National Recovery Plan for the

Plains Mouse

Pseudomys australis

2012

Australian Government

Government of South Australia

Northern Territory Government

Queensland Government

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Note:
This recovery plan sets out the actions necessary to stop the decline of, and support the recovery of, the listed threatened species or ecological community. The Australian Government is committed to acting in accordance with the plan and to implementing the plan as it applies to Commonwealth areas.

The plan has been developed with the involvement and cooperation of a broad range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

Queensland disclaimer:
The Australian Government, in partnership with the Queensland Department of Environment and Heritage Protection, facilitates the publication of recovery plans to detail the actions needed for the conservation of threatened native wildlife.

The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved, and may also be constrained by the need to address other conservation priorities. Approved recovery actions may be subject to modification due to changes in knowledge and changes in conservation status.

Copies of the plan are available at:
www.environment.gov.au/biodiversity/threatened/recovery.html

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Plains Mouse *Pseudomys australis* by Peter Canty.

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SUMMARY

Scientific name:	*Pseudomys australis*
Common name:	Plains Mouse
Indigenous name:	Palyoora
Recent synonyms:	*Pseudomys auritus, P. minnie, P. rawlinnae*
National status (EPBC Act):	Vulnerable
SA status (NPW Act):	Vulnerable
NT status (TPWC Act):	Endangered
Qld status (NC Act):	Endangered
IUCN criteria:	*Vulnerable* (B2b(iii); c(ii,iii,iv))
Distribution:	Stony deserts in SA and NT arid zone
Area of extent:	~100 000 km²
Area of occupancy:	< 20 000 km²
Population numbers:	Five sub-populations
Population size:	?
Habitat requirements:	Cracking clay soils and gilgais in open plains
Threats:	• *Habitat degradation from introduced livestock* • *Introduced small herbivores/competitors* • *Predation* • *Climate change*
Recovery plan:	First Recovery Plan for the species
Recovery plan period:	Five years from the time of adoption
Recovery objectives:	1. Clarify the current distribution of the Plains Mouse, and habitat use across the species' range. 2. Clarify threats to current populations. 3. Vibrant communities, government and industries using and managing natural resources within ecologically sustainable limits to adequately protect enough habitat to maintain and increase current distribution of the Plains Mouse. 4. Vibrant communities, governments and industries working together to manage the recovery process in an integrated way and with the capability, commitment and connections to support, guide and coordinate the implementation of the recovery plan.
Recovery team:	Not formed at present

PART A: SPECIES INFORMATION AND GENERAL REQUIREMENTS

Current taxon status

The Plains Mouse (*Pseudomys australis*) (herein referred to as Plains Mouse), is listed as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (where its common name is given as 'Plains Rat'). This classification is consistent with IUCN criteria [IUCN 2001,

The Plains Mouse is listed as 'Vulnerable' in South Australia under *Schedule 8* of the *National Parks and Wildlife Act 1972* (NPW Act); and 'Endangered' in the Northern Territory and Queensland under the *Territory Parks and Wildlife Conservation Amendment Act 2000* (TPWC Act) and Queensland *Nature Conservation Act 1992* (NC Act), respectively. The species is considered 'Extinct' in New South Wales (Dickman *et al*. 1993) and Victoria (Mansergh and Seebeck 1992). In Western Australia, it is listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 2006* as 'Fauna that is rare or is likely to become extinct'.

The current population size is unknown but the species' range has significantly declined since European settlement (Breed and Head 1991; Lee 1995).

Taxonomy

Watts and Aslin (1981) included within the Plains Mouse (*P. australis*) all specimens of *P. auritus*, *P. minnie* and *P. rawlinnae*. However, while several authors have indicated that further taxonomic studies might be carried out to clarify this taxonomic group (e.g. Baynes 1987; Watts and Aslin 1981), recent taxonomic work on the remaining populations of *P. australis* in northern South Australia has indicated that they were all from the same species (Brandle *et al.* 1999).

Description of species

The Plains Mouse is an Australian native murid rodent weighing between 30 and 50 g (Brandle and Moseby 1999). The species is one of the largest rodents still inhabiting the arid zone and is grey to grey-brown above and white or cream below. The tail is shorter than, or equal with, the head and body length (Watts 1995). The tail is also bicoloured being brown/grey above and white underneath. In some specimens the entire tail and hind feet are white.

PART B: DISTRIBUTION AND LOCATION

Distribution

Historical records (pre-1980) and sub-fossil bone material suggests the Plains Mouse was once widespread throughout the arid and semi-arid regions of Australia (Brandle *et al*. 1999; Fig. 1). The species occurred on the western edge of the Nullarbor Plain (Western Australia), south to the Murray Mouth (South Australia), along the inland slopes of the Great Dividing Range in northern New South Wales and southern Queensland, and in the Lake Eyre Basin as far north as the southern Northern Territory and into central Queensland.

The distribution of the Plains Mouse has declined by 50-90% since European settlement (Lee 1995) and the species is now primarily restricted to the Stony Plains Bioregion in South Australia (Fig. 1). In the southern Northern Territory, the Plains Mouse occurs in the Stony Plains Bioregion adjacent to South Australia and also in the south-western Simpson Strrzelicki Dunefields Bioregion. There is a single record from the Finke Bioregion (Neagle 2003; Fig. 2). Four modern records of the species exist east of Lake Eyre, South Australia in the Simpson and Strzelecki Deserts and an outlying population in Queensland in the Channel Country Bioregion (see Fig. 2).

