The Minister approved this conservation advice and retained this species in the Endangered category, effective from 1 September 2020

Conservation Advice

Pseudomys oralis

Hastings River Mouse

Taxonomy

Conventionally accepted as *Pseudomys oralis* (Thomas, 1921). No subspecies are recognised.

Summary of assessment

Conservation status

The highest category for which *Pseudomys oralis* (Hastings River Mouse) is eligible to be listed is Endangered.

Pseudomys oralis has been found to be eligible for listing under the following categories:

Criterion 2: B2(a),(b)(i, ii, iii, v): Endangered.
Criterion 3: C2(a)(i): Vulnerable.

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

Reason for conservation assessment by the Threatened Species Scientific Committee

Pseudomys oralis was listed as Endangered under the predecessor to the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), the *Endangered Species Protection Act 1992*, and transferred to the EPBC Act in July 2000.

This advice follows assessment of new information provided to the Committee to list *Pseudomys oralis.*

Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 32 business days between 17 May 2019 and 3 July 2019. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

Species/sub-species information

Description

The Hastings River Mouse is native to Australia and one of the rarest members of the *Pseudomys* genus (Jerry et al. 1998; Meek et al. 2003). It is superficially similar in size and general appearance to *Rattus fuscipes* (Bush Rat) – which it is often mistaken for – and the introduced Black Rat (*Rattus rattus*) (Pyke & Read 2002; Meek et al. 2013; Meek & Vernes 2016).

Males are slightly larger than females. Adults weigh 80–100 g, with a head-body length of 120–155 mm and a tail length of 110–150 mm (Townley 2008). The fur is brownish-grey above and beige to greyish-white below. The tail is two-toned, being dark brown above and white below.

The feet are distinctly white, with the fifth toe of the hind foot notably joining well backward of the other toes (Pyke & Read 2002).

The Hastings River Mouse can be distinguished from other rodents found in sympatry by its two-toned tail, a narrow 1 mm band of black fur surrounding the eye, and a strongly rounded snout (Roman nose) (Pyke & Read 2002; Townley 2008). Other distinguishing features include adult females having four teats instead of eight or ten as in the *Rattus* species (Tweedie & York 1993; Pyke & Read 2002).

Distribution

The Hastings River Mouse is endemic to Australia. It was thought to be extinct but was rediscovered in Queensland in 1969 and NSW in 1981. Approximately 40 subpopulations are known (Meek 2012), patchily distributed along a section of the Great Dividing Range, within a biogeographic subregion referred to as the Macleay-McPherson overlap zone (DECC 2005). The distribution range stretches from Warwick, Queensland (30 km north of the Queensland-NSW border) to Muswellbrook, NSW (approximately 175 km north of Sydney) (Woinarski et al. 2014a). However, Pyke & Read (2002) reported the southernmost point of the distribution range to be 120 km further south, at Newnes, NSW. The species has been observed at elevations from 250–1250 m (Pyke & Read 2002; Meek & Shields 2005), with the majority of sites above 500–600 m (Townley 2008).

Subfossil and genetic evidence suggest that the distribution range has undergone a substantial contraction both before and after European settlement in Australia (Jerry et al. 1998; Pyke & Read 2002; Bilney 2010; Rowe et al. 2011; Smissen 2017). Range contraction has been estimated at 65 percent since European settlement, and 75 percent since the Pleistocene (Smith et al. 1996, cited in Woinarski et al. 2014a). As recently as 5000 years ago, the range extended from Maleny (inland from the Sunshine Coast), south-east Queensland to Buchan, eastern Victoria (Wakefield 1972, cited in Fox et al. 1994).

Genetic analysis of Hastings River Mouse tissue samples (ear and tail clippings) indicates that the population is split into two evolutionary lineages: a northern lineage and a southern lineage, overlapping at Washpool National Park, NSW (Jerry et al. 1998; Rowe et al. 2011; Smissen 2017). Smissen (2017) identified that the maternal mitochondrial haplotype genetic differences observed between the two lineages are not reflected in the nuclear genome, which exhibited only minor allele frequency differences. This suggests that the lineages do not represent distinct species, as previously proposed. However, Smissen (2017) believed the genetic differences between the northern and southern lineages great enough that they should be considered separate Evolutionarily Significant Units.

Within the separate lineages, a low level of gene flow between subpopulations has also been observed, with limited haplotype sharing in the maternal mitochondrial DNA recorded between individuals caught at different localities (Jerry et al. 1998; Rowe et al. 2011). Jerry et al. (1998) carried out genetic analyses at five sampling sites, which revealed significant genetic differentiation, even at a relatively small spatial scale, with individuals captured at Gambubal and Lamington National Parks in south-east Queensland (approximately 70 km apart) sharing just one of 11 haplotypes. These results were repeated by Rowe et al. (2011), who expanded the genetic analysis to 12 sample sites, finding that 88 percent of haplotypes were restricted to individual site localities. In Rowe's analysis, sample sites within 13 km and 20 km of each other showed significant genetic differentiation. Jerry et al. (1998) identified that this genetic divergence is consistent with the isolation and fragmentation of a once widespread population now restricted to pockets of refugia, following both historical and contemporary habitat contraction events.

