004, presence in 8 of 8 sites in Maragle State Forest (Belcher & Leslie 2011).
New South Wales	Barrington Tops National Park and State Conservation Area	Barrington Tops site	Presence detected at 7 of 15 sites surveyed (47%) (DPIE 2020) As at 2008 3 breeding subpopulations (O'Brien et al. 2008). Confirmed in Polblue Swamp via presence of pellets (Slade 2022. pers comm 13 April) and subsequently the capture of 6 individuals in 2022. No trapping conducted between 2018 and August 2020. Intensive trapping only occurred in early 2022 and was limited to three locations heavily impacted by horses (NSW DPE 2022b. pers comm 2 May). Classified as an "Endangered population" in 2001 and described as 'in imminent risk of extinction' (NSW SC 2001).
New South Wales	Southeastern Barrington Tops National Park	Gloucester Tops site	Presence detected at 1 of 2 areas surveyed in 2019/2020 and 2018/2019. The broad-toothed rat (mainland) was recorded as locally extirpated at the 3 swamps that make up this site as of 2004 (O'Brien et al. 2008), however ongoing surveys have detected the subspecies as recently as 2020 DPIE 2020a). Opportunistic surveys conducted in 2021 detected broad-toothed rat (mainland) scats at several locations. More targeted surveys are required to better record the distribution in this area (NSW DPE 2022. pers comm 2 May). Classified as an "Endangered population" in 2001 and described as 'in imminent risk of extinction' (NSW SC 2001).
New South Wales	Barrington Tops State Forest	Barrington Tops State Forest	Likelihood of subpopulations within Barrington Tops State Forest (Slade 2022. pers comm 13 April).
Australian Capital Territory	Namadgi National Park	Namadgi National Park	Summary: Between 2013 and 2020 (7 years): 83% decline based on presence at 2 of 12 historically occupied fire-effected sites. Evidence: As of 2013, there were 23 sites known to support the broad-toothed rat (mainland) (Milner et al. 2015). Post the 2019/2020 fires, surveys were undertaken in 2020 at a total of 14 sites, 2-6 months post fire, where broad-toothed rats (mainland) had previously been known to occur (Milner et al. 2015). No scats were found at 10 of the 12 burnt sites (83%), while scats were found at the 2 unburnt sites (ACT Government 2022. pers comm 29 April).

Cultural and community significance

The cultural, customary and spiritual significance of species and the ecological communities they form are diverse and varied for Traditional Owners and their stewardship of Country. This section describes some examples of this significance but is not intended to be comprehensive or applicable to, or speak for, Traditional Owners. Such knowledge may be held by Traditional Owners who are the custodians of this knowledge and have the rights to decide how this knowledge is shared and used.

The cultural significance of the broad-toothed rat (mainland) to Traditional Owners is not documented. The broad-toothed rat (mainland) (post 1999) occurs on the lands of many Traditional Owner groups. In Victoria, the subspecies occurs within the boundaries of 5 Registered Aboriginal Parties (RAPs); Taungurung Land and Waters Council Aboriginal Corporation, Wurundjeri Woi Wurrung Cultural Heritage Aboriginal Corporation, Bunurong Land Council Aboriginal Corporation, Gunaikurnai Land and Waters Aboriginal Corporation, and Eastern Maar Aboriginal Corporation (Carrizo 2021). In New South Wales, the subspecies occurs within the boundaries of 8 Local Aboriginal Land Councils (LALC); Bega LALC, Brungle/Tumut LALC, Wagonga LALC, Eden LALC, Merrimans LALC, Wanaruah LALC, Forster LALC and Karuah LALC (Carrizo 2021). In the Australian Capital Territory, the subspecies occurs on the lands of the Ngunnawal People (Carrizo 2021).

The word 'Tooarrana' was assigned as an Aboriginal common name by the Federal government to the broad-toothed rat across the species range, including Tasmania, circa 1995 (Braithwaite et al. 1995). The assignation of the word 'Tooarrana' to the species was part of an initiative to provide 'Australian names for Australian rodents' and to avoid the undesirable associations, of introduced vermin, often attached to the words 'rat' and 'mouse' that impede the conservation of native rodents due to negative public perception and associated challenges of securing funding for conservation (Braithwaite et al. 1995). However, Traditional Owners were not consulted on this assignation, and the reliance on the spelling and interpretations of Aboriginal words by European recorders can be problematic (Tasmanian Aboriginal Centre 2023a). 'Tooarrana' is not an Aboriginal word, but a spelling made by a European recorder attempting to reproduce unfamiliar sounds in his own spelling system (Tasmanian Aboriginal Centre 2023b).

The below are words that have been verified with Traditional Owners. The word 'tuna' means 'rat' in palawa kani, the language of Tasmanian Aborigines (Tasmanian Aboriginal Centre, 2023b). The local name for the broad-toothed rat on Ngunnawal Country is "Luda" (Winanggaay Ngunnawal Language Aboriginal Corporation 2022).

Collaborative work with Traditional Owner organisations to benefit the broad-toothed rat is yet to be established. However, in Victoria, there are plans to conduct some scat surveys with Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) commencing in 2022 (Burns 2022. pers comm 12 May). Additionally, the Jaithmathang TABOO (Jaithmathang Traditional Ancestral Bloodline Original Owners First Nation Aboriginal Corporation) have expressed interest in the broad-toothed rat and its protection and recovery on Bimble (Country) (Parrott 2023. pers comm 14 February).

Relevant biology and ecology

Many aspects of the ecology and life history of the broad-toothed rat (mainland) are relatively well known due to a series of intensive studies (Happold 1989, 1998, Carron et al. 1990, Bubela et al. 1991, Bubela & Happold 1993), although these studies are not necessarily representative of the full environmental range occupied by the species, due to their focus on one location: Smiggin Holes in Kosciuszko National Park.

Behaviour and Diet

The broad-toothed rat (mainland) is a terrestrial and mostly nocturnal rodent. It is herbivorous, with grasses forming the major component of its diet (Carron et al. 1990). In summer it nests in burrows in the soil. In alpine areas in winter, it dens communally during the day in nests of shredded grass situated in dense undergrowth or under logs beneath the snow (Bubela & Happold 1993). In alpine and sub-alpine areas, it is active in the vegetation layer under snow cover (Happold 1998). The broad-toothed rat (mainland) builds tunnels which are important features of its life-history and behaviour but are also a focal point of predation by feral cats (*Felis catus*) (Parrott 2022. pers comm 8 April).

Habitat

Broad-toothed rats (mainland) are now predominantly found on sites that have a cooler climate, significant annual rainfall (> 1000 mm), a plentiful food supply and adequate vegetative cover (Green & Osborne 2003, VSAC 2012). Currently most such sites are at higher elevations (> 1500 m), although the subspecies is also found in some coastal and foothill areas (Shipway et al. 2020, VSAC 2012). The subspecies occupies a variety of areas across its range, but typically is highly selective in any region. Preferred habitat includes alpine and subalpine heathlands, grassland adjacent to boulder outcrops, swamps, sedgelands, coastal grassy or shrubby dunes, and sometimes forests with grassy understories (Wallis et al. 1982, Green & Osborne 2003). Habitat suitability is largely determined by the availability of cover and grasses (Green & Osborne 2003, Menkhorst et al. 2008). Proximity to drainage lines is also important, with a decreasing likelihood of detecting the subspecies with increasing distance from a drainage line (Milner et al. 2015). Drainage lines are likely to support a higher density and complexity of vegetation, and a higher abundance of grasses (Carron et al. 1990). In mainland alpine areas its preferred habitat has rocks, grasses and shrubs (including *Poa*, *Phebalium* and *Prostanthera* species) (Carron et al. 1990).

In part, the habitat now occupied by the subspecies is naturally discontinuous, creating a fragmented distribution for this subspecies. However, many areas of apparently suitable habitat are unoccupied (Green & Osborne 2003), and the subspecies may have limited ability to disperse across unfavourable habitat. Where discrete habitat patches are relatively close together, there may be sufficient dispersal to treat these fragmented occurrences as a metapopulation (O'Brien et al. 2008).

Life history

Home range size and social dispersion vary seasonally, from approximately 0.1 ha to 0.3 ha. Breeding is seasonal, with females giving birth to one or 2 litters (of 1 to 4 young) per season, between October and March (Happold 1998, Green 2007). Sexual maturity is reached in 6–12 months (Happold 2008, 2011) and longevity is estimated between 2 and 3 years (Happold 2011). Generation length is assumed to be 1 to 2 years (Woinarski et al. 2014).

Fire Ecology

Sphagnum peatlands (an Endangered Ecological Community under the EPBC Act) and surrounding woodland habitat should not be subject to fires, particularly the fire-sensitive Sphagnum moss bog communities. While peatlands in good condition are relatively resistant to low-intensity fire, increased evaporation and reduced rainfall with a changing climate (Lucas et al. 2007) is predicted to dry out Sphagnum peatlands and significantly increase the risk and impact of fire on the community (Macdonald 2009, Milner et al 2016). The reliance on, and use of, above-ground dense tunnel structures for travel and foraging likely makes broad-toothed rat (mainland) particularly susceptible to fire, leaving them exposed to the elements and predators if fire destroys their tunnel systems (Parrott 2022. pers comm 8 April).

Correlative studies demonstrate requirements for unburnt (>15 years post-fire) vegetation (Hocking & Driessen 2000, Green 2007) whilst, more recently, abundance of the subspecies has been found to be greater at sites that had not burnt for 80 years (Walker et al. 2021). It should be noted that several heath plant species associated with the subspecies require fire for reproduction. A low intensity fire frequency of 10–40 years is likely to be appropriate for maintaining or improving heath habitat for the broad-toothed rat (mainland) (NPWS 2005).

In general, recent observed declines from fire affected sites across the ACT, New South Wales and Victoria, show that fire removes the subspecies from areas occupied. As vegetation recovers, these areas can be recolonised from areas of unburnt habitat adjacent or within the burnt patch where the subspecies may persist. However, it takes a long time for the vegetation to recover to a point where it is suitable for broad-toothed rats (mainland) to move back in (NSW DPE 2022c. pers comm 13 April). In a post-fire review in Alpine National Park, sites outside the 2019/2020 burn area that had been burnt 2 to 3 times in the last 20 years during previous bushfires were structurally similar to recently burnt sites and generally contained no vegetation considered to be suitable broad-toothed rat (mainland) habitat (Macak & Rowe 2022).