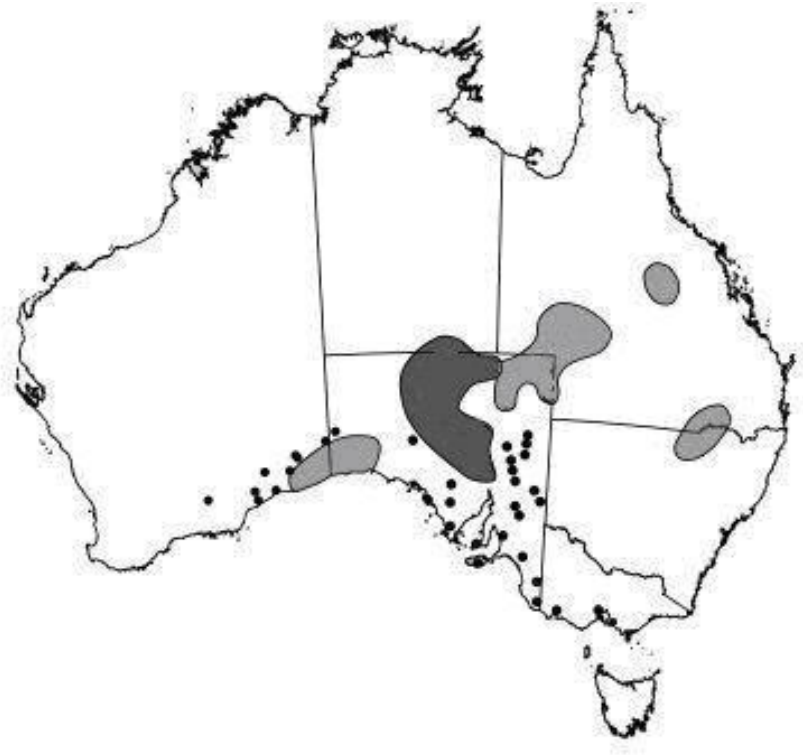


Figure 1: Historical (pre-1980; light grey) and extant (post-1980; dark grey) distribution of the Plains Mouse in Australia. Black dots indicate sub-fossil bone material.

Areas formerly occupied

Finlayson (1961) recorded this species as periodically abundant on the north-eastern floodplains of the Lake Eyre Basin, including the Goyders Lagoon area. The species had not been recorded in this north-east region since 1969, when it was recorded on the Kachumba Plain (Watts and Aslin 1981), until 5-6 individual remains were extracted from fresh Barn Owl pellets in 2001 within Diamantina National Park, Queensland. Intensive survey work between 1992 and 2005 by the Department of Environment, Water and Natural Resources, South Australia (SA DEWNR) failed to record the species in this region (Brandle *et al*. 1999). That period included both above and below average rainfall years.

In the Northern Territory, the species was first recorded in 1974 near Bloodwood Bore on Lilla Creek Station (Corbett *et al*. 1975). Watts and Aslin (1981) report seeing large numbers of Plains Mice between Charlotte Waters and the South Australian border and Breed and Head (1991) date this observation as 1975. The Plains Mouse was not recorded in the Northern Territory again until April 1994 when it was captured east of Charlotte Waters near the South Australian border (Eldridge and Reid 2000). Extensive surveys were conducted throughout the Finke Bioregion by the Northern Territory (NT) Parks and Wildlife Service between 1999 and 2003 (Neave *et al*. 2004). Despite considerable trapping effort on Lilla Creek Station (the original locality of the species in the Northern Territory) during these surveys, the species was not recaptured (Pavey 2007). The species was located at a series of sites on Andado Station in the south-western Simpson Strzelecki Dunefields Bioregion and the Mac Clark Conservation Reserve, which is an excision from Andado Station, between 2000 and 2002. Intensive surveys between 2007 and 2010 have located the species at a number of new sites on Andado Station.

Despite being formerly widespread in New South Wales and Queensland, the Plains Mouse had not been recorded from these states since 1936 (Breed and Head 1991), until the pre-described remains were found in Diamantina National Park, Queensland. The species is present in Pleistocene and Holocene fossil deposits in western Victoria but despite anecdotal reports from the 1840s (Seebeck 1984), there are no confirmed records in the modern era in that state (Seebeck and Menkhorst 2000). In Western Australia it was known only from the Nullarbor Plain and was last collected near Mundrabilla in 1969 but identified at the time as *Pseudomys gouldii* (Morris 2000).

Current distribution

The species now occupies a north/south band of stony plain habitat to the west of Lake Eyre and extending from Pernatty Station in South Australia to Andado Station in the Northern Territory. Surveys between 1994 and 1997 recorded the Plains Mouse from 18 of 589 sites within the stony deserts of South Australia (Brandle 1998; Brandle *et al.* 1999). The Plains Mouse is also permanently established within the Arid Recovery Reserve, where it has been trapped each year for five years. Three modern records (two live captures and one remain found in a dingo scat) have been made in the sandy deserts of north-east South Australia and an outlying specimen (remains found in barn owl pellets) has been detected at Diamantina National Park, Queensland.