Since rediscovery, renewed interest and increased surveying for the Hastings River Mouse has resulted in a steady rise in the number of recorded locations (Pyke & Read 2002). Before the turn of the century, 400 captures at 50 trapping locations (sites at least one km apart) (i.e. eight captures per location) had been recorded (Fox et al. 1994; Pyke & Read 2002); by 2002, 717 captures at 233 trapping locations (3.1 captures per location) were recorded (DECC 2005).

Since rediscovery, 1215 records have been uploaded to the Atlas of Living Australia (ALA 2019). The majority of capture sites are in state forestry estates (49 percent) and state managed land (32 percent) (Woinarski et al 2014a). More recent larger capture sites in NSW include: Gibraltar Range and Washpool National Parks, and Styx River, Billilimbra, and Marengo State Forests (Meek et al. 2003); and in Queensland: Lamington National Park and Gambubal State Forest in the Main Range National Park (Rowe et al. 2011).

The population density at capture sites is low, frequently less than one animal per hectare (Townley 2008; Woinarski et al. 2014a). Pyke & Read (2002) reported that most capture sites appear to have under 10 individuals and noted the disappearance of the Hastings River Mouse from five sites during a 15 year period. However, these observations may be due, in part, to poor targeting of the species in surveys occurring shortly after rediscovery. Early surveys focused on habitat associated with riparian features, which has since been identified as habitat rarely used, even where available (Meek 2002; 2003; Meek et al. 2003); had sub-optimal placement of traps (away from logs and rocks); or may have occurred at a disadvantageous later phase in forest succession (Meek 2003; Meek & Shields 2005), which promotes the influx of competitive *Rattus* species.

Even with optimal spatial and temporal placement of traps, detection of the Hastings River Mouse is difficult. Tasker & Dickman (2002) found that the sampling duration that is required to detect less common species with Elliott traps is large, with over a thousand trap nights required before less abundant species are captured. Camera traps provide for greater detection, as individuals do not have to respond and enter the trap. However, differentiating the Hastings River Mouse from other sympatric rodents is difficult from photographs (Meek et al. 2013; Meek & Vernes 2016). Even with traditional trapping methods, the Hastings River Mouse has been confused with the Bush Rat, and this may partially account for the scarcity of early locality records (Read 1993).

Citing captures of 200 mice in four years by Forests NSW, Meek & Shields (2005) proposed that, if present, there is a high probability of Hastings River Mouse capture, and that the population size is greater than first believed. In addition, Meek et al. (2006) observed swift occupation of newly created territories by the Hastings River Mouse in the Marengo State Forest, showing that this subpopulation is capable of recruitment and migration. However, if the species is easily detected, then the Hastings River Mouse is probably very rare and highly localised across the broader landscape, given that many general mammal surveys fail to record it, or record it only at low densities (Pyke & Read 2002).

Adequacy of survey

Surveys have been undertaken for the Hastings River Mouse in various parts of its range. Although the results of the surveys to date are highly variable, and mostly conducted in an ad-hoc fashion (mainly undertaken to meet requirements under Regional Forestry Agreements), the surveys are considered adequate to inform an assessment of the species' listing status.

Relevant biology/ecology

The Hastings River Mouse is found in open wet or dry sclerophyll forests and woodlands, predominantly *Eucalyptus campanulata* (New England Blackbutt) in Queensland, and New England Blackbutt, *E. microcorys* (Tallowwood), *E. pilularis* (Blackbutt), and *E. saligna* (Sydney Blue Gum) in NSW, with a native grass, sedge, fern or heath understorey (Pyke & Read 2002; Graham et al. 2005; Meek & Shields 2005; Townley 2008; Meek 2012). From quantitative habitat surveys, the Hastings River Mouse appears to be primarily selecting habitat based on shrub-layer canopy cover in the 1–1.5 m layer, followed by the availability of shelter sites, primarily logs, and head and butt residue. Rock piles and boulders are also important for shelter, but studies have observed their usage at significantly less than those available. At ground level, leaf litter and grass are the most frequently used microhabitats (Meek et al. 2003; Graham et al. 2005; Meek et al. 2006).

Previously believed to be found predominately near watercourses (King 1984; Read 1993; Tweedie & York 1993; Pyke & Read 2002), spool-and-line and radio tracking habitat surveys

have shown the Hastings River Mouse rarely uses riparian habitat even where available (Meek 2002; 2003; Meek et al. 2003). Individuals have also been trapped across a wider range of topography than previously thought, including habitat considered to be unsuitable under the *Hastings River Mouse Microhabitat Prediction Model* (detailed in DECC 2005). Individuals have been trapped at the forest edge, outside of old growth forest (Meek 2003; Meek et al. 2003; 2006) and at grazed and frequently burnt sites (Tasker & Dickman 2004; Graham et al. 2005). Pre-harvest surveys in the State Forests of NSW have confirmed the existence of several populations in forests with long histories of timber harvesting and burning (Meek et al. 2003; Meek 2004; Law et al. 2016).