While broad-toothed rats (mainland) are good dispersers and have been shown to recolonise high-quality patches following local extinction (such as following high intensity fires), re-colonisation following such events will depend on the level of connectivity between subpopulations, as well as proximity from source subpopulations. The persistence of broad-toothed rat (mainland) subpopulations in partially burnt and remaining unburnt habitat, and their effective fragmentation, is further threatened/mediated by the compounding impacts of feral herbivores and predators (Macak & Rowe, 2022). Feral herbivore impacts increase following fire due to higher activity in unburnt habitats and delay in recovery of burnt habitats. Predation threat increases due to the reduced area of unburnt habitat, the loss of cover in burnt habitat and the increased activity of cats and foxes at burnt areas (Macak & Rowe 2022).

As fires become more frequent and if feral herbivores increase, impact on vegetation recovery post-fire is likely to reduce the species resilience (NSW DPE 2022a. pers comm 31 May). These fire-induced reductions of broad-toothed rat occupancy and abundance are likely to have long-term implications for subpopulations as evidenced by the finding that the subspecies was more abundant at long-unburnt sites (no fire in the past 80 years), and with abundance steadily declining with increasing number of fires (Walker et al. 2021).

Habitat critical to the survival

All habitat (as described above) where the broad-toothed rat (mainland) occurs, or could occur, is considered critical to the survival of the species. In summary, preferred habitat includes alpine and subalpine heathlands, grassland adjacent to boulder outcrops, swamps, sedgelands, coastal grassy or shrubby dunes, and sometimes forests with grassy understories (Wallis et al. 1982, Green & Osborne 2003). The subspecies prefers a cooler climate, annual rainfall greater than 1000 mm (Green & Osborne 2003), proximity to drainage lines (Milner et al. 2015) and is typically at elevations greater than 1500 m, although the subspecies is also found in some coastal and foothill areas (Shipway et al. 2020, VSAC 2012) and the species climatic niche may be considerably broader than indicated by the areas currently occupied (McDowell et al 2023). A higher density and complexity of vegetation, with a higher abundance of grasses is preferred. Grasses and shrubs preferred include *Poa, Phebalium* and *Prostanthera* species (Carron et al. 1990).

No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

Important populations

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

At the time of preparing the Conservation Advice, sufficient information to enable description of all important populations was not available, although genetic work is underway for the subspecies. The Barrington Tops population is important due to being disjunct and the Kosciuszko population is important due to being a stronghold of the subspecies. However, due to ongoing declines, and the broadscale nature of the threats, all populations require protection to support the recovery of the subspecies.

Threats

The broad-toothed rat (mainland) faces a continuing and widespread range of threats including selective predation by introduced predators, such as the European red fox (*Vulpes vulpes*) and feral cat, fire regimes that cause declines in biodiversity, habitat degradation and destruction by feral herbivores, climate change, habitat loss and fragmentation. Climate change also represents a significant and increasing threat through its effects on the frequency, intensity and scale of fire, as well as effects on drought frequency and duration.

The threats listed above are likely to be synergistic. For example, a disturbance event such as a fire may facilitate predation opportunities for introduced predators due to reduced vegetative cover. Trampling by feral horses promotes drying of alpine bogs, exacerbating the effects of climate change. Additionally, grazing by feral herbivores has a negative impact on regenerating vegetation at burnt sites, impairing the ability of habitats to return to the previously suitable habitat for the broad-toothed rat (mainland).

Table 2 Threats

Threats in Table 2 are noted in approximate order of highest to lowest impact, based on available evidence.

Threat	Status [a]	Evidence
Invasive predators		
Predation by the European red fox (*Vulpes vulpes*)	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: increasing • Extent: across entire range	The broad-toothed rat (mainland) is at high risk of population decline and extinction through predation from the European red fox (*Vulpes vulpes*) as it falls within the Critical Weight Range (Burbidge & McKenzie 1989) of prey species typically targeted by the European red fox. The European red fox has a broad and opportunistic diet and has switched to consuming more native species, including native rodents, in response to biological control of the invasive European rabbit (*Oryctolagus cuniculus*) over the last 70 years (Fleming et al. 2021). Milner et al. (2015) suggest that control of both the European red fox and rabbits is likely to be more effective when undertaken concurrently at a landscape scale. Native rodents are more commonly preyed upon by foxes around intact vegetation and with increasing distance from the coast (Fleming et al. 2021). The broad-toothed rat (mainland) has been identified in the diet of European red foxes (Brunner et al. 1975, Wallis et al. 1986, Bubela & Happold 1993, Green 2002, Davis et al. 2015). More recently, European red foxes have been found to selectively prey upon broad-toothed rats (mainland). Green (2002) found that European red foxes preferred to hunt broad-toothed rats (mainland) over bush rats (*Rattus fuscipes*), despite the two species occurring at similar densities, at both alpine and subalpine altitudes. Milner et al. (2015) suggest the disparity in predation rate to be because the broad-toothed rat (mainland) is slower and less aggressive than the bush rat. The broad-toothed rat also uses well established runways and nests communally above ground in winter, making them more detectable by foxes. In a comparative study of European red fox and dingo(*Canis familiaris dingo*) diets across Victoria, the broad-toothed rat (mainland) was the threatened species most frequently eaten by European red foxes and comprised a greater proportion of the European red fox diet than that of dingoes (Davis et al. 2015). Shipway et al. (2020) found predation rates by European red foxes on the subspecies to be greater at higher elevations. Predation pressure from European red foxes may be compounded following fire (Shipway et al. 2020, Hradsky et al. 2017, Legge et al. 2023) and habitat modification by feral herbivores (VSAC 2012). Predation by introduced predators has caused range and niche contraction for the broad-toothed rat (mainland) and continues to prevent niche expansion to areas that would otherwise be suitable (Bilney et al. 2010). At all but 1 of 14 sites surveyed in the Australian Capital Territory, the presence of feral animals, including foxes, was found to have a negative effect on the relative

Threat	Status [a]	Evidence
		abundance of broad-toothed rat (mainland) (Milner et al. 2015).
Predation by feral cats (*Felis catus*)	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: unknown • Extent: across entire range	The broad-toothed rat (mainland) is at high risk of population decline and extinction through predation from feral cats (*Felis catus*) as it falls within the Critical Weight Range (Burbidge and McKenzie 1989) of prey species typically targeted by feral cats. Predation by feral cats on broad-toothed rats (mainland) has been observed in monitored subpopulations via cameras traps, with cats potentially using the subspecies tunnel systems and more predictable behaviour for hunting (Parrott 2022. pers comm 8 April). The broad-toothed rat (mainland) has been recorded as being a species killed or consumed by feral cats in a continental-scale analysis of feral cat diet (Doherty et al. 2015). Feral cats specifically target broad-toothed rats (mainland), with the species being found in a higher proportion of cat stomach contents, than more locally abundant rodents (Schroder et al. in review). In the subalpine areas of Kosciuszko National Park, stomach and bowel contents from 167 feral cats were sampled from 2004-2019. In total there were 220 morphological identifications of prey detected. In most cases only one type of prey was detected per sample. Ten species of mammals were detected, with bush rat and the threatened broad-toothed rat (mainland) detected in over 70% of samples (43.71% and 31.14% respectively) (NSW DPE unpublished). In New South Wales, feral cat predation occurs especially around ski resorts (NSW OEH -), probably because cats attain higher densities near human infrastructure. Predation by feral cats is exacerbated in areas that have recently burned (Green and Sanecki 2006, Milner et al. 2015, Shipway et al. 2020, NSW DPE 2022a. pers comm 31 May).
Climate Change		
Fire regimes that cause declines in biodiversity [b]	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: increasing • Extent: across entire range	Fire regimes that cause declines in biodiversity (i.e., fire being too frequent and too severe) can cause localised population extinction (DAWE 2022). High-severity fire significantly impacts subpopulations of the subspecies in periods immediately following fires through direct mortality and loss of resources (for example food and shelter via reduced habitat extent and suitability) (Walker et al. 2021, Menkhorst et al. 2008, Happold 2008, VSAC 2012). The removal of vegetation by fire makes the subspecies more vulnerable to predation by cats and foxes (NSW DPE 2022a. pers comm 31 May). Although the broad-toothed rat (mainland) can survive the immediate impacts of a fire event in nearby unburnt patches, subpopulations may still decline because fire compounds threats from feral herbivores and predators. Grazing from feral herbivores prevents regeneration of habitat and can prevent restoration of suitable vegetation structure. Pressure from predators is increased as individuals of the subspecies begin recolonising an area (Green and Sanecki 2006, Woinarski et al. 2015, Milner et al. 2015, Shipway et al. 2020). The extirpation of the broad-toothed rat (mainland) following high severity fire may fragment and isolate subpopulations, making them more susceptible to stochastic extinction events (Walker et al. 2021).