The primary extant population distribution (see Fig. 2) can be divided into five broad, contiguous geographic zones based on latitude and catchments:

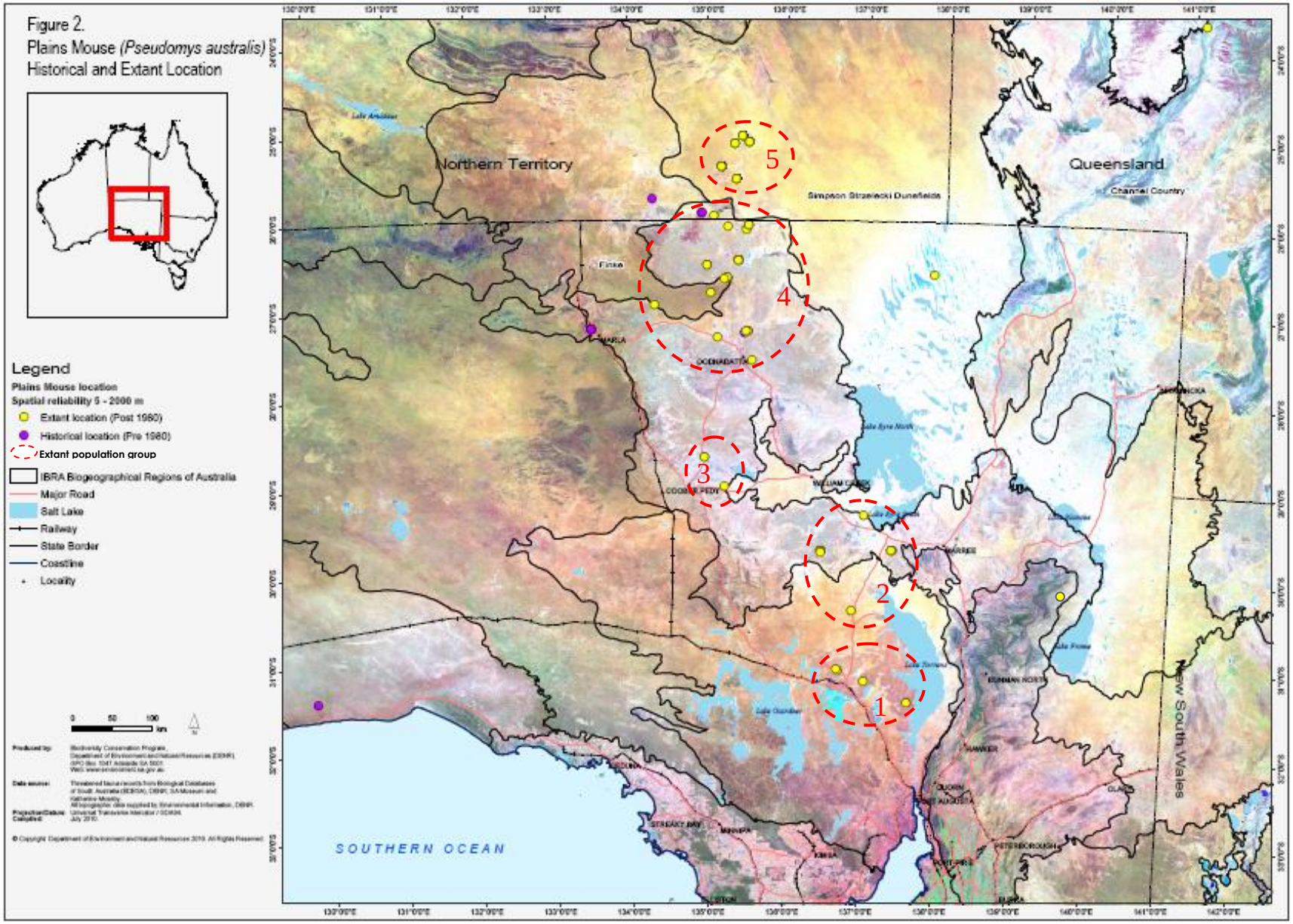
1) Arcoona Tableland including Pernatty Station, South Australia;
2) Southern Lake Eyre region including Billa Kalina Station, Stuart Creek Station, Finniss Springs Station and Roxby Downs (Arid Recovery Reserve), South Australia;
3) Moon Plain region around Coober Pedy to Evelyn Downs, South Australia;
4) Oodnadatta region (Macumba Station, Todmorden Station) and Witjira National Park (including Mt Dare), South Australia, extending into the extreme south of the Northern Territory on New Crown Station; and
5) Andado Station and Mac Clark Conservation Reserve in the Northern Territory.

Outlying recent records (Figure 2) include;

- A single male Plains Mouse captured (in atypical habitat of Sandhill Canegrass (*Zygochloa paradoxa*) grassland, on a dune slope with ephemeral understorey) in the Simpson Desert Regional Reserve, South Australia in 1998;
- Specimens collected from areas near the Beverley Uranium Mine, South Australia on the West side of Lake Frome in stony plains habitat (R. Pedler pers. comm.);
- The discovery of a Plains Mouse in a dingo scat from Quinyambie Station, South Australia in the Strzelecki Desert in March 2009 (Allen *et al. 2011*); and
- Five or six individual Plains Mouse's remains extracted from fresh Barn Owl pellets in 2001 within Diamantina National Park, Queensland.

Outlying recent records indicate the present of the species further east but may not be an indicator of additional isolated population or an extension of its range. These are one-off records and may be due to temporary increases and spread of the species due to good conditions or large scale dispersal by predators (K. Moseby and R. Pedler pers. comm.). Further follow-up surveys of these records are required to clarify the distributions and are identified as a priority recovery action in this plan.