The Hastings River Mouse is nocturnal (Meek et al. 2012) and during night-time foraging it covers distances of around 200 m within a relatively small home range of around two ha for males and one ha for females (Pyke & Read 2002; Meek & Shields 2005; Meek et al. 2006; Townley 2008). Studies show that individual home ranges can overlap (Pyke & Read 2002; Meek et al. 2006).

The Hastings River Mouse is essentially granivorous, feeding predominantly on seeds and fruit when they are present, but depends on leaves and stems in winter. Fox et al. (1994) identified both monocotyledon and dicotyledon plant material in the diet, with *Poaceae* species (grasses) making up to 55 percent of the diet in some sampled areas. The most common seeds selected were from *Juncus* species (rushes) and *Carex* species (sedges). Lesser food items include insects, flowers, pollen, fern sporangia, and fungi (Fox et al. 1994). This dietary composition is similar throughout the range of the Hastings River Mouse, indicating it is relatively selective in its foraging (Fox et al. 1994; Pyke & Read 2002; Tasker & Dickman 2004; Meek et al. 2006). Unlike other *Pseudomys* species, the Hastings River Mouse does not appear to broaden its diet in winter, although it has not been established whether this is due to active selection or food availability (Fox et al. 1994).

From available records, mating and gestation occurs between July and February, with most births occurring between July and March (Pyke & Read 2002). A study by Meek (2002) revealed no evidence of communal nesting, and the number of young per pregnancy ranges from one to four but is usually two or three (Pyke & Read 2002; Meek & Shields 2005). Pyke & Read (2002) stated that females are able to produce more than one litter per year and Townley (2008) contended that up to three litters can be produced in one season. This represents an extremely low reproductive rate compared to many other rodents (Jerry et al. 1998; Pyke & Read 2002). Individuals do not breed in the year of their birth and longevity is up to three years (Townley 2008; Ingleby 2019), making the generation length for this species two years.

Threats

Table 1: Threats impacting the Hastings River Mouse in approximate order of severity of risk, based on available evidence.

Number	Threat factor	Threat type and status	Evidence base
1.0	Habitat loss and fragmentation		
1.1	Vegetation clearance/habitat fragmentation	known current	Restricted gene flow has been observed between Hastings River Mouse subpopulations that is consistent with both historic and contemporary isolation, resulting from habitat contraction, fragmentation, and loss (Jerry et al. 1998; Rowe et al. 2011; Smissen 2017). Isolation, together with low numbers recorded at site localities (Pyke & Read 2002; Townley 2008; Woinarski et al. 2014a), increases subpopulation

			susceptibility to local extinction, with little possibility of re-establishment from surrounding areas. Further habitat loss and fragmentation could exacerbate this situation, isolating currently contiguous site localities from each other. Major causes of habitat loss and fragmentation are disturbance through forestry, land clearing, fire, and grazing. These disturbances open up the understorey and may simplify the ground cover to an extent that is unfavourable to the Hastings River Mouse (through the removal of adequate shelter or foodstuffs) and can lead to increased predation pressure (Tasker & Dickman 2004; DECC 2005; Leahy et al. 2015; McGregor et al. 2015; Hradsky et al. 2017). However, studies indicate the Hastings River Mouse may benefit from a degree of disturbance (Sousa 1984; Pyke & Read 2002; Meek et al. 2003; Meek 2004; Tasker & Dickman 2004; Law et al. 2016). The Hastings River Mouse is an early-mid successional species and has been shown to occur at the forest edge, and at grazed and frequently burnt sites (Catling & Burt 1997; Tasker & Dickman 2004; Graham et al. 2005). Pre-harvest surveys in the State Forests of NSW have confirmed the existence of several populations in forests with a long history of timber harvesting and burning (Meek et al. 2003). Disturbance can maintain an understory that favours the Hastings River Mouse by preventing cover reaching a point that allows sympatric rodents from becoming established and competing for resources (Fox 1990; Smith & Quin 1997; Monamy & Fox 2000; Meek 2004; Tasker & Dickman 2004; Law et al. 2016; Pereoglou et al. 2016). The forestry management practice of limiting forest disturbance by employing protective buffer zones around Hastings River Mouse site localities, promotes progression to a climax community (Meek & Shields 2005) and may create a habitat unfavourable to the Hastings River Mouse. Townley (pers comm), cited in Jerry et al. (1998), indicated this practice may create barriers to Hasting River Mouse movement and result in further population fragmentation by isolating currently contiguous sites.