Threat	Status [a]	Evidence
		Climate projections for south-eastern Australia include reduced rainfall, increased average temperatures, greater frequency of extreme droughts, greater frequency of extreme fire weather days and an extension of the fire season (CSIRO & BOM 2015). Such conditions are conducive to greater frequency, severity and size of bushfires in south-eastern Australia (Abrahm et al. 2021). **2003, 2006 and 2009 bushfires** In Victoria, a high proportion of the subspecies range was burnt by major bushfires in 2003, 2006 and 2009, the impacts of which were unknown but presumed to be detrimental (VSAC 2012). In the Australian Capital Territory, the major bushfires of 2003 burnt 70-90% of known and potential habitat of the subspecies with moderate to high severity (Carey et al. 2003, Milner et al. 2015). Evidence of the species persistence post-fire was found in unburnt habitat refugia at Ginini Flats (Ramsar site) and Snowy Flats. No scats were found in the burnt areas surrounding the habitat refugia (Carey et al. 2003). Thirteen years post-fire the species appeared to still maintain its pre-fire distribution in the Australian Capital Territory, but the extent to which subpopulations declined and whether a genetic 'bottleneck' occurred is not known (Milner et al 2016). In New South Wales, approximately 69% of the subspecies' modelled habitat in Kosciuszko National Park was impacted by the 2003 fires (OEH 2011) causing declines in broad-toothed rat (mainland) subpopulations (Green and Sanecki 2006). At some long-term monitoring sites, subpopulations were only just returning to pre-fire numbers, whilst others had not recovered, as of 2019 (Green unpublished data in DPIE 2019). **2019/2020 bushfires** The bushfires that burnt across south-eastern Australia's temperate forests in the 2019/2020 bushfire season were unprecedented in their scale, intensity, and impacts (Abrahm et al. 2021). The Australian alpine region was heavily impacted, with over 570,000 ha burnt, 60% of which was at high or very high severity (DAWE 2020a) Occupancy modelling by Walker et al. (2021) based on surveys in burnt and unburnt areas of the Australian Alpine region, in the Australian Capital Territory, New South Wales, and Victoria, showed that the probability that a site was occupied substantially decreased with increasing fire severity. Broad-toothed rats (mainland) were more abundant at long-unburnt sites (no fire in the past 80 years), and abundance models showed that abundance declined with increasing fire severity, increasing number of past fires and increasing impact of feral horses. In the Australian Capital Territory, post the 2019/2020 fires, surveys were undertaken in 2020 at a total of 14 sites, 2-6 months post fire, where broad-toothed rats (mainland) had previously been known to occur (Milner et al. 2015). No scats were found at 10 of the 12 burnt sites (83%), while scats were found at the 2 unburnt sites (ACT Government 2022. pers comm 29 April). In Victoria, 23% of modelled habitat was within the fire extent, with 15% of modelled habitat impacted by high severity fire. The catastrophic loss of habitat, and

Threat	Status [a]	Evidence
		potentially subpopulations, following the widescale 2019/2020 bushfires has increased concerns about the persistence of the broad-toothed rat in Victoria (Macak & Rowe 2022). In the eastern section of the Alpine National Park, Victoria, surveys of sites with suitable treeless alpine grassland, heathland, and peatland habitats and in which broad-toothed rats (mainland) occurred in the last decade found that they persist in 16 (67%) of 24 unburnt sites surveyed and in 4 (25%) of 16 burnt sites surveyed (within the study area). In Mount Hotham and surrounds, Victoria, the broad-toothed rat (mainland) was found during targeted searches in 9 (69%) of 13 unburnt sub-alpine woodland and treeless alpine grassland/heathland sites within the study area. None were found at the 8 burnt sites searched. It is unknown whether the subspecies was in forested habitat (such as wet forest) pre-fire. However, no suitable broad-toothed rat (mainland) habitat was observed in forested locations post-fire within the fire boundary (Macak & Rowe, 2022). In Kosciuszko National Park, approximately 36.6% of the modelled species habitat was affected by the 2019/2020 fires (DPIE 2019) (which included 43% of approximately 160 existing scat survey monitoring sites). Sixty-nine monitoring sites were impacted by fire in 2020. In 2017, 88% (61) of these sites, were occupied by broad toothed rat but declined in 2021 to 7% (5). In 2022, 2-years post-fire, detections had increased to 37% (NSW DPE 2022). In the Barrington Tops, the 2019/2020 fire significantly impacted the Edwards Swamp complex on the southern plateau. Approximately 80% of the Barrington and Edwards Swamps were burnt, as well as two small swamps on the upper reaches of the Barrington River and Edwards Creek. Saxby Swamp suffered some fire damage but remained largely unburnt. Surveys conducted by NPWS in the months following the fire, and again in 2021 and 2022 found evidence of broad-toothed rat (mainland) in many of the unburnt areas (NSW DPE 2022b. pers comm 2 May). Despite the impacts from the fire to the Edwards Swamp complex the remainder of the swamps on the southern plateau were not affected. These include the large Brumlow Swamp and Brumlow Creek complex, Black Swamp, Beean Beean, Little Murray, and Polblue/Nolans. All these swamps contain persisting subpopulations of broad-toothed rat (mainland). A series of smaller swamps on the south-eastern edge of the plateau remain largely unexplored. Opportunistic searches conducted in a number of these swamps have found evidence of broad-toothed rat (mainland), so it is expected that many of these swamps contain broad-toothed rat (mainland) as well (NSW DPE 2022b. pers comm 2 May). Across State Forest in New South Wales, only 6 sites with previously known records have been surveyed post-fire in Bago State Forest (six months post-fire), with the subspecies only found at one small unburnt patch. There was no evidence of occupation at any burnt site at the time of the survey (Bilney 2022. pers comm 13 April). An expert elicitation to estimate the effects of the 2019/2020 fires on broad-toothed rat population predicted declines of 70% in areas subject to high to very high fire severity, and declines of 45% in areas subject to low-moderate fire severity (Legge et al 2022)

Threat	Status [a]	Evidence
Increased frequency and severity of extreme weather events such as droughts and floods	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: increasing • Extent: across the entire range	Climate projections for south-eastern Australia include reduced rainfall, increased average temperatures, and greater frequency of extreme droughts (CSIRO & Bureau of Meteorology 2015). Climate change is recognised as a key threatening process to the long-term persistence of the broad-toothed rat (mainland) due to shifts in the composition and distribution of alpine vegetation communities (DECC 2007, Milner et al 2015). Drought, increased temperatures, lower rainfall or less evenly distributed rainfall, increased evaporation, increased frequency and severity of fires, may each result in the drying of drainage lines leading to changes in density and composition of vegetation in sphagnum bogs, fens and other associated vegetation communities across the alpine and subalpine regions (Milner et al, 2015, Lucas et al. 2007). Brereton et al. (1995) predicted that with a 1°C rise in temperature the range of the broad-toothed rat (mainland) would decrease by 36% and with a 3°C rise in temperature it would decrease by 75%., O'Brien et al. (2008) predicted that, under almost any climatic warming scenario, broad-toothed rat (mainland) would be expected to go extinct at Barrington Tops. Low elevation subpopulations are currently at greatest risk from climate change. It is likely that the species range will contract to subalpine and alpine regions with climate change (Green and Osborne 2003, Green et al. 2008, Woinarski & Burbidge 2016). Management actions implemented in alpine resorts and surrounding areas, such as conservation of heathland, and maintaining or enhancing habitat connectivity, may therefore be critical to the conservation of the subspecies (Whisson et al. 2015, Beilharz & Whisson 2016). While restricted altitudinal movement is recognised as a significant impact of climate change for subpopulations in the Barrington Plateau (New South Wales), the significance of such processes in the Australian Capital Territory subpopulations are currently unknown. Subpopulations of the subspecies have been identified across a range of altitudinal gradients (1028 m to 1629 m) and unlike the Barrington Plateau subpopulations, altitudinal movement for the subspecies in the Australian Capital Territory is less restricted. Indeed, subpopulations have been identified at relatively low altitudes in the Australian Capital Territory (for example at 1028 m) (Milner et al 2016). In Victoria, the subspecies persisted at 32 of 68 historically occupied sites (pre-1990), with occurrence more likely at sites of higher elevation and precipitation and less likely at sites with a higher temperature (Shipway et al. 2020). The mean annual temperature at each site had on average increased by 0.7°C since the subspecies was last seen at a given site. Minimum temperature of the coldest month was found to be the single best predictor of persistence. Thus, climate change is expected to lead to further range reductions, pushing the subspecies to higher elevations and cooler, wetter areas (Shipway et al. 2020). Early snow thaws in the Snowy Mountains, New South Wales, were found to have detrimental impacts on subpopulations (Woinarski et al., 2014) with a

Threat	Status [a]	Evidence
		population reduction of 25% associated with lack of snow cover in 1999, increasing susceptibility to predation by foxes (Green & Osborne 2012). Early snow thaw also impacted the timing of breeding detected in 1982 (Green & Osborne 2012). Climate change may lead to competitive interactions as the distributions of species change to have a greater degree of overlap. A greater overlap in high-elevation sites between the broad-toothed rat (mainland) and the native swamp rat (*Rattus lutreolus*) through predicted climate-induced elevational range contractions in both species may lead to increased competition for food and further exacerbate threats to the broad-toothed rat (mainland) (Green et al. 2008). While there is evidence to suggest that these changes will be detrimental for the subspecies, there has been suggestion that climate change may increase available habitat. For example, drying of bogs and an increase in occurrence of wildfires, as is predicted with climate change, may lead to an increase in the number of sedgelands and/or grasslands and a reduction in sphagnum (McDougall & Broome 2007, Macdonald 2009, NSW DPE 2022a. pers comm 31 May). The broad-toothed rat (mainland) shows a positive association with both *Poa* grasslands and sedgelands and negative association with sphagnum (NSW DPE 2022a. pers comm 31 May, Williams & Costin 1994). However, with elevated summer temperatures, woody vegetation is likely to increase in alpine areas (Williams & Costin 1994). The broad-toothed rat (mainland) was shown in Milner et al. (2015) to utilise woodlands adjacent to high quality habitat, though results of the habitat selectivity analysis showed that the subspecies tended to avoid woodland habitat and therefore the expansion of woody vegetation may reduce available optimal habitat and lead to an overall reduction in habitat complexity and structure. In subpopulations monitored via camera traps (upper Yarra reservoir, Victoria), whole areas of habitat were destroyed by flooding in 2021/2022, with broad-toothed rats (mainland) frequently seen on the cameras prior to the floods, and none seen after the floods. Flooding can be due to both extreme weather events and due to flooding after water releases from dam structures. Water releases may also be a key issue in some locations after the 2021/2022 floods (Parrott 2022. pers comm 8 April). *Interactions:* The drying of sphagnum peatlands is predicted to significantly increase the risk and impact of fire within the community (Macdonald 2009; Milner et al. 2016). Damage from feral horses (*Equus caballus*) also increases evaporation and dries sphagnum bogs compounding the effects of climate change (Eldridge et al. 2019). If climate change leads to a loss of snow grass meadows, then it is likely the impact on the broad-toothed rat (mainland) would be catastrophic as their distribution is closely tied to habitats with sedges and grasses, especially snow grasses on which they exclusively feed (Green et al. 2014).