Therefore, the extent of occurrence is estimated at approximately 100,000 km² (based on polygon area of the five primary extant populations; from Pernatty Station to Coober Pedy, Todmorden Station and Andado Station), approximately 700 km in length and 250 km in width. This estimate excludes the four outlying recent records as there are no accurate location details (scat collections) or evidence to indicate an extant population. The area of occupancy is approximately 20,000 km² (based on polygon areas of each of the 5 primary extant populations. However, the actual area of occupancy is considered to be much smaller and is extremely fragmented with the species inhabiting small patches of suitable cracking clay and gilgai stony plains habitat within these polygons.



Note: Figure 2 does not include the Plains Mouse dingo scat record from Quinyambie Station in the Strzelecki Desert, east of Lake Frome

Figure 3.
Plains Mouse *(Pseudomys australis)*
Current and Potential Habitat

Land tenure

The majority (around 80%) of extant Plains Mouse population records occur on private pastoral leasehold land. In the last 20 years, the Plains Mouse has been recorded on the following pastoral leases:

SOUTH AUSTRALIA: *Cattle Stations* - Macumba, Billa Kalina, Stuarts Creek, Anna Creek (Moon Plain), Todmorden, Evelyn Downs
Sheep Stations - Arcoona, Pernatty

NORTHERN TERRITORY: *Cattle Stations* - Andado, New Crown.

Some Plains Mouse colonies have been recorded on Crown Lands and private reserves such as the Moon Plain (SA), Witjira National Park (SA), the Mac Clark Conservation Reserve (NT), Diamantina National Park (Qld) and the Arid Recovery Reserve (SA). A single specimen has been collected from within the Simpson Desert Regional Reserve (SA). Witjira National Park is jointly managed by SA DEWNR and the Irrwanyere Aboriginal Corporation and other populations could potentially occur on indigenous land, particularly Finniss Springs Station. The Plains Mouse has also been recorded within the Woomera Prohibited Area, an area of pastoral leasehold land under the jurisdiction of the Australian Government – Department of Defence, and on the BHP Billiton, Olympic Dam Special Mine Lease.

Habitat critical to the survival of the species

Although previously inhabiting a range of habitats, the Plains Mouse has been recently recorded from two main habitat types (Brandle *et al.* 1999; Brandle and Moseby 1999):

- large open gypseous cracking clay areas associated with minor drainage features, and
- depressions within gibber stony plains.

These habitat types are the most productive patches in their respective environments because they form run-on areas, receiving water and nutrients even after relatively minor rainfall events (Brandle *et al.* 1999). Both habitat types are patchily distributed and considered critical for the survival of the species.

The gypseous cracking clay plains are characterised by deep cracks, extremely friable self-mulching clays and little perennial vegetation. These areas become extremely productive after significant rains (usually events more than 60 mm), supporting extensive ephemeral forb growth (Brandle *et al.* 1999). Such areas are considered important breeding sites, providing large numbers of dispersing individuals after rains.

The other main habitat type comprises smaller gilgais and minor drainage lines with heavier clays and fewer, more structured cracks. These areas are recognisable as small patches of perennial vegetation on large open gibber plains and considered to be more widespread but supporting fewer individuals (Brandle and Moseby 1999). However, this habitat type is believed

to be important in sustaining individuals during dry conditions due to the presence of perennial vegetation and the fact that the gilgais are surrounded by gibber flats allowing small rainfall events to stimulate vegetation production. This habitat type is more abundant and widespread throughout the stony plains in South Australia and Northern Territory, and would provide essential habitat for maintaining genetic diversity and the distribution of the species.

The presence of cracking clay soils appears to be more critical than the type or structure of vegetation, as the Plains Mouse has been recorded from a variety of vegetation communities (Brandle 1998) as well as areas where vegetation is virtually absent during dry periods. Brandle (1998) recorded the Plains Mouse from four main vegetation communities including:

- *Eucalyptus coolabah* (Coolibah) Low Woodland
- *Atriplex nummularia* (Oldman Saltbush) / *Abutilon halophilum* (Plains Lantern-bush) Low Very Open Shrubland
- *Maireana aphylla* (Cottonbush) / *Eragrostis setifolia* (Bristly Love-grass) / *Astrebla pectinata* (Barley Mitchell-grass) / *Atriplex vesicaria* (Bladder Saltbush) Low Very Open Shrubland
- *Sclerolaena divaricata* (Tangled Bindyi) / *Eragrostis Setifolia* / *Atriplex vesicaria* Low Open Shrubland.

The Plains Mouse has also been captured in Lignum (*Muehlenbeckia* spp.) swamps (SA Museum Records). During natural irruptions after significant rainfall events, the Plains Mouse temporarily inhabits a variety of habitat types.

A broad-scale map of current and potential Plains Mouse habitat based on vegetation characteristics is provided in Figure 3. (Note that vegetation data are unavailable for parts of the species range, and habitat has not yet been mapped based on soil characteristics).

Cracking clay gibber plains in the north-east of South Australia represent essential habitat that is currently unoccupied or possibly supporting low numbers of Plains Mice. The modern (1998, 2009 & 2011) records of Plains Mice in the Simpson Desert Regional Reserve and the Strzelecki Desert, suggests that a population of the Plains Mouse may be extant on the eastern side of Lake Eyre in South Australia but this is not substantiated and may only be an indicator of a temporary increase after significant rain-fall seasons or dispersal from close gilgai habitat (K. Moseby pers. comm.). Further surveys are required.

Although clay is recognised as the core habitat for the species, the species has also been observed in sandy habitats in the Arid Recovery Reserve during boom periods (K. Moseby pers. comm.).