			Declines in capture numbers (by 60–82 percent) have been recorded over time in previously sampled sites in transects where logging has been excluded (35–45 years since logging). In comparison, recently logged sites (between 7–15 years since logging) show a far higher level of occupation than sites where logging is excluded (Law et al. 2016). These results conform to observations that native rodents can show rapid recovery after logging, particularly where adequate shelter is retained for cover dependent species (Lindenmayer et al. 2010; Stephens et al. 2012; Law et al. 2016).
1.2	Habitat degradation and resource depletion by livestock	known current	Intensive grazing can cause habitat loss and fragmentation through alteration of ground shelter cover, and the removal or trampling of foodstuffs (Tasker & Dickman 2004; DECC 2005). Floristics may be further altered by burning practices used by graziers as a management tool to promote feed for grazing stock (DECC 2005). Despite the potential for habitat fragmentation, the specific effects of grazing on the Hastings River Mouse remain unclear (Meek & Triggs 1999). Low intensity grazing and fire can maintain an understory that favours the species by preventing cover reaching a point that allows sympatric rodents from becoming established and competing for resources (Fox 1990; Smith & Quin 1997; Monamy & Fox 2000; Meek 2004; Tasker & Dickman 2004; Law et al. 2016; Pereoglou et al. 2016). Tasker & Dickman (2004) trapped the Hastings River Mouse in low intensity grazed forests, characterised by an open grassy understorey with a few scattered shrubs. Several studies, not targeting the Hastings River Mouse, recorded the species at frequently burnt and grazed sites (Catling & Burt 1997; Tasker & Dickman 2004), and almost all of the locations in National Parks and State Forests where the Hastings River Mouse is known to occur, were recently, or still are, subject to grazing and associated burning (Tasker & Dickman 2004).
1.3	Habitat degradation and resource depletion through altered fire regime	known current	Frequent and/or severe fire events can result in the death of individuals. In the aftermath of a fire, the survivors may be isolated in an environment without shelter (hollow logs) and thereby becoming far easier to catch by

			predators (DECC 2005; Leahy et al 2015; McGregor et al. 2015). In addition, number of predators attracted to the area (Hradsky et al. 2017) and predator activity (Leahy et al. 2015) increase where habitat has been modified through frequent or intense burning. In 2019-20, following years of drought (DPI 2020), catastrophic wildfire conditions culminated in fires that covered an unusually large area of eastern and south-eastern Australia. In many places, the fires burnt with high intensity. The full impact of the 2019-20 bushfires has yet to be determined. The bushfires will not have impacted all areas equally: some areas burnt at very high intensity whilst other areas burnt at lower intensity, potentially even leaving patches unburnt within the fire footprint. However, an initial analysis estimates that 70 percent of the Hastings River Mouse's distribution range was affected by fire. The very large overlap between the fire extent and the species distribution, together with the Hastings River Mouse's vulnerability to mortality during and after fire, has led to it being identified as one of the highest priority species for urgent management intervention (DAWE 2020). Outside of catastrophic wildfire situations, indications are that the Hastings River Mouse may be advantaged by periodic, low-intensity fires, being able to migrate in from pockets of refugia once habitat reaches a threshold to fulfil its resource requirements (usually shelter) (Fox 1990; Smith & Quin 1997; Meek 2004; Tasker & Dickman 2004; Law et al. 2016). Much of its range is subject to low-intensity burns (Catling & Burt 1997; Meek et al. 2003; Law et al. 2016), with individuals known to occur in areas burnt at a rate of less than every 10 years, and in some areas, every five years (Meek et al. 2003; DECC 2005). Such burns exclude more dominant sympatric rodents (Fox 1990; Smith & Quin 1997; Monamy & Fox 2000; Meek 2004; Tasker & Dickman 2004; Law et al. 2016; Pereoglou et al. 2016) and promote a mix of plant species that are part of the diet (Tasker & Dickman 2004).

2.0	Climate change		
2.1	Severe wildfires	suspected future	Climate projections for eastern Australia include reduced rainfall, increased average temperatures, and more frequent droughts; these conditions will increase the scale, frequency and intensity of wildfires (CSIRO 2007; CSIRO & Bureau of Meteorology 2015). In 2019-20, catastrophic wildfire conditions culminated in very extensive fires that overlapped with about 70 percent of the Hastings River Mouse's distribution (see row above). This sort of event is increasingly likely to reoccur, as a result of climate change.
3.0	Invasive species		
3.1	Predation by feral cats (*Felis catus*)	suspected current	Predation by feral cats has been implicated in the decline and extinction of many terrestrial, non-volant, mammal species (Dickman 1993; Smith & Quin 1996; Woinarski et al. 2014b; Hardman et al. 2016; Davies et al. 2017; Radford et al. 2018; Woolley et al. 2019). The abundance of feral cats has been found to be the best predictor of decline of small sized conilurine rodents (10–90 g) (Smith & Quin 1996). Woinarski et al. (2014b) considered feral cats to be the most significant current threat to threatened and near threatened mammalian taxa. The *threat abatement plan for predation by feral cats* (DoE 2015) identified the Hastings River Mouse as having a high threat rating from feral cat predation, with it being in the target weight range for vertebrate prey (under 220 g). The impacts from predation are magnified by the mouse's low rate of reproduction, which greatly reduces the chance of population recovery (Smith & Quin 1996). Availability of shelter sites can limit predation and enable susceptible species to co-exist with the feral cat (Smith & Quin 1996). Therefore, the threat from predation could increase where there is excessive log removal, grazing, or burning that reduces ground cover and shelter sites (Law et al. 2016). However, Meek & Shield (2005) stated that there is limited evidence that feral cats have an impact on the Hastings River Mouse. Feral cat scats have been collected in the