Threat	Status [a]	Evidence
Habitat loss, disturbance or modification		
Habitat degradation and competition due to introduced herbivores	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: increasing • Extent: across entire range	Introduced herbivores alter the structure, composition and function of ecosystems, contributing significantly to erosion and to the establishment and spread of weeds. Habitat degradation may result in a loss of important ground-layer vegetation, such as snow grass, which the broad-toothed rat (mainland) relies on as a food source (Milner et al. 2015). There is evidence of impact to the broad-toothed rat (mainland) from feral horses (*Equus caballus*), deer such as sambar (*Rusa unicolor*), cattle (*Bos taurus*), pigs (*Sus scrofa*), rabbits (*Oryctolagus cuniculus*) and hares (*Lepus europaeus*) (Menkhorst et al., 2008). Scat surveys have demonstrated a negative relationship between the abundance of broad-toothed rats (mainland) and habitat disturbance due to feral herbivores (Schulz et al 2019, Milner et al., 2015). Feral horses are currently the main threat to broad-tooth rat (mainland) among the feral herbivores (Driscoll et al. 2019). Grazing and trampling of broad-toothed rat (mainland) habitat by introduced herbivores removes cover, particularly important as protection against predators and shelter during winter, and food sources for the subspecies rendering habitat unsuitable (Belcher & Leslie 2011, Green & Osborne 2003). These impacts are greater at higher elevations (Green and Pickering 2002, Hughes 2003, Eldridge et al. 2019, Schulz et al. 2019). Habitat degradation and loss by feral horses is a Key Threatening Process under the Novel Biota and their impact on Biodiversity KTP (DAWE 2013, DSEWPC 2011). Feral horses reduce subpopulations of broad-toothed rat (mainland) via degrading the suitability of vegetation (Eldridge et al. 2019). Some impact-control experiments demonstrate decline of the broad-toothed rat (mainland) in areas with feral horse impact (K. Green pers. comm., cited in Woinarski et al. 2014). In a 2017 study of 20 sphagnum bog sites across Alpine National Park and Nunniong and Nunnet State Forests in Victoria, the broad-toothed rat (mainland) was less likely to be present in areas affected by feral horses (Cherubin et al. 2019). Across 180 sites in Kosciuszko National Park, strong negative effects of feral horses were detected on the subspecies, with no detections at the 47 sites where feral horse impacts were severe (Schulz et al. 2019). In Kosciuszko National Park there has been a 13% increase in feral horse activity across the study areas from being detected at 130 (2017) to 147 (2021) sites (NSW DPE 2022). There have been no resident feral horses in the Australian Capital Territory since 2011 due to the zero-tolerance policy on the presence of feral horses in Namadgi National Park (ACT Government 2020). Grazing by rabbits can result in the removal or modification of tussock structure that provides shelter and nesting habitat for the broad-toothed rat (mainland), and rabbits compete directly with the subspecies for food (Milner et al. 2015). In the Australian Capital Territory, Green and Osborne (2003) found damage caused by rabbits and pigs was significantly correlated with lower detection rate of the subspecies across all 14 sites surveyed except Cotter Gap. Feral pig and rabbit activity is likely to result in erosion, a reduction in food resources and a change in

Threat	Status [a]	Evidence
		habitat structure and composition. Additionally, it is possible that feral pigs could play a key role in the spread of *Phytophthora*, which poses a significant threat to the species' habitat, leading to a loss of heath and other vegetation essential to the species' survival (Milner et al. 2015).
Habitat loss and fragmentation	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: moderate • Trend: increasing • Extent: across part of range	Some habitat destruction has been associated with ski resort development (Menkhorst et al. 2008, Whisson et al. 2015). Enhancing the capacity of species to move between habitat patches should be incorporated into alpine resort management plans. Such management will become increasingly important as anthropogenic disturbance increases in alpine regions (Whisson et al. 2015). Powerline easement vegetation can support small mammal communities, including broad-toothed rat, provided the vegetation is managed to maintain structural complexity without mass slashing (Clarke & White 2008). Drainage of wetlands had also altered the vegetation composition resulting in *Poa* spp. Dominated grasslands with larger inter-tussock distances resulting in open areas between tussocks, and the absence of the subspecies as it removes cover for runways which are typically constructed between tussocks (Belcher & Leslie 2011). The broad-toothed rat (mainland) has been found to persist in small, isolated patches of suitable habitat (a few square metres in size). These patches are susceptible to complete destruction, for example, slashing of grassy tussock areas on roadsides, possibly for fire management, has resulted in no signs of presence of broad-toothed rats afterwards. Maintenance of small, isolated patches of grass or sedge should be considered in broad-toothed rat management practices (Kazi 2021. pers comm 17 December). Sphagnum bogs and associated fens are an endangered ecological community of importance to the broad-toothed rat (mainland). Drought, increased temperatures, increased frequency of wildfires and increased occurrence of invasive species are predicted to significantly impact the functioning of the endangered ecological community and result in the loss of many ecosystem services (Macdonald 2009). There is evidence to suggest that these changes will be detrimental for the broad-toothed rat (mainland) (Green & Osborne 2003, Green et al. 2008).
Other invasive species		
Weed invasion	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: moderate • Trend: increasing • Extent: across part of range	The invasion of exotic plant species into key habitat poses a significant threat to the subspecies survival (Milner et al. 2015). The invasion of exotic grasses is likely to result in the loss of important ground layer vegetation such as Snow grass with the potential to reduce the availability of that food source for the subspecies (Milner et al. 2015). Orange hawkweed (*Hieracium aurantiacum*) is a noxious weed that is known to occur primarily in Kosciuszko National Park, outcompeting native species, creating monocultures, impacting endangered ecological communities and thus threatening species habitats (DPIE 2020b). The weed rendered at least one known broad-

Threat	Status [a]	Evidence
		toothed rat (mainland) site inaccessible during the 2021 survey (NSW DPE 2022a. pers comm 31 May). Infestations of Ox-eye daisy (*Leucantheum vulgare*), which cover several hundred hectares in Kosciuszko National Park as of 2022, are impacting broad-toothed rat (mainland) habitat, especially post-fire (NSW DPE 2022a. pers comm 31 May). Yorkshire fog (*Holcus lanatus*) has been identified as a potential threat to subpopulations in Barrington Tops where there is concern that this grass may displace significant native ground layer species such as Snow Grass, which the subspecies is known to rely heavily on as a food resource (DECC 2007, Milner et al. 2015). Invasion of habitat by scotch broom (*Cytisus scoparius*) is occurring in NSW (NSW OEH -) including at Barrington Tops and is outcompeting the native species required by the broad-toothed rat (mainland). An aim of scotch broom control, funded by NSW OEH – in recent years, has been to remove it from the montane swamps and associated broad-toothed rat (mainland) habitat and create 20-30m weed free buffers around these high value areas (NSW DPE 2022b. pers comm 2 May). Further weeds impacting broad-toothed rat (mainland) habitat include willow (*Salix species*) in alpine Victoria. (Woinarski & Burbudge 2016) and blackberry (*Rubus* spp.) in NSW. The latter acts as a refuge area for feral pigs, cats, and foxes (NSW OEH -) although is controlled at Barrington Tops as of 2022 (NSW DPE 2022c. pers comm 13 April).
Dieback caused by *Phytophthora cinnamomi*	• Timing: current • Confidence: observed • Likelihood: almost certain • Consequence: minor • Trend: unknown • Extent: across minor part of range	The root rot fungus, *Phytophthora cinnamomi.* Poses a significant threat to the species' habitat in some regions leading to dieback of heath and other vegetation essential for species survival (NSW DEC 2007, Menkhorst et al., 2008, Milner et al. 2016, Woinarski & Burbudge 2016). Feral pigs may play a role in spreading *P. cinnamomi* (Milner et al. 2016).
Competition and other agonistic interaction with introduced rodents	• Timing: current • Confidence: observed • Likelihood: possible • Consequence: moderate • Trend: increasing • Extent: across part of range	Black rats (*Rattus rattus*) and house mice (*Mus musculus*) are increasing in abundance in many areas occupied by broad-toothed rat. There is very limited published literature on their impacts on the broad-toothed rat (mainland) (Rowe 2002. pers comm 17 May) including the potential for displacement of the broad-toothed rat (mainland). Increased abundance of native rodents would also sustain higher abundance of invasive predators and thus increase the impact of predation on the broad-toothed rat (mainland).
Small and fragmented populations		
Small population size and genetic isolation	• Timing: current • Confidence: observed • Likelihood: possible • Consequence: moderate • Trend: unknown • Extent: across major part of range	Most subpopulations of the Broad-toothed rat (mainland) are small, fragmented and isolated, possibly except for some locally abundant areas in Kosciuszko National Park. Barrington Tops is isolated with a small effective subpopulation size. Otway Range (Western Coastal VIC) is almost certainly isolated, but the effective subpopulation size is yet unknown. Genetic samples will be collected during trapping initiatives to identify

Threat	Status [a]	Evidence
		genetically isolated subpopulations (Parrott 2022. pers comm 8 April, Rowe 2022. pers comm 17 May). Subpopulations that are small and isolated generally are subjected to low genetic diversity which exposes species to higher risks of extinction. This is due to the reduced ability of the subpopulation to adapt to changes in the environment or various pressures and threats, as well as increasing the risks of inbreeding within a subpopulation (IUCN 2019). Small subpopulations are also more likely to go extinct due to stochastic events.
Habitat Destruction		
Impacts from timber harvesting operations	• Timing: current • Confidence: inferred • Likelihood: Possible • Consequence: moderate • Trend: static • Extent: across part of range	A large proportion of sites where the species occurs in Victoria and NSW are within areas subject to Regional Forest Agreements. Although forestry operation impacts are not well documented, they have been assessed as a significant risk in the Victorian Gippsland RFA region (DELWP 2020). In Victoria, timber harvesting has been considered a likely threat, but impacts are uncertain (VSAC 2012). The threats posed by timber harvesting operations could include destruction, disturbance or fragmentation of habitat and subpopulations and impacts on subspecies dispersal potential. In Victoria, road construction and road-side slashing to facilitate forestry is a threat to fragmented subpopulations (Parrott 2022. pers comm 8 April). Note: harvesting of native timber in state forests in Victoria will cease on 1 January 2024, and any threats from forestry on this tenure will be those relating to legacy impacts. In New South Wales, typical habitat occupied by broad-toothed rats (mainland) is unlikely to occur within the footprint of harvesting (Bilney 2022. pers comm 13 April), however, timber harvesting operations are likely to exacerbate the spread of blackberries (OEH NSW 2012). Timber harvesting prescriptions have been put in place to mitigate potential impacts on the broad-toothed rat (mainland) in New South Wales (NSW EPA 2020).
Native competitors		
Competition with native rodents	• Timing: current • Confidence: observed • Likelihood: likely • Consequence: unknown • Trend: increasing • Extent: across part of range	Competition with the bush rat and the swamp rat (*Rattus lutreolus*) has been noted in different parts of the broad-toothed rat (mainland) range and some correlative evidence exists of potential competitive interactions (Green & Osborne 2003). The bush rat is a common, generalist species that occurs in a variety of habitats and at a wider range of elevations than the broad-toothed rat (mainland) (Beilharz & Whisson 2016). Keating (2003) noted that a significant increase in the number of bush rats trapped coincided with a dramatic decrease in the number of broad-toothed rats (mainland) trapped at Nolans Swamp (New South Wales) (Milner et al. 2015). However, it has been suggested that the results obtained in Keating (2003) may be due to broad-toothed rats (mainland) not entering a trap that has been previously occupied by a bush rat, and that daily replacement or cleaning of traps would be required to obtain an unbiased result (NSW DPE 2022c. pers comm 13 April). In the Australian Capital Territory, the bush rat was detected in 4 of 14 bogs surveyed by Milner et al. (2015), however, it is uncertain under what circumstances the bush rat would pose a competitive threat to the broad-toothed rat