Biology and ecology

The Plains Mouse is a social rodent and lives in colonies that are usually small in size but increase dramatically after good rains, sometimes irrupting into plagues (Finlayson 1939). Rainfall triggers an increase in available resources in the species' habitat that results in high levels of reproduction. Numbers

remain high while conditions are favourable and then decline rapidly. Brandle and Moseby (1999) studied two sub-populations of the Plains Mouse in northern South Australia over a three year period. The Plains Mouse exhibited a boom/bust population cycle with one colony exhibiting an 80-fold decline in estimated population size over the three year study period. The number of animals per hectare varied from 9.8 to 0. As population size declined, recapture rates increased up to a maximum of 71% after six months. Weights also declined as conditions became dry and parasite loads increased. Trapping in the Northern Territory within the Mac Clark Conservation Reserve between 2000 and 2002 yielded more than 237 captures at three sites (trap success 8%). However, recent trapping at these sites failed to record the species, further highlighting the boom/bust nature of populations.

The Plains Mouse is nocturnal and lives in burrows located at the base of bushes or within cracks. Nest chambers built from dried grass and other vegetation are dug into cracks or within warrens up to two metres in area, dug into friable soils around the bases of low shrubs. Burrows in breeding populations usually contain one male and one or more females whilst burrows in non-breeding areas contain up to 20 individuals of both sexes (Watts and Aslin 1981). Individuals range over areas of up to 1.6 ha in size (Brandle and Moseby 1999).

Previous records cite colonies up to 40 km long and 1 km wide (Watts and Aslin 1981). Despite very good seasons in the mid 1970s and 1989, colonies of this size have not been documented since the late 1960s.

Co-existing species

Several other small mammal species are known to co-exist with the Plains Mouse including the House Mouse (*Mus domesticus*), Forrest's Mouse (*Leggadina forresti*) and the Stripe-faced Dunnart (*Smithopsis macroura*) in South Australia and Northern Territory, Fat-tailed Dunnart (*Sminthopsis crassicaudata*) and Giles' Planigale (*Planigale gilesi*) in South Australia and Kultarr (*Antechinomys laniger*) in the Northern Territory (Brandle and Moseby 1999; Read 1994; C. Pavey pers. comm.).

Diet

The Plains Mouse is a herbivore feeding mostly on seeds with some green plant material and a few insects also taken (Watts and Aslin 1981).

Reproduction

The Plains Mouse breeds continuously in captivity (Watts and Aslin 1981) and in the wild breeds opportunistically in response to rainfall events (Brandle and Moseby 1999). The oestrous cycle averages 8.5 days, gestation lasts 30-31 days and average litter size is 3.6 (Smith *et al*. 1972). The Plains Mouse possesses four teats and females have given birth at 12 weeks of age (Smith *et al.* 1972). A copulation plug is formed during mating. The young attach themselves to the mother's teats and may be dragged around during lactation.

Predators

Especially during irruptions in South Australia and the southern Northern Territory the Plains Mouse is fed on heavily by Letter-winged Kites (*Elanus scriptus*), Barn Owls (*Tyto alba*), Red Foxes (*Vulpes vulpes*), Feral Cats (*Felis catus*) and Dingoes (*Canis lupus dingo*) (Brandle and Moseby 1999; Eldridge *et al.* 2002; Owens and Read 1999; Pavey *et al.* 2008a; Pavey *et al.* 2008b; Watts and Aslin 1981; K. Moseby pers. obs.). Other known native predators include Mulga Snakes (*Pseudechis australis*) (K. Moseby pers. obs.), Grass Owls (*Tyto capensis*) (Read 1995) and large snakes such as Inland Taipans (*Oxyuranus microlepidotus*) (Read 1994).

Important populations

Due to marked fluctuations in the extent of occurrence and abundance of Plains Mouse populations, it is difficult to define the relative importance of different populations, and further important populations may yet be identified.

Any larger populations that persist in drought conditions are likely to be important source-populations for breeding and recolonisation after significant rains. Populations in large open plains with extensive, closely spaced patches of cracking gypseous soils such as the Moon Plain (near Coober Pedy) and the Arcoona Tableland in South Australia, are therefore likely to be important. Such habitat patches are often devoid of perennial vegetation but are extremely productive after significant rains. It is likely that similar refuge sites are present in the Northern Territory but are yet to be discovered. Important populations of the species in the Northern Territory are located on Andado Station. This includes a population that persists at high densities during drought conditions and that appears to act as a source for irrupting populations.

The Arid Recovery Reserve population in South Australia is important as it supports high densities of the Plains Mouse, and is protected through fencing from predation. This site is also important in understanding the impacts of predation on this species (e.g. by comparing Plains Mouse densities and habitat use inside and outside the predator-proof fence). Surveys by Read and Cunningham (2010) captured 19 Plains Mice from three sites in the Arid Recovery Reserve compared to only a single capture from 18 sites outside the reserve. Moseby *et al.* (2009) monitoring research into the response of reptiles and non-critical weight range (CWR) mammals to the complete removal of three of the commonly perceived threatening processes (exotic rabbits, cats and foxes), found that rodent abundance in the Roxby Downs region may be suppressed more than small marsupials or reptiles due to their higher susceptibility to cat predation and their dietary reliance on vegetation and seed. Rodents, particularly Spinifex Hopping-mouse (*Notomys alexis*) and Bolam's Mouse (*Pseudomys bolami*), increased to 15 times higher inside the feral-proof Arid Recovery Reserve compared with outside sites, where rabbits, cats and foxes were still present.