			vicinity of sites known to be occupied by the Hastings River Mouse, but no remains were identified (Pyke & Read 2002). Meek, cited in DECC (2005), recorded only one potential feral cat predation event.
3.2	Predation by European red fox (*Vulpes vulpes*)	suspected current	Predation by the European red fox has been implicated in the decline and extinction of many terrestrial, non-volant, mammal species (Woinarski et al. 2014b; Radford et al. 2018). Predation from foxes can be significant for small isolated populations, particularly those with low reproductive rates, and even at low densities the European red fox can eliminate remnant populations of threatened species (Smith & Quin 1996). The *threat abatement plan for predation by the European red fox* (DEWHA 2008) identified the Hastings River Mouse as a species affected by the European red fox and mouse remains have been found in its scats. However, there is no study demonstrating direct predation (the European red fox is a known scavenger) or evidence that European red fox predation is a key threat to the Hastings River Mouse (Meek & Triggs 1999; Law et al. 2016). In addition, sand pad surveys across many forests in northern NSW indicate a low to medium abundance of the European red fox, suggesting predation rates on the Hastings River Mouse may be low (Meek & Shields 2005). Availability of shelter sites can limit predation and enable susceptible species to co-exist with the European red fox (Smith & Quin 1996). Therefore, the threat from predation could increase where there is excessive log removal, grazing, or burning that reduces ground cover and shelter sites (Law et al. 2016). There is some concern that control efforts focused solely on the European red fox may lead to an increase in feral cat abundance (Risby et al. 2000). In addition, Marlow et al. (2016) identified that sustained suppression of European red fox numbers is difficult to achieve. Therefore, there is a need to better understand the impact of the European red fox, both target and non-target impacts of control measures, and fox interactions with other species (DEWHA 2008).

4.0	Competition		
4.1	Increased competition with sympatric rodents	known current	The Hastings River Mouse is an early-mid seral stage specialist, able to use resources relatively soon after disturbance. As the vegetation regenerates, late seral stage specialists, such as the sympatric Bush Rat and Swamp Rat, can become established as the habitat reaches a threshold to fulfil their resource requirements. When established, these more dominant species are thought to exclude the Hastings River Mouse (Fox 1990; Smith & Quin 1997; Monamy & Fox 2000; Tasker & Dickman 2004; Law et al. 2016). Law et al. (2016) advocated for active management that considers the effects of reduced disturbance (often promoted through forestry practices of providing buffer zones to protect threatened species). They concluded that a lack of disturbance can lead to a complex chain of interactions within the small mammal community and leave vegetation conditions more suitable to competitively dominant species.

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

Criterion 1. Population size reduction (reduction in total numbers)
Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered Very severe reduction	Endangered Severe reduction	Vulnerable Substantial reduction
A1	**≥ 90%**	**≥ 70%**	**≥ 50%**
A2, A3, A4	**≥ 80%**	**≥ 50%**	**≥ 30%**

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

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

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

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

based on any of the following:

(a) direct observation [*except A3*]

(b) an index of abundance appropriate to the taxon

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

(d) actual or potential levels of exploitation

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

Evidence:

Insufficient data to determine eligibility.

The Hastings River Mouse has a longevity of up to three years but does not breed in its first year (Townley 2008; Ingleby 2019), making the generation length two years. As three generations gives just a six-year time scale, the default is a 10-year period for this criterion.

There is no robust estimation of Hastings River Mouse population size or rate of reduction. The results from surveys undertaken to date are highly variable, with surveys mostly conducted in an ad-hoc fashion (mainly undertaken to meet requirements under Regional Forestry Agreements). Woinarski et al. (2014a) provide an estimate of under 10 000 mature individuals (with a low-medium reliability rating), with the population believed to be declining. Before the turn of the century, 400 captures at 50 trapping locations (i.e. eight captures per location) had been recorded (Fox et al. 1994; Pyke & Read 2002); by 2002, 717 captures at 233 trapping locations (3.1 captures per location) were recorded (DECC 2005). Since rediscovery (in 1969), 1215 records have been uploaded to the Atlas of Living Australia (ALA 2019).