Threat	Status [a]	Evidence
		(mainland) as the 2 species are naturally sympatric (Milner et al. 2015). The swamp rat is a common species in coastal areas but occurs only at low densities in some low-elevation subalpine areas. The swamp rat is predicted to become more common and widespread with climate change, raising concerns that it may compete with the broad-toothed rat (mainland) (Green et al. 2008, Beilharz & Whisson 2016). Swamp rats were caught in Barrington Tops for the first time in 1999, concurrent with a reduction of broad-toothed rats. It is not known whether swamp rats displaced broad-toothed rats, or if broad-toothed rats had declined due to other causes with swamp rats then filling the niche (Green et al. 2008).
Disease	• Timing: current • Confidence: no data • Likelihood: unknown • Consequence: minor • Trend: unknown • Extent: across entire range	Invasive species such as black rats (*Rattus rattus*) and mice (*Mus musculus*) have been observed, via remote infrared cameras, using broad-toothed rat tunnels. There is potential that disease from the invasive species could be contributing to declines in the broad-toothed rat (mainland), however no data are currently available. Toxoplasmosis from feral cats and other parasitic diseases may also be impacting the subspecies (Parrott 2023. pers comm 9 March).

[a]Timing—identifies the temporal nature of the threat
Confidence—identifies the nature of the evidence about the impact of the threat on the species
Likelihood—identifies the likelihood of the threat impacting on the whole population or extent of the species
Consequence—identifies the severity of the threat
Trend—identifies the extent to which it will continue to operate on the species
Extent—identifies its spatial context in terms of the range of the species

Categories for likelihood are defined as follows:
Almost certain – expected to occur every year
Likely – expected to occur at least once every five years
Possible – might occur at some time
Unlikely –known to have occurred only a few times
Unknown – currently unknown how often the threat will occur
Categories for consequences are defined as follows:
Not significant – no long-term effect on individuals or populations
Minor – individuals are adversely affected but no effect at population level
Moderate – population recovery stable or declining
Major – population decline is ongoing
Catastrophic – population trajectory close to extinction

[b]Fire regimes that cause declines in biodiversity include the full range of fire-related ecological processes that directly or indirectly cause persistent declines in the distribution, abundance, genetic diversity or function of a species or ecological community. 'Fire regime' refers to the frequency, intensity or severity, season, and types (aerial/subterranean) of successive fire events at a point in the landscape

Each threat has been described in 3 in terms of the extent that it is operating on the species. The risk matrix (Table) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect, the duration of the impact, the spatial extent, and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with experts and using available literature.

Table 3 Risk Matrix

Likelihood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
Almost certain		**Dieback caused by *Phytophthora cinnamomi***	**Habitat loss and fragmentation** **Weed invasion**	**Increased frequency and severity of extreme weather events** **Increased extent, frequency and severity of fire** **Predation by European red foxes (*Vulpes vulpes*)** **Predation by feral cats (*Felis catus*)** **Habitat degradation and competition due to introduced herbivores**	
Likely		**Competition with native rodents**	**Impacts from timber harvesting**		
Possible			**Small population size and genetic isolation** **Competition and other agonistic interaction with introduced rodents**		
Unlikely					
Unknown					

Risk Matrix legend/Risk rating:

Low Risk	Moderate Risk	High Risk	Very High Risk

Priority actions have then been developed to manage the threats, particularly where the risk was deemed to be 'very high' (red shading) or 'high' (orange shading). For those threats with an unknown or low risk (blue and green shading respectively) research and monitoring actions have been developed to understand and evaluate the impact of the threats, where appropriate.

Conservation and recovery actions

Primary conservation objective

By 2033, the trends in key parameters (for example, abundance, occupancy, AOO, EOO, genetic health) for important subpopulations of broad-toothed rat (mainland) have improved across the subspecies range.

Conservation and management priorities

Fire impacts

- Develop and implement an evidence-based fire management strategy that minimises risks of decline and optimises subpopulation persistence for the subspecies. This is likely to focus on reducing the risk of frequent, extensive, severe fire.
- Partner with cultural knowledge custodians and land rights holders with the intention to enable knowledge sharing and Caring for Country practices, including cultural burning.
- Protect broad-toothed rat habitat from fire mitigation work by marking broad-toothed rat habitat onto maps used for planning bush fire control, hazard reduction burns and other management works (NSW OEH 2020) such as road widening, fire break development and road-side slashing.
- Mitigate post-fire impacts by increased control of predators and provision of artificial habitat structures to provide cover from predators post-fire (NSW OEH).
- Investigate and develop (where required) nutritionally suitable supplementary food items and techniques for safe provision after emergencies (Zoos Victoria).

Ex situ and translocation recovery actions

- Establish intensive captive breeding facilities and at least one insurance subpopulation to supplement wild/semi-wild subpopulations, preserve genetic diversity, and reintroduce the subspecies to areas it has become locally extinct.
- Undertake research to support captive breeding such as understand potentially fatal agonistic interactions among individuals (as noted in the first captive breeding attempt by Calaby & Wimbush 1964), along with nutrition, genetics and other factors underpinning successful captive breeding.
- Develop a national translocation strategy that considers the relative merits of wild-to-wild translocation versus using animals bred ex-situ on a case by case basis. Prepare a population management plan that includes identification of appropriate areas for translocation across the species range, from coastal and lowland areas to alpine areas, including (but not restricted to) predator and herbivore-proof fenced areas that are managed for fire risk and consider future climatic suitability. The population management plan should include monitoring the survivorship of translocated individuals.
- Cryopreserve living cells of subpopulations to preserve genetic diversity in living subpopulations.
- Prepare ex situ housing, transportation and emergency care for post-fire rescue and release, where needed (Zoos Victoria).

Climate change and severe weather impacts

- Identify all habitat that is likely to remain or become suitable under climate change scenarios and manage those areas to reduce threats to the subspecies. Protect the diversity of habitat types the subspecies occupies from coastal to alpine as potential translocation sites.
- Support actions to reduce global warming (NSW OEH 2020).

Invasive species impacts (including from competition, grazing, trampling, predation)

- Implement control programs for feral herbivores and feral predators, in accordance with the relevant threat abatement plans, targeting known high quality broad-toothed rat habitat and recently disturbed habitat.
- Protect alpine dingo populations from baiting to ensure bio-control of introduced feral cat and fox numbers.
- Re-examine evidence-based feral horse control options in New South Wales and Victoria and implement the most effective measures.
- Avoid the use of pindone or other rabbit/hare poisons likely to be ingested by broad-toothed rats. Instead use harm-free traps such as cage traps and check them daily to release native animals.
- Implement appropriate control measures if there is evidence that weeds are, or have the potential to become, a threat capable of causing a decline of important broad-toothed rat (mainland) subpopulations.

Habitat loss, disturbance and modifications impacts

- Restore and/or maintain suitable habitat at priority locations and increase connectivity to allow dispersal between areas.
- Ensure land managers are aware of the subspecies' occurrence to avoid accidental habitat damage. Develop and disseminate guidance on mowing, burning and other management actions to manage broad-toothed rat habitat appropriately.
- Support actions from the National recovery plan for the Alpine Sphagnum Bogs and Associated Fens ecological community (DOEE 2015).

Genetic threats resulting from small and fragmented populations

- Assess genetic diversity, inbreeding and genetic structure across the range of the subspecies.
- Trial and implement translocations and monitoring of individuals to improve genetic diversity and health, where required.

Damage from timber harvesting and dam releases

- Work with the forestry bodies of New South Wales and Victoria to ensure forestry prescriptions are adequate to maintain habitat and protect the viability of subpopulations in areas subjected to timber harvesting (this includes logging, road construction, coupe burning).

- Work with dam managers to ensure that the impacts of dam releases are, as far as possible, mitigated across the portion of the broad-toothed rat range that is within flood zones downstream of dams.

Stakeholder engagement/community engagement

- Establish a diverse National Recovery Team to enhance governance and co-ordination (high-priority).
- Develop plans for recovery and restoration actions in partnership with Traditional Owners. Ensure Traditional Owners are active collaborators on recovery actions, including but not limited to, fire management, survey, reintroduction, monitoring (via new and existing partnerships and funding streams where required).
- Enable the mutual sharing of knowledge, ensuring the processes and protocols to record, store, and share any Aboriginal knowledge are agreed (free, prior and informed consent) and appropriately resourced. Information on the application of cultural burning and integrated Caring for Country practices to protect and enhance habitat is of critical importance. Understand concerns and/or cultural practices Traditional Owners may have in translocating individual animals across Aboriginal borders if applicable. Work with Traditional Owners to identify local Aboriginal names for the subspecies and to document the cultural significance of the broad-toothed rat.
- Engage interested nature conservation, land management and landholder groups in conservation management activities. Continue to seek conservation covenants on private land holdings for important subpopulations.
- All stakeholder projects, research, and activities currently underway to promote species recovery should be documented and coordinated to maximise efficiencies and ensure efficacy.
- Obtain media and social media opportunities to raise awareness and love for the broad-toothed rat and other native rodents (such as Zoos Victoria's Love your Locals campaign) and engage the broader local community through participation at local community events and collaboration with local schools.