As significant genetic divergence has been recorded amongst geographic regions of Plains Mouse populations (Brandle *et al.* 1999), it is important to

conserve populations throughout the species range in order to maintain genetic variability.

The records from south-west Queensland detected via Barn Owl pellets in 2001 and other modern records in the Simpson and Strzelecki Deserts in South Australia are significant as these may indicate a range extension or temporary increases in the area of occupancy due to good seasonal conditions. However, further surveys are required.

Given the issues discussed above and current knowledge of the populations, all known and any newly discovered populations should be considered important for survival of the species.

PART C: KNOWN AND POTENTIAL THREATS

Threats

Threatening processes have not been clearly identified for the Plains Mouse but Watts and Aslin (1981) suggest predation and habitat degradation due to intensive stock grazing may significantly impact their colonies. Pavey (2007) also considers populations close to watering points to be under threat as a result of stock grazing and predation. These threatening processes are thought to be responsible for the decline of many arid zone mammal species, especially those within the critical weight range of 35 g to 5.5 kg (Burbidge and McKenzie 1989; Morton 1990). Habitat degradation from overstocking with sheep and/or with cattle is thought to have been responsible for the historical decline of the Thick-billed Grasswren (*Amytornis textilis modestus*), a nationally 'Vulnerable' species (EPBC Act) that inhabits similar habitat to the Plains Mouse (NPWS 2002).

However, the threatening processes that led to the historical decline of the Plains Mouse may be different from the current threats to the remaining populations. Although Plains Mice were formerly recorded from a range of habitats over a wide geographic area, the species is now seemingly confined to cracking clay patches, often located within the most productive parts of the landscape. Historical records noted that Plains Mice lived in shallow burrows often only a few centimetres below the surface (Watts and Aslin 1981). Recent observations at Wire Creek in South Australia observed a network of burrows but with very few occupied (Brandle and Moseby 1999). Shallow burrows would be extremely vulnerable to both trampling by sheep and cattle and being excavated by cats and foxes. In the absence of these introduced species, Plains Mice may be able to use burrows and occupy a wider variety of habitats. This has already been observed within the Arid Recovery Reserve where Plains Mice are occupying shallow burrows on rocky slopes and chenopod plains without gilgais (K. Moseby pers. obs.).

Habitat degradation from introduced livestock

Habitat degradation from cattle and sheep is likely to be a threat to Plains Mouse populations in gilgai habitats where grazing pressure is high (i.e. around watering points where stock numbers are concentrated). Gilgais are often the most productive areas of the landscape and are thus attractive to stock. Gilgais can be impacted by stock through removal of vegetation cover, trampling of burrows and siltation of cracks.

The 'puffy' self-mulching cracking clays can become hard and compacted leading to the loss of cracks and lower productivity after rain. This issue may be of particular concern in the Northern Territory because all but one of the known colonies occurs on pastoral leases. The Mac Clark Conservation Reserve has now been fenced to exclude stock.

The current trend of increasing stock watering points in the South Australian pastoral areas means this threat may be increasing as less habitat becomes remote from stock grazing. The increase in stock watering points may also

benefit introduced predators leading to a regional and local increase in predator numbers around water sites (Davies *et al.* 2010).

Introduced small herbivores/competitors

Habitat degradation from rabbits is unlikely to be a significant threat to current populations, as rabbits are unable to dig permanent burrows in hard or friable clay substrate and are typically in low abundance in stony plain habitat. However, in good seasons, rabbit numbers may increase in peripheral habitats and provide a food source for introduced predators to increase in numbers.

The threat of House Mouse (*Mus domesticus*) to the Plains Mouse through competition for food and shelter is unknown. However, research on other small arid mammal species, suggests that house mice may not have a significant negative impact (Moseby & Read 1999, Read *et al.* 1999, Moseby *et al.* 2009).

Predation

Predation by introduced cats and foxes during good conditions may suppress sub-population irruptions and prevent large-scale dispersal events. Local sub-population irruptions and resultant dispersal are likely to be important mechanisms for maintaining area of occupancy, extent of occurrence and genetic diversity. In the southern Northern Territory there is evidence that feral cats and red foxes prey on colonies during non-irruptive periods, as these "refuge" sites support relatively high densities during dry periods (Pavey 2007). Such predation can impact the ability of these populations to act as sources for population expansion following rain.

Predation during drought conditions may also threaten populations when they contract back to isolated pockets of habitat and are more vulnerable to local extinction. Increases in stock watering points may exacerbate this situation as the artificial water points provide a reliable source of water all year round, and are shown to benefit introduced predators and can lead to regional and local increases in predator numbers around these sites (Davies *et al.* 2010). Cat and fox predation may have contributed to the local extinction of Plains Mice in other habitat types where they constructed shallow burrows which would have been easy to excavate (Curtis *et al.* 2012).

Dingoes have been known to prey on the Plains Mouse (Allen *et al.* 2011), however their preferred prey items are generally larger species such as rabbits or kangaroos (Christensen and Burrows 1994; Newsome *et al*. 2001). Any dingo management outside of the dingo barrier fence requires careful consideration as the dynamics between dingoes, introduced predators and Plains Mice are not completely understood.

Climate change

Climate change is likely to be a future threat to remaining populations. Increased temperatures within the arid zone may mean shallow burrows become too hot for habitation and populations may contract even further to

just the deepest cracking clay areas. Further fragmentation of the population would result and this could potentially lead to extinction. An increase in the incidence and variability of flooding would also affect the Plains Mouse as it occupies drainage areas within the landscape. Although it could benefit from an increase in frequency of high rainfall events, resulting in increased seed production, the species could also be negatively impacted by an increase in competitors, weeds or predators.