Based on pre-logging surveys conducted by Forests NSW, which captured 200 mice, Meek and Shield (2005) proposed that if the Hastings River Mouse is present, there is a high probability of capture. However, population density at other capture sites is usually low, frequently less than one animal per hectare (Townley 2008), and Pyke & Read (2002) reported that most capture sites appear to have under 10 individuals. If detectability of the species is high, then the general absence or low capture rates of Hastings River Mouse during non-targeted mammal surveys suggests that the mouse is highly localised across the broader landscape (Pyke & Read 2002).

In recent years a substantial rate of decline has been observed at monitoring sites in northern NSW, with a 44 percent decline in occupancy reported over a three-year period (2015-2018) (Gonsalves et al. 2019) and declines of 60–82 percent reported at monitoring sites where logging has been excluded (35–45 year timeframe) (Law et al. 2016). In support of these demonstrated declines, Rowe et al. (2003) indicate that the southern lineage (distributed within NSW) may show a genetic signature of a recent population decline.

In addition, the recent 2019-20 bushfires in eastern and southern Australia may have accelerated any population decline, with about 70 percent of the Hastings River Mouse's distribution range overlapping with the fire-affected areas. These fires covered an unusually large area and, in many places, burnt with an unusually high intensity. The impact of bushfires on the Hastings River Mouse has yet to be examined but the extent of potential mortality as a result of fire, as well as mortality due to unfavourable post-fire conditions (loss of shelter, increased susceptibility to predators, and loss of food-stuff), has led the Department to identify it as one of the highest priority species for urgent management intervention (DAWE 2020).

Although the available information suggests there is population decline, and that the decline may represent a substantial or even severe reduction in population size, the data are inadequate to estimate the overall rate of decline. Therefore, the Committee considers that there is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

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

Evidence:

Eligible under Criterion 2 B2(a),(b)(i, ii, iii, v) for listing as Endangered.

Based on the mapping of point records from a 20 year time period (1997-2017) (obtained from state governments, museums and CSIRO) the Extent of Occurrence (EOO) has been estimated at 83 266 km^2 and the Area of Occupancy (AOO) at 504 km^2. The EOO was calculated using a minimum convex hull, and the AOO calculated using a 2x2 km grid cell method, based on the IUCN Red List Guidelines 2014 (DoE 2015). Indicating an even smaller geographic distribution, Woinarski et al. (2014a) estimated the EOO at 23 200 km^2 and the AOO at 468 km^2.

Woinarski et al. (2014c) identified that AOO is a difficult parameter to assess for most Australian mammalian taxa, and highly influenced by sampling effort across the taxon's range, often leading to a significant under-estimate of the actual area. However, the Hastings River Mouse is generally absent from many areas that contain habitat deemed suitable (Townley 2008) and is rarely recorded during non-targeted mammal surveys (Pyke & Read 2002). This indicates that across the broader landscape it is highly localised. Therefore, the AOO for the Hastings River Mouse may be less of an under-estimate than it generally is for other species of small mammal.

In addition, the recent 2019-20 bushfires in eastern and southern Australia overlapped with about 70 percent of the Hastings River Mouse's distribution, potentially greatly reducing both the EOO and AOO. These fires covered an unusually large area and, in many places, burnt with an unusually high intensity. The impact of bushfires on the Hastings River Mouse has yet to be examined but the extent of potential mortality as a result of fire, as well as mortality due to unfavourable post-fire conditions (loss of shelter, increased susceptibility to predators, and loss of food-stuff), has led to it being identified as one of the highest priority species for urgent management intervention (DAWE 2020).

Given that the calculated AOO before the 2019-20 fires is very close to the criterion threshold value for Endangered listing, that the AOO was following a decreasing trend (Woinarski et al. 2014a), and that the 2019-20 bushfires will have further reduced the AOO, the Committee considers it likely that the current AOO is under 500 km^2. The species therefore meets the threshold for listing as Endangered under subcriterion B2.

Jerry et al. (1998) stated that the Hastings River Mouse population appears to be severely fragmented, with restricted gene flow observed between subpopulations. Rowe et al. (2011) confirmed these findings, demonstrating that sites at a relatively small spatial scale from each other (within 13 km and 20 km) showed significant genetic divergence. Jerry et al. (1998) carried out genetic analyses on individuals caught at five different localities, finding that only one out of 11 haplotypes was present in more than one sample locale. Rowe et al. (2011) expanded the analysis to 12 sites, finding that 88 percent of haplotypes were restricted to individual site

localities. These observations are consistent with the fragmentation of a historic population, following both historic and contemporary habitat contraction events, with resulting subpopulations restricted to pockets of refugia (Jerry et al. 1998; Rowe et al. 2011; Smissen 2017).