Survey and monitoring priorities

- Establish standardised protocols and robust monitoring methods (that account for changes in detectability between sites, seasons and years and provide a measure of variance) to be implemented across the subspecies range for clarity and consistency of monitoring the status and trends of the subspecies at the national, state and subpopulation levels.
- Establish the status of key populations such as Barrington Tops.
- Monitor subspecies status and threat impacts using standardised protocols and adaptively manage recovery actions accordingly.
- Continue to expand the survey effort, undertake a targeted survey of all suitable habitat within the subspecies range and identify subpopulations.
- Obtain robust occupancy and population estimates for all subpopulations, and then prioritise management actions for each subpopulation.

- Continue expansion of the detection dog program (areas and number of dogs) for both scat and live animal detection to complement/supplement human survey methods, and for emergency extraction requirements. Expanded programs should build upon the recommendations from the detection dog program thus far (Jamieson & Hodgens 2022).

Information and research priorities

- Continue to research population genetics to assess connectivity and resilience of (disparately occurring) subpopulations and determine the appropriate level of genetic mixing to avoid both inbreeding and outbreeding depression. Improvement of the success rate of live trapping techniques is required for genetic studies.
- Research the dispersal (patterns and potential) of the broad-toothed rat to understand potential connectivity among isolated patches of suitable habitat and the ability of the broad-toothed rat to recolonise vacant habitat patches (requires genetic studies).
- Conduct long-term mark-recapture or telemetry studies to obtain information on survivorship and fecundity to then develop reliable population viability, habitat, and climate change models for the subspecies.
- Assess the efficacy of alternative survey techniques (e.g., detection dogs and eDNA from water samples) compared to existing methods.
- Continue research into diet and nutrition and develop or identify nutritionally suitable supplementary food items, plus techniques for safe provision, after emergencies.
- Conduct research on the spatiotemporal extent to which feral herbivores delay or prevent habitat from re-establishing after the fires, and the risk of broad-toothed rat (mainland) metapopulation collapse in the meantime (Walker et al. 2020).
- Assess the efficacy of complimentary control programs to concurrently reduce non-native predators.
- Assess the impact of competition with non-native and native rodents.
- Investigate the likelihood of disease transmission from invasive species, and the impacts of disease.

Recovery Plan decision

As an approved, updated, and detailed Conservation Advice for the species would provide sufficient direction to implement priority conservation actions, mitigate against key threats, enable recovery and provide foundation for further planning, a national Recovery Plan is not required at this time.

Consequently, the Threatened Species Scientific Committee has not recommended that a recovery plan be required (see Attachment A for TSSC recommendations regarding the need for a recovery plan).

Links to relevant implementation documents

ACT Government 2019, Conservation Advice – Broad-toothed Rat Mastacomys fuscus mordicus, Scientific Committee, ACT

ACT Government 2019, Conservation Advice — High Country Bogs and Associated Fens Ecological Community, Scientific Committee, ACT.

ACT Government 2020, *Namadgi National Park Feral Horse Management Plan*, ACT Government.

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The Threatened Species Scientific Committee finalised this assessment on 7 June 2023.

Attachment A: Listing Assessment for *Mastacomys fuscus mordicus*

Reason for assessment

The broad-toothed rat (mainland) was listed as Endangered under the *Endangered Species Protection Act 1992* and transferred to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) when it commenced in July 2000.

This assessment follows evaluation by experts of the conservation status of the species following the 2019/2020 bushfires.

Assessment of eligibility for listing

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

Key assessment parameters

Table 4 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria. The definition of each of the parameters follows the Guidelines for Using the IUCN Red List Categories and Criteria.

Table 4 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	Unknown			There are no robust estimates of total population size, nor that of most populations, of the broad-toothed rat (mainland). Woinarski et al. (2014) reported that the population size is probably substantially > 10 000 mature individuals but no methodology was provided. In suitable habitat, the subspecies may attain relatively high densities. For example, the density of one population in Kosciuszko National Park was 12.1 individuals/ha (range 8-19/ha) during a 12-year period (Happold 1989, 1998). However, most sources consider the subspecies to be scarce and patchily distributed. Seebeck & Menkhorst (2000) noted that the subspecies was generally rare and localised but may be locally common in appropriate habitat. Happold (2008) considered it sparse to common, whilst the IUCN (2008) did not consider the subspecies to be common. Based on the available data on occupancy reductions across the subspecies range further declines will occur as threats to the subspecies continue. The most plausible estimate for the number of mature individuals is unknown but declining.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Declining			Trend is declining based on evidence of local extirpations at 36 out of 68 sites across Victoria (Shipway et al. 2020). There is evidence of decline of populations in Victoria, New South Wales and Australian Capital Territory following large fire events including 2019/2020 (see Fire Ecology section of the CA). There is also evidence of continuing decline in habitat suitability (See Table 2 Threats and Table 1 Subpopulations of the broad-toothed rat (mainland)). It is expected that further declines and site extirpations will occur as threats to the species are ongoing. Based on expert elicitation, one year after the 2019/2020 bushfires, an overall population decline of around 18% (or up to 26.5%, the lower 80% confidence bound) is suspected under current management. This is expected to increase to 22.2% (or up to 37.3%) in ten years after the fires (Legge et al. 2021).
Generation time (years)	1-2 years	1 year	2 years	Sexual maturity is reached at 6-12 months (Happold 2008, 2011); longevity is probably 2-3 years (Happold 2011), so generation length is here assumed to be 1-2 years (Woinarski & Burbidge 2016). Mark-recapture studies at Barrington Tops never re-captured animals in consecutive years, which suggested 1 year was more likely (NSW DPE 2022c. pers comm 13 April).
Extent of occurrence	52 290 km^2	52 290 km^2	60 149 km^2	The Extent of Occurrence (EOO) was calculated using a minimum convex hull as described in Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2022) and using location records from either the past 5 years or from the past 10 years. The EOO was calculated based on records that had been compiled from state governments, along with museums, research institutions and non-government organisations. The EOO from the past 5 years and 10 years are approximately 52 290 km^2 (2017–2022) and 60 149 km^2 (2012–2022) respectively. The decision regarding how many years of data to include is a trade-off between increasing accuracy by including more years of data (thus increasing sample size) and increasing the currency of the estimate by using only data from more recent years (TSSC 2021).

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Contracting			The Barrington Tops National Park population (NSW) at the northern extreme of the distribution is disjunct from the rest of the subspecies range and is experiencing declines due to continued threats, such as climate change. As there is no altitudinal range for the subspecies to shift to in a warming climate it will likely become locally extirpated. The Wilsons Promontory (Vic) population at the southern extreme of the distribution may become locally extirpated within 5 years (by 2027) due to risk of encroachment by weeds, intensive overgrazing by invasive species and severe reduction of *Poa* grass. The decline in the extent of occurrence will likely continue since the main threats, such as climate change, fires that cause reductions in biodiversity, weed encroachment, and overgrazing, competition and predation from introduced species are compounding and have not ceased.
Area of Occupancy	912 km^2	912 km^2	1152 km^2	The Area of Occupancy (AOO) was calculated using location records from either the past 5 years or from the past 10 years and applying the 2 x 2 km grid cells recommended by the IUCN Red List Categories and Criteria (2022). The calculation resulted in an estimated AOO of 912 km^2 (2017–2022) and 1152 km^2 (2012–2022) using recent data provided by state governments, museums, research institutions and non-government organisations. The 2x2 km grid cell method is likely to Overestimate AOO for the broad-toothed rat (mainland) as the subspecies are patchily distributed and are unlikely to occupy 4 km^2 continuously (Rowe 2022. pers comm 17 May). TSSC (2016) provided an AOO estimation of 444 km^2. This figure was based on the mapping of point records from the 20-year period, 1995-2015, however it was noted that the AOO could possibly be as high as 1256 km^2. Woinarski et al. (2014) suggested that their estimate of 428 km^2 for the AOO was likely to be a significant under-estimate due to limited sampling across the occupied range and considered that the AOO is likely to be greater than 2000 km^2. The decision regarding how many years of data to include is a trade-off between increasing accuracy by including more years of data (thus increasing sample size) and increasing the currency of the estimate by using only data from more recent years (TSSC 2021). As with most area calculations, AOO estimates for the broad-toothed rat (mainland) also depends on the availability of monitoring data across its geographic range.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
AOO is a standardised spatial measure of the risk of extinction, that represents the area of suitable habitat known, inferred or projected to be currently occupied by the taxon. It is estimated using a 2 x 2 km grid to enable comparison with the criteria thresholds. The resolution (grid size) that maximizes the correlation between AOO and extinction risk is determined more by the spatial scale of threats than by the spatial scale at which AOO is estimated or shape of the taxon's distribution. It is not a fine-scale estimate of the actual area occupied. In some cases, AOO is the smallest area essential at any stage to the survival of existing populations of a taxon (e.g., breeding sites for migratory species).				
Trend	Contracting			AOO is contracting due to most populations having declining occupancy due to combined pressure from predation from introduced predators such as the European red fox and feral cats, habitat degradation and competition from feral herbivores, fires that cause declines in biodiversity and climate change, making some historical habitat patches no longer suitable (Shipway et al. 2020 and see Table 1). For example, the population in the Dandenong Ranges (Vic) has not been detected since 1992 despite multiple surveys and may be locally extirpated. The Barrington Tops (NSW) and the Wilsons Promontory (Vic) populations will likely become extinct due to climate change and the range of compounding threats as described in EOO section above.
Number of subpopulations	20	10	20	See below
Trend	Decreasing			
Basis of assessment of subpopulation number	Data are lacking to clearly define the number of subpopulations across the range but there are 10-20 areas that could be identified from Table 1. The Dandenong ranges is possibly locally extirpated and Wilsons Promontory is likely to become extirpated within the next 5-10 years. Thus, the trend in number of subpopulations is decreasing.			
No. locations	<10	5	10	See below
Trend	Declining			
Basis of assessment of location number	The IUCN definition of a location is 'a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present' (IUCN 2019). Given the extent and severity of the 2019/2020 fires, the most likely threat that could affect large areas of the subspecies range in one generation is likely to be one or two consecutive extreme fire seasons. Despite heterogeneity of fire scars, and potential for unburnt refugia, extreme fire events have immediate impacts of widespread mortality and delayed impacts effecting longer term population viability across large parts of the subspecies range. The 2019/2020 bushfire events burnt a large area of Eastern Australia (100 000 km^2), overlapping c. 27% of the broad-toothed rat (mainland) distribution (Legge et al 2021). It is thus plausible that the subspecies range comprises 5-10 locations based on the regions listed in Table 1.			