Areas under threat

Threatening processes to the Plains Mouse are not clearly understood. The threat of predation by cats and foxes is widespread across habitats however the Plains Mice that occur in gilgai habitat near watering points are likely to be under the greatest threat. The recent trend towards increasing water points on pastoral properties may also mean that gilgai areas previously remote from water may soon be threatened from increased grazing and trampling by stock and possible increase in introduced predators (DeStefano *et al.* 2000; Davies *et al.* 2010; Brawata & Neeman 2011).

Plains Mice on large gypseous cracking clay plains may be less threatened than sub-populations in gilgai areas for several reasons. The lack of perennial vegetation means water points are not usually placed in these areas, thus resulting in lower grazing pressure. Rabbits are virtually absent from these areas due to the lack of suitable burrowing habitat. Even if these areas are close to water, the lack of perennial vegetation means these areas may not be attractive to rabbits or stock during dry periods when Plains Mouse populations may be most vulnerable. Although such habitats are highly productive after significant rains, abundant feed throughout the region during these times may prevent rabbits and stock from causing extensive damage. Cattle are also thought to try and avoid these areas due to the friable, unstable nature of the soil, rendering walking through these areas difficult (C. Greenfield, Billa Kalina Station pers. comm.; Moseby pers. obs.).

Populations under threat

All remaining Plains Mouse populations are potentially under threat with the probable exception of those colonies within the Arid Recovery Reserve where stock, foxes, cats, dingoes and rabbits are excluded from a 6000 ha area. Colonies inside Witjira National Park, the Mac Clark Conservation Reserve, possibly Diamantina National Park and a number of pastoral properties owned by mining companies (Stuart Creek Station) are under less threat from habitat degradation due to domestic stock exclusion or very low stocking levels.

PART D: OBJECTIVES, CRITERIA AND ACTIONS

Recovery Objective 1

Clarify the current distribution of the Plains Mouse, and habitat use across the species' range.

Performance Criteria

- The current range of the species is clarified and documented.
- Fine-scale maps of occupied and apparently unoccupied gilgai and cracking clay habitats throughout the species range are available.
- At least one persistent core area used by Plains Mice in dry conditions is identified for each of the five geographic zones.
- Characteristics that define habitat critical for survival during dry periods are identified and documented.
- Known and potential habitats critical for survivals during dry periods are mapped.
- Monitoring data are available from each geographic region.

Actions

1) MAPPING DISTRIBUTION AND HABITAT

Improve documentation of known and potential habitat critical to the survival of the species, through the creation of fine-scale maps of the occupied and apparently unoccupied habitats throughout the Plains Mouse's range. Gilgai and gypseous cracking clay habitat should be mapped separately using GIS imagery, soil and vegetation data. Landsat imagery was used in 2006/2007 to identify potential Gilgai habitats at a high level scale, however fine-scale mapping and ground truthing is still required.

A significant amount of work has been undertaken on Andado Station in the Northern Territory and the critical drought habitat has been identified for most of the property (C. Pavey pers. comm.).

- Wages $10 000 year 1
- Satellite Images $ 5 000 year 1

2) DEVELOP DETECTION METHODS

Develop methods for easy detection of Plains Mice at low densities when trapping becomes ineffective, to be used for determining core areas used during drought conditions. Possible methods include the use of owl pellets, hair tubes, spotlighting, burrow cameras or different baits (e.g. lucerne pellets). A comparison of trapping, spotlighting, burrow searches and hair tube methods was conducted at the Arid Recovery Reserve and is being written up for publication. Results suggest hair tubes may be useful for surveying large areas but that problems with accurate hair identification meant that trapping at individual sites is still warranted (K. Moseby and R. Pedler pers. comm.).

- Student project - travel and equipment $15 000 year 1

3) DEFINE RANGE EXTREMITIES

Improve knowledge of the distribution of the species by surveying areas of potentially suitable habitat to the east of Lake Eyre, within 500 km of the location of the Simpson Desert Regional Reserve and Strzelecki Desert specimens, west of Lake Frome near the Beverley Uranium Mine specimens and in the vicinity of the 2001 Queensland record, following good recent rainfalls. The northern most extent of the species range in the Northern Territory should also be defined,

- Survey wages $20 000 year 1
- Survey travel and equipment $10 000 year 1

4) MONITOR POPULATIONS TO IDENTIFY HABITAT CRITICAL FOR SURVIVAL DURING DRY PERIODS

Determine the habitat occupied during dry conditions by monitoring the persistence of populations in each geographic zone. 'Dry' is defined as no rainfall events of more than 20 mm recorded within the last 6 months and lower than average rainfall recorded in the last three 6-month periods. Encourage the Department of Defence (Woomera), BHP Billiton, and other mine operations to incorporate this into their environmental monitoring. Combine monitoring trips with other threatened species surveys to maximise cost-effectiveness. Monitoring data should be disseminated appropriately (newsletter, webpage, media –release) with changes to the species extent made available publicly and should make reference to its contribution to the implementation of this Recovery Plan.

- Annual survey trips to five geographic zones - wages $45 000 annual
- Annual survey trips (incl. fuel, car hire and equipment) $20 000 annual
- Database design, data collation, analysis and report $ 5 000 annual

Recovery Objective 2

Clarify threats to current populations.

Performance Criteria

- The impacts of moderate and heavy stock grazing; and of cat, fox and dingo predation on Plains Mouse populations have been determined in each habitat type (gilgai and gypseous plains).