This fragmentation has potentially been exacerbated through the forestry management practice of employing protective buffer zones around Hastings River Mouse site localities, in order to limit forest disturbance, which promotes progression to a climax community. Under this practice, the habitat develops into a complex, unburnt forest, with a very dense understorey, which is thought unfavourable to the Hastings River Mouse (Meek & Shields 2005). Townley (pers comm), cited in Jerry et al. (1998), indicated this practice may create barriers to movement, and result in further population fragmentation by isolating currently contiguous sites.

Substantial declines in the Hastings River Mouse at sites in northern NSW have been observed through monitoring studies undertaken by Law et al. (2016) and Gonsalves et al. (2019). In support of these demonstrated declines, genetic analysis conducted by Rowe et al. (2011) indicates that the southern lineage (distributed in NSW) may show a signature of recent population decline, and Pyke & Read (2002) noted the disappearance of the Hastings River Mouse from five sites since its rediscovery. The 2019-20 bushfires is likely to have caused further decline. A continuing decline in extent of occurrence, area of occupancy, quality of habitat, and number of mature individuals, can also be projected from the on-going threats impacting the Hastings River Mouse (Woinarski et al. 2014a), the implementation of inappropriate management actions resulting from poor ecological knowledge of the species, and the increasing frequency of extensive and intense bushfires.

The Committee considers that the species' area of occupancy is very restricted, and the geographic distribution is precarious for the survival of the species because its occurrence is severely fragmented, and continuing decline in extent of occurrence, area of occupancy, habitat, and number of individuals has been observed, inferred and projected. Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as **Endangered**.

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

Evidence:

Eligible under Criterion 3 C2(a)(i) for listing as Vulnerable.

There is no robust estimation of Hasting River Mouse population size. The results from surveys undertaken to date are highly variable, with surveys mostly conducted in an ad-hoc fashion (mainly undertaken to meet requirements under Regional Forestry Agreements). Woinarski et al. (2014a) provide an estimate of under 10 000 mature individuals (with a low-medium reliability rating), with the population believed to be declining. Before the turn of the century, 400 captures at 50 trapping locations (i.e. eight captures per location) had been recorded (Fox et al. 1994; Pyke & Read 2002); by 2002, 717 captures at 233 trapping locations (3.1 captures per location) were recorded (DECC 2005). Since rediscovery (in 1969), 1215 records have been uploaded to the Atlas of Living Australia (ALA 2019). Taken together, these figures are consistent with a limited overall population size.

Substantial declines in numbers at sites in northern NSW have been observed through monitoring studies undertaken by Law et al. (2016) and Gonsalves et al. (2019). In support of these demonstrated declines, genetic analysis conducted by Rowe et al. (2011) indicated that the southern lineage (distributed in NSW) may show a signature of recent population decline, and Pyke & Read (2002) noted the disappearance of the Hastings River Mouse from five sites since its rediscovery. The 2019-20 bushfires, which affected about 70% of the Hastings River Mouse's distribution, have likely caused further population reduction.

A continuing decline in population numbers can also be projected based on the on-going threats impacting the Hastings River Mouse (Woinarski et al. 2014a), the implementation of inappropriate management actions resulting from poor ecological knowledge of the species, and the likely impact of increasing frequencies of extensive and intense fire.

The number of mature individuals in each subpopulation is believed to be under 1000 (Woinarski et al. 2014a). Population density at capture sites is usually low, frequently less than one animal per hectare (Townley 2008), and Pyke & Read (2002) reported that most capture sites appear to have under 10 individuals. In addition, non-targeted mammal surveys have very rarely captured the Hastings River Mouse, indicating that across the broad landscape it is very rare and highly localised (Pyke & Read 2002). This number of individuals in each subpopulation meets the threshold for listing as Vulnerable under subcriterion C2(i).

The Committee considers that the estimated total number of mature individuals of this species is limited, with an observed and projected continuing decline, and the geographic distribution is precarious for the survival of the species because the number of mature individuals in each population is less than 1000. Therefore, the species has met the relevant elements of Criterion 3 to make it eligible for listing as **Vulnerable**.

Criterion 4. Number of mature individuals			
	Critically Endangered Extremely low	**Endangered Very Low**	**Vulnerable Low (Medium-term future)[1]**
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 km^2 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.

Evidence:

Ineligible.

There is no robust estimate of population size or number of mature individuals for this species. However, Woinarski et al. (2014a) estimated the number of mature individuals to be under 10 000 (with a low-medium reliability rating). In addition, the Hastings River Mouse does not meet the quantitative threshold for Vulnerable under subcriterion D2. The area of occupancy is estimated to be <500 km^2. Therefore, the species does not meet the requirements for listing under D2.

The Committee considers that the Hastings River Mouse is not eligible for listing 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**

Evidence:

Insufficient data to determine eligibility.

Population viability analysis has not been undertaken.