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Fragmentation	The distribution may be severely fragmented. The habitat occupied by the broad-toothed rat (mainland) is naturally discontinuous. The broad-toothed rat (mainland) has a high habitat specificity and small home range sizes (Ensbey et al. 2022), prompting a fragmented distribution for the subspecies. Additionally, many areas of apparently suitable habitat are unoccupied (Green & Osborne 2003), suggesting the subspecies may have limited ability to disperse across unfavourable habitat (O'Brien et al. 2008). Although data are lacking to clearly define subpopulations for the broad-toothed rat (mainland), there are isolated subpopulations in the Otways, far East Gippsland (Victoria), Barrington Tops (New South Wales), and scattered across the Great Dividing Range from near Healesville (Victoria) to the Brindabella Range (Australian Capital Territory) (Woinarski et al. 2014, TSSC 2016, Table 1). A study by Seebeck and Menkhorst (2000) considered the subspecies to be scarce and patchily distributed, noting it may be locally common in appropriate habitat. Ongoing and recent declines in occupancy (especially due to the 2019/2020 fires) is increasing fragmentation across the range due to increases in distance between occupied sites. The effective fragmentation caused by selective predation at disturbed sites (due to fires or feral herbivores) is limiting dispersal potential and success and thereby increasing fragmentation further.			
Fluctuations	The broad-toothed rat (mainland) is not subject to extreme fluctuations in population size or distribution over any time period i.e., no parameter (EOO, AOO, number of locations or number of mature individuals) changes by at least an order of magnitude.			

Criterion 1 Population size reduction

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

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

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

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

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

Based on any of the following

(a) direct observation [except A3]

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Criterion 1 evidence

Eligible under Criterion 1 A2bce+3bce+4bce for listing as Endangered

Generation length for the subspecies is 1-2 years (Woinarski & Burbidge 2016). Thus 10 years (which is longer than three generations) is the appropriate time period on which to base the assessment, i.e., 2012-2022.

Population declines

Sub-criterion A2bc and A3bc) Table 5 extrapolates the population size reduction over the 10-year assessment time period (2012-2022) using occupancy as an index of abundance. Declines include post-fire assessments as well as general decline assessments where available. The observed occupancy reductions of the surveyed areas range from 26% to 100% with most reductions being greater than 50% of historically occupied surveyed sites. The key one-year post-2019/2020 fire declines we can draw from are 75% (Vic, Macak & Rowe 2022), 83% (ACT, ACT Government 2022. pers comm 29 April) and 92% (NSW, NSW DPE 2022). An average of all surveyed declines across the subspecies range (including from declines unrelated to the 2019/2020 fires) is 55.2%. When the observed occupancy changes are extrapolated to their equivalent changes from 2012-2022 based on the assumption of linear decline, the estimated overall reduction for the subspecies is 74%.

Occupancy modelling by Walker et al. (2021) based on surveys in burnt and unburnt areas of the Australian alpine region, in the Australian Capital Territory, New South Wales, and Victoria, and alpine resorts adjacent to these parks, showed that the probability that a site was occupied substantially decreased with increasing fire intensity. Broad-toothed rats (mainland) were more abundant at long-unburnt sites (no fire in the past 80 years), and abundance models showed that abundance declined with increasing fire severity, increasing number of past fires and increasing horse impacts. The local extirpation of broad-toothed rat (mainland) following high severity fire may fragment and isolate populations, making them more susceptible to stochastic extinction (Walker et al. 2021).

The 2019/2020 fires affected c. 27% of the known distribution of the subspecies (Legge et al. 2021), and we can assume similar impacts on the subspecies occupancy across all fire-effected areas. These are set on a background of a 53% decline across Victoria pre 1990 – 2014/2015 (Shipway et al. 2020).

Additionally, the Barrington Tops population is classified as an Endangered population under Schedule 1 of the NSW Biodiversity Conservation Act 2016 based on life history susceptibility (small litters, low fecundity and slow growth rate) to habitat degradation and introduced predators and herbivores leading to population decline (NSW SC 2001). The Barrington tops population has continued to decline since that classification due to a range of threats, but especially the impact of feral horses (NSW DPE 2022b. pers comm 2 May).

Sub-criterion A2e and A3e) Evidence of population declines due to introduced taxa have been recorded; Shultz et al. 2019 has noted extirpations due to feral horse impacts while selective predation by feral predators (Green and Osborne, 1981, Green, 2002, Schroder et al. in review) and the subspecies being in the critical weight range, make it suspectable to declines and extinction due to predation from feral predators. Introduced taxa are still present and impacting the broad-toothed rat (mainland) throughout the subspecies range, and it is unlikely that their combined impact will be alleviated sufficiently to stall declines due to known challenges with eradicating introduced taxa (Driscoll et al. 2019). It is therefore reasonable to expect declines of broad-toothed rat (mainland) will continue at current rates (see Table 2 Threats for further evidence).

Sub-criterion A4) In a project run by the Threatened Species Recovery Hub (Legge et al. 2021), expert elicitation was used to estimate the extent of population decline after fires of varying severity, and the predicted population trajectories out to three generations after the 2019/2020

fires. Information on population response to fires of varying severity was combined with spatial estimates of the overlaps between the subspecies distribution and fire severity mapping. The analysis suggests that *site-level* decline at severely affected sites is around 70.3 percent (80 percent confidence bounds: 83.5 to 57.3 percent) one week after the fires and 61 percent (80 percent confidence bounds: 81 and 38 percent) ten years after the fires (Legge et al 2021), with the 10–year estimate based on an assumption of no further extreme fire seasons. These estimates are lower than the site-level one-year post-fire empirical declines summarised in Table 1; 75% (Vic, Macak & Rowe 2022), 83% (ACT, ACT Government 2022. pers comm 29 April) and 92% (NSW, NSW DPE 2022) so the actual outlook for the subspecies is likely worse than or near the upper bound inferred by Legge et al. (2021).

Moreover, habitats of the broad-toothed rat (mainland) have been transformed by the 2019/2020 fires and may never return to pre-fire structure, for example alpine areas are easily disturbed and slow to recover (Williams 2019).

Conclusion

Although the rate of decline is not well established across the subspecies' range, there is evidence of continuing decline in most regions of the range, in habitat suitability and extent, and area of occupancy. Threats are ongoing and some appear to be increasing (e.g., the impact of feral herbivores, feral predators, spread of weeds, effects of climate change, and increased fire frequency). Post-fire surveys have found that broad-toothed rat (mainland) is a fire sensitive species with declines of at least 75% in fire affected areas. Based on the scale of impacts from the bush fires in 2019/2020 and the increased impact from feral horses, impacts of climate change on key habitats, and the compounding impact of feral predators, we infer the overall population size reduction to be greater than 50 percent over 10 years (74% across fire and non-fire effected areas Table 5).

Therefore, the subspecies has met the relevant elements of Criterion 1 to make it eligible for listing as Endangered.

Table 5: Calculating population reduction over the 10-year assessment period (2012-2022) using occupancy as the index of abundance.

Subpopulation	Observed occupancy (Year 1)	Observed occupancy (Year 2)	# years between 2012 and Year1	# years between Year2 and 2022	# years between Yr2 and Yr1	Absolute annual change	Change between 2012 & Year1	Change between Year2 & 2022	Calculated occupancy in 2012	Calculated occupancy in 2022	10-year change
Yarra Ranges NP	19 (1990)	14 (2014)	-22	8	24	0.2	-4.6	1.7	14	12	-14.5%
Alpine NP - eastern	40 (2017)	20 (2020)	5	2	3	6.7	33.3	13.3	73	7	-90.9%
Alpine NP - Mt Hotham	12 (1990)	8 (2015)	-22	7	25	0.2	-3.5	1.1	8	7	-18.9%
Bunyip State NP	4 (1990)	2 (2014)	-22	8	24	0.1	-1.8	0.7	2	1	-38.5%
The Otways	12 (1990)	3 (2014)	-22	8	24	0.4	-8.3	3.0	4	0	-100.0%
Far east Gippsland	1 (1980)	1 (2014)	-32	8	34	0.0	0.0	0.0	1	1	0.0%
Kosciuszko NP	61 (2017)	26 (2022)	5	0	5	7.0	35.0	0.0	96	26	-72.9%
Namadgi NP	12 (2013)	2 (2021)	1	1	8	1.3	1.3	1.3	13	1	-94.3%
Dandenong Ranges	6 (1990)	0.01 (2014)	-22	8	24	0.2	-5.5	2.0	1	0	-100.0%
Leongatha and south	3 (1979)	0.01 (2015)	-33	7	36	0.1	-2.7	0.6	0	0	-100.0%
Moondara State Park	2 (1982)	0.01 (2015)	-30	7	33	0.1	-1.8	0.4	0	0	-315.9%
								Total:	213	55	**-74.4%**

Assumptions and caveats:

- Calculations follow IUCN (2019).
- The locations of data used to estimate population reduction are spatially representative of the known subspecies range.
- Declines from both 2019/2020 fire-affected and non-affected sites are included.
- Linear pattern of decline is assumed as threat impacts would not be alleviated as the population declines.
- Uniform density across the subspecies range is assumed as there are no density data with which to weight the declines for various regions.
- Impacts of threats leading to declines at surveyed sites are assumed to be representative of unsurveyed sites across the subspecies range.
- This is an approximate guide to population reduction at the national level based on available evidence of occupancy reductions across the subspecies distribution for which there were two years of observed data per subpopulation.
- We acknowledge the assumptions and caveats listed in the references cited in Table 1 from which the above estimate is derived.
- We do not account for variation among the source studies e.g., season, location, survey effort etc.

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

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

Criterion 2 evidence

Eligible under Criterion 2 B2ab(i,ii,iii,iv,v) for listing as Vulnerable

Extent of occurrence (EOO) and area of occupancy (AOO)

The EOO from the past 5 years and 10 years are approximately 52 290 km2 (2017–2022) and 60 149 km2 (2012–2022), respectively. The AOO was calculated using records from either the past 5 years or from the past 10 years, resulting in estimates of 912 km2 (2017–2022) and 1152 km2 (2012–2022).

Taking the lower estimates of the ranges; EOO is > 20,000 km² and therefore the subspecies does not meet the criterion based on the EOO. AOO is < 2000 km² and so the subspecies has a limited AOO under criterion B2.

Number of locations

The 2019/2020 bushfire season burnt a large area of Eastern Australia (100 000 km2), overlapping c. 27% of the broad-toothed rat (mainland) distribution (Legge et al. 2021), thus it is plausible that the broad-toothed rat (mainland) range is comprised of 5-10 locations based on the regions listed in Table 1.

Severely fragmented

The habitat occupied by the broad-toothed rat is naturally discontinuous, the broad-toothed rat has a high habitat specificity and small home range sizes (Ensbey et al. 2022), prompting a fragmented distribution for the subspecies. Additionally, many areas of apparently suitable habitat are unoccupied (Green & Osborne 2003), suggesting the species may have limited ability to disperse across unfavourable habitat (O'Brien et al., 2008).

Broad-toothed rats have been observed dispersing over several hundred metres (Bubela et al., 1991, Belcher, 1988, Green, 2000) and 2 males were observed dispersing up to 1km at an alpine

ski resort (Whisson et al. (2015). However, long distance movements are uncommon, especially in the absence of riparian cover or creek lines (Bubela et al. 1991, Happold 1995, O'Brien 2008, Milner et al. 2016). 2021 surveys detected the presence of broad-toothed rat in small, isolated patches of suitable habitat (such as a few square metres of grass or sedge on a roadside). The patches were up to hundreds of metres from the nearest large grassy meadow, suggesting that broad-toothed rat may be able to disperse through the landscape to these isolated patches (Kazi pers. comm., 2022).

In addition, effective fragmentation is increased with the presence of introduced predators as the success rate of dispersal attempts is reduced even when the quality and carrying capacity of habitat patches is stable. Selective predation on broad-toothed rat by feral foxes (Green and Osborne, 1981, Green, 2002, Schroder et al, in review) and feral cats (Schroder et al, in review) has been documented in areas throughout the subspecies range. Invasive predators often have increased activity and hunting success in burnt habitats, particularly following high severity fire (McGregor et al. 2016, Geary et al. 2020, Hradsky 2020). Predation is also intensified in any small unburnt patches of refugia where the subspecies may be confined following fire. Thus, predation by feral predators on dispersing individuals is contributing to increasing effective fragmentation of subspecies across its range. When combined with factors that have fragmented habitat, via destruction and/or degradation of vegetation cover (such as bushfires, feral herbivores, land management practices) and reduced snow fall and cover from subnivean spaces (climate change impacts), the impacts of feral predators are compounded such that effective fragmentation and geographic fragmentation are increased.

The broad-toothed rat (mainland) distribution is severely fragmented with isolated subpopulations in the Otways, far East Gippsland, Barrington Tops, Wilsons Promontory, and scattered across the Great Dividing Range from near Healesville (Victoria) to the Brindabella Range (ACT) (Woinarski et al., 2014, TSSC 2016). Most sources consider it scarce and patchily distributed: Seebeck and Menkhorst (2000) noted that it was 'generally rare and localised but may be locally common in appropriate habitat'. Happold (2008) considered it 'sparse to common', and IUCN (2008) considered it 'not a common species' (TSSC 2016). With the documented declines in occupancy (see Criterion 1) and common threats throughout the species range, we can infer similar declines throughout the range thus it is plausible that the distribution of the broad-toothed rat is severely fragmented and the processes rendering it such are expected to continue.

Continuing decline (EOO, AOO, number of subpopulations, number of mature individuals)

(bi) This distribution has declined since European settlement and with changing climate in more recent years (Shipway et al. 2020). Continued declines at disjunct populations on the boundaries of the subspecies range such as Barrington Tops in the north, far East Gippsland in the east, and Wilsons Promontory in the south, may reduce the EOO in the near future. The historically documented estimates for EOO for broad-toothed rat are probably a gross underestimate of their natural distribution on the mainland since they were not detected until the 1930s, after much of their range was already lost to habitat conversion. Thus, declines in EOO are likely substantially greater than estimates from survey data show (Rowe 2022. pers comm 17 May).

(bii) The AOO has declined, most recently due to the impacts of the 2019/2020 bushfires (Walker et al. 2021, Macak & Rowe 2022, ACT Government 2022) and, over the last 10 years, due to the ongoing and pervasive range of threats the subspecies faces across its range (selective

predation by feral foxes and cats, habitat degradation and destruction by feral herbivores, climate change, inappropriate fire regimes, habitat destruction of remnant habitat due to management practices at roadsides, alpine resorts etc)(Schroder et al. in review, Schulz et al. 2019, Kazi, pers. comm., 2022, Parrott pers comm., 2022, Whisson et al. 2015, Beilharz & Whisson 2016). There is evidence of reductions in AOO with 53% decline in occupancy across Victoria (Shipway et al. 2020), declines and potential extirpation of the populations in the Dandenong Ranges (See Table 1), reduction of AOO north of Forest Way in the Barrington Tops where broad-toothed rat have not been found since 2002 despite yearly surveys (NSW DPE 2022c. pers comm 13 April).

(biii) Habitat degradation and destruction by feral herbivores is a key threat to the broad-toothed rat throughout the subspecies range. Following fire, the impact of feral herbivores on regenerating soils and vegetation is compounded as trampling and herbivory disturbances impair habitat regeneration such that burnt areas may not return to the same quality of habitat pre-fire (Walker et al. 2021). Fires can also promote weed invasion which degrades the quality of the habitat for the broad-toothed rat. Many areas of habitat are highly susceptible to destruction and disturbance from mowing or fire hazard reduction operations. With the 53% decline in occupancy across Victoria, areas more likely to have persisting populations of broad-toothed rat where at higher altitudes, cooler and wetter, providing evidence that climate change is rendering lower lying areas unsuitable/less suitable habitat (Shipway et al, 2020). Habitats in alpine resorts becoming unsuitable or are being completely removed due to management practices (Whisson et al. 2015, Beilharz & Whisson 2016, Whisson, pers. comm., 2022). Alpine sphagnum bogs and associated fens, important habitat for the broad-toothed rat, are a threatened community due to climate change and the impacts of feral herbivores.

(biv) Given declines in AOO and habitat quality it follows that the number of subpopulations is likely to also have declined. Subpopulations of broad-toothed are not clearly defined, but areas such as the Dandenong Ranges, and north of the Barrington Tops are examples where numbers of subpopulations have declined given the lack of detections during the last 10 years. The number of subpopulations is also likely to have declined in some fire effected areas since the 2019/2020 bushfires.

(bv) Given declines in AOO and habitat it follows that the number of mature individuals is likely to have declined throughout the fire effected areas since the 2019/2020 bushfires. Declines of mature individuals are also likely to underpin the widespread declines in occupancy documented throughout the subspecies' range over the last 10 years.

Conclusion

The AOO estimate is less than 2000 km^2, (B2), the distribution is comprised of less than 10 locations and may be severely fragmented (a). There is also evidence of continuing declines (b) in EOO (i), AOO (ii), habitat quality (iii) and number of subpopulations (iv), and therefore number of mature individuals (v) (also see Criterion 1). Therefore, the subspecies has met the relevant elements of Criterion 2 to make it eligible for listing as Vulnerable.

Criterion 3 Population size and decline

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

Criterion 3 evidence

Insufficient data to determine eligibility

There are no estimates of total population size, nor that of most subpopulations, of the broad-toothed rat (mainland). Therefore, it is not possible to determine an estimate for the number of mature individuals.

The Committee considers that there is insufficient information to determine the eligibility of the subspecies for listing in any category under this criterion.

Criterion 4 Number of mature individuals

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

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

Criterion 4 evidence

Insufficient data to determine eligibility

There are no estimates of total population size, nor that of most subpopulations, of the broad-toothed rat (mainland). Therefore, it is not possible to determine an estimate for the number of mature individuals.

The Committee considers that there is insufficient information to determine the eligibility of the subspecies for listing in any category under 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

Criterion 5 evidence

Insufficient data to determine eligibility

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

Adequacy of survey

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

Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 31 business days between 3 January 2023 and 15 February 2023 inclusive. Any comments received that were relevant to the survival of the subspecies were considered by the Committee as part of the assessment process and provided to the Minister for the Environment with the Committee's advice.

Listing and Recovery Plan Recommendations

The Threatened Species Scientific Committee recommends:

i) that the list referred to in section 178 of the EPBC Act be amended by **transferring** *Mastacomys fuscus mordicus* in the list from Vulnerable to the Endangered category.

ii) that there not be a Recovery Plan for this species in accordance with the provisions of the EPBC Act and the Committee's conservation planning principles as follows:

- An approved Conservation Advice is an effective, efficient and responsive document to guide the implementation of priority management actions, mitigate key threats, and support the recovery for this EPBC Act listed Endangered species.
- Although the species has significant and interacting threats across its range, many populations are on managed lands and the large number of stakeholders are actively and effectively working together to understand the status and needs of the species and support its recovery.
- Implementation of many recovery actions is already underway.
- The cross-jurisdictional context and the need to support complex actions such as translocations and fire management require co-ordination, but given stakeholders are effectively working together, the Committee believes that these can be guided via a Conservation Advice aligned with other existing planning mechanisms.
- The TSSC also recommended that the department facilitate the formation and coordination of a national recovery team to support national coordination.

Having regard to the above factors, the approved Conservation Advice for *Dasyuroides byrnie*, the TSSC's initial and final advice that a Recovery Plan is not required for this species, the precautionary principle, and the recommendations of the department on this decision, a Recovery Plan is not required as it would not provide a significant conservation planning benefit above existing mechanisms.

As an approved, updated, and detailed Conservation Advice for the species would provide sufficient direction to implement priority conservation actions, mitigate against key threats, enable recovery and provide foundation for further planning, a national Recovery Plan is not required at this time.

Consequently, the Threatened Species Scientific Committee has not recommended that a recovery plan be required (see Attachment A for TSSC recommendations regarding the need for a recovery plan).

Cataloguing data

This publication (and any material sourced from it) should be attributed as: Department of Climate Change, Energy, the Environment and Water 2023, Conservation Advice for *Mastacomys fuscus mordicus* (Broad-toothed rat (mainland)), Canberra.

This publication is available at the SPRAT profile for *Mastacomys fuscus mordicus* (Broad-toothed rat (mainland)).

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Conservation Advice	Approved Conservation Advice for *Mastacomys fuscus mordicus* (Broad-toothed Rat (mainland)).	5 May 2016