Conservation actions

Recovery plan

The 'Recovery Plan for the Hastings River Mouse (*Pseudomys oralis*)' (DECC 2005) was developed by the NSW government, and adopted under the EPBC Act in 2008. It is due to expire in 2022.

The Recovery Plan has been partially implemented, with some management and research actions undertaken at state levels. Once the Recovery Plan expires, the Committee recommends that developing a new national Recovery Plan for *Pseudomys oralis* would not be warranted.

The species has a discontinuous range across southern Queensland and Northern NSW, generally occurring in discrete areas, with recognised separate northern and southern lineages. Cross-jurisdictional coordination of actions are therefore not required. Most of the species' range occurs in state forestry estates or state managed land (81 percent), with management and research activities being undertaken at state level. A Conservation Advice should provide sufficient direction to implement priority actions and mitigate against key threats.

Primary conservation actions

1. 2019-20 bushfire response (Immediate to medium term):
    - Conduct rapid on-ground surveys to establish extent of population loss as a result of the 2019-20 bushfires, and to provide a baseline for ongoing monitoring.
    - Protect unburnt areas within or adjacent to recently burnt areas from further fire, in order to provide refuge sites, as well as protecting (from fire) unburnt areas that are not adjacent to burnt areas.
    - Control red foxes and feral cats to support recovery of populations affected by fires, or populations near areas that have been affected by fire.
    - Control introduced herbivores in burnt areas to support habitat recovery post fire.
    - Weed control and habitat restoration works may support the regeneration of forest at some localised sites.
    - Salvage logging in forestry areas is likely to adversely impact the species and should be avoided at sites with populations of Hastings River Mouse.
2. Medium to longer term:
    - Identify and implement appropriate levels of shelter site log, and head and butt residue retention, and the logging rotation that provides for that level of retention.
    - Assess population impacts by both the feral cat and red foxes and implement control measures as necessary.

Conservation and management priorities

- Habitat loss, disturbance and modifications
    - Protect unburnt areas within or adjacent to recently burnt areas from further fire, in order to provide refuge sites, as well as protecting (from fire) unburnt areas that are not adjacent to burnt areas.
    - Designate protection zones around known site locations to ensure habitat is not fragmented by roads, timber harvesting or clearing of freehold land. Activities permitted in protection zones should be dictated by further research into the effects of disturbance on the Hastings River Mouse.
- Invasive species (including threats from grazing, trampling, predation)
    - In areas burnt by the 2019-20 bushfires, control of introduced predators may be required to support population recovery, and control of introduced herbivores will aid habitat recovery. Weed control and habitat restoration may be needed in localised areas to support forest regeneration.
    - Develop and implement longer-term strategies to control predation by red foxes and feral cats, particularly in designated protection zones, as detailed in the red fox and feral cat Threat Abatement Plans (DEWHA 2008; DoE 2015).
    - Conduct baiting and/or exclusion trials to determine the effect of predation by cats and red foxes on the Hastings River Mouse and refine control measures as determined by the research.

- Use data from survey and monitoring work to better understand the impact of livestock on the Hastings River Mouse, and how the species responds to varying grazing intensities.

- Fire

  - Implement appropriate fire regimes as determined by further research.

Survey and monitoring priorities

- Conduct rapid on-ground surveys to establish extent of population loss caused by the 2019-20 bushfires, and to provide a baseline for ongoing monitoring.
- Conduct ongoing strategic surveys of known or potential Hastings River Mouse sites (identified through habitat suitability models). Identify important populations and conduct long-term monitoring to determine whether the populations are stable, and the requirements to maintain connectivity between currently contiguous populations.
- Re-survey old sites where populations are believed to have disappeared to check whether absences recorded were temporary.

Information and research priorities

- Use data from surveys and monitoring to better understand the habitat requirements of the Hastings River Mouse and how the species responds to different fire regimes and disturbance by forestry.
- Use the results of surveys and monitoring to examine population dynamics and determine whether populations persist at low abundance or are becoming locally extinct and re-occupied (metapopulation model).
- Conduct before and after habitat manipulation experiments, such as placement of hollow logs in historical sites to determine if this encourages recolonisation, and *Rattus* species removal to determine the role of interspecific competition in the absence of Hastings River Mouse from some sites.
- Investigate the impact of bushfires, planned burns and fire suppression activities on Hastings River Mouse populations and use this information to refine prescriptions for planned burns in areas of their habitat.
- Update harvesting prescriptions for State Forests where Hastings River Mouse populations occur, to minimise the impact of logging on the species, and to improve the actions designed to protect populations (such as the management of buffer zones around populations).

Recommendations

(i) The Committee recommends that *Pseudomys oralis* (Hastings River Mouse) be confirmed in its current listing status of Endangered in the list referred to in section 178 of the EPBC Act as there is sufficient evidence to support the category since the species' rediscovery in the wild.

(ii) The Committee recommends that there not be a new Recovery plan developed for this species.

Threatened Species Scientific Committee

5 April 2020

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