Actions

5) DETERMINE GRAZING IMPACTS

To determine the impacts and threshold levels (safe carrying capacity) of stock grazing on Plains Mouse populations, use stock-proof exclosures close to, and remote from, watering points with a range of grazing species and

intensity. Monitor persistence, shelter preference and breeding of colonies close to, and remote from, water over several years (dependent upon local rainfall patterns). Alternatively, monitor populations before and after the installation of new watering points for a range of grazing species and intensity, including control sites.

- Establish and monitor sites at water points with a range of grazing species and intensity (first year only; annual wages and travel included in Action 4 above, plus costs for equipment and establishing exclosures) $ 50 000 year 1

6) DETERMINE PREDATION IMPACTS

To determine impact of cat/fox predation on Plains Mouse populations across the species range. Compare densities and persistence of colonies at multiple sites across the species range including inside and outside of the Arid Recovery Reserve. Read and Cunningham (2010) found a significant difference between the capture rates of Plains Mouse within (19 from three sites) and outside (one from 18 sites) the feral-proof Arid Recovery Reserve. Moseby *et al.* (2009) found that rodent abundance in the Roxby Downs region may be suppressed more than small marsupials or reptiles, rodents, particularly Spinifex Hopping-mouse (*Notomys alexis*) and Bolam's Mouse (*Pseudomys bolami*), increased to 15 times higher inside the feral-proof Arid Recovery Reserve compared with outside sites, where rabbits, cats and foxes were still present.

Over the longer term, determine whether Plains Mice will occupy shallow burrow systems in a variety of habitats such as sandy habitats (Allen *et al.* 2011; K. Moseby pers. comm.) in the absence of cats, foxes and stock. Where possible, establish links with other predator impact studies to determine the impacts of cat and fox predation on Plains Mouse populations in other geographic zones. Regional studies on the importance of dingoes in the control of cats and foxes should also be supported to help determine whether dingo control is likely to have an adverse impact on Plains Mouse populations by facilitating an increase in cat and fox populations. Establishing the role dingoes' play in the population dynamics between introduced predators and Plains Mice needs to be considered.

- Establish and monitor sites within and adjacent to Arid Recovery Reserve $ 15 000 annual

Recovery Objective 3

Vibrant communities, government and industries using and managing natural resources within ecologically sustainable limits to adequately protect enough habitat to maintain and increase current distribution of the Plains Mouse. Ensure a latitudinal spread of occupied habitat throughout the species' range as a buffer against climate change.

Performance criteria

- There is no sustained contraction in the range of the species [to be assessed through (annual monitoring as part of Action 3 & 4) but not during "wet" (as defined in Action 4) periods].
- Threats are effectively managed (through stock management practices and/or predator control) in at least 30% of habitat critical to survival within two years.
- Populations are present during dry periods in two core areas within each geographic zone.

Action

7) INTERIM PROTECTION FOR HABITAT CRITICAL TO THE SURVIVAL OF THE SPECIES

Determine the proximity to watering points of current populations and percentage of known populations currently remote from water. Until threats are clearly identified, ensure at least 30% of current known gilgai-dependent habitat is remote (i.e. more than five kilometres for sheep and eight kilometres for cattle) from high grazing pressure. It is important that the precautionary principle is applied and that no new watering points are placed in areas of habitat critical to survival (e.g. gilgai or gypseous plains) without first conducting a detailed appraisal of likely negative affects. In SA, any new watering points (5km away from existing water points) require approval from the SA Pastoral Board and development of a watering point management plan.

- Mapping $ 10 000 year 1
- Meetings and facilitation between Pastoral Board, Natural Resource Management (NRM) Board and recovery team $ 10 000 year 2
- Education and extension material for land managers $ 10 000 year 2

8) LONG TERM PROTECTION FOR HABITAT CRITICAL TO THE SURVIVAL OF THE SPECIES

As data are gathered from Actions 1-7, use the information to implement adaptive management actions to ensure 30% of habitat used by Plains Mice during both wet and dry conditions is protected from the identified threats in each geographic zone (grazing pressure, predation and competition). Establish monitoring for any management actions (including control) to assess success/failure and to inform/adapt current and future management actions.

Ensure the Moon Plain near Coober Pedy remains remote from watering points as it is the largest area of gypseous cracking clay known to be inhabited by the Plains Mouse and is likely to be an important source population. Installing water points in this area may lead to an increase in predation by cats and foxes. Part of the Moon Plain is Crown Land and this should be given permanent protection through addition to the reserve system.

- Administrative processes for the inclusion of Moon Plain in the reserve system $ 15 000 year 1

- Write an adaptive management plan for habitat critical to survival (and improve/change as additional threats/information are gathered) which could include the establishment of voluntary conservation agreements, aerial or ground baiting, waterpoint exclusion areas, fencing, monitoring etc. $ 40 000 year 4
- Implement adaptive management plan (from above) $200 000 year 5

Recovery Objective 4

Vibrant communities, governments and industries working together to manage the recovery process in an integrated way and with the capability, commitment and connections to support, guide and coordinate the implementation of the recovery plan.

Performance criteria

- An effective recovery team is established that:
  - meets at least annually
  - ensures that all key stakeholders are aware of, and support planned actions, and are kept informed of progress
  - ensures that the results of actions in this plan are assessed, reported and reviewed.
- Engage, involve and promote to landholders, Pastoral Board, NRM Board, mining companies and communities the significance of the Plains Mouse.

Action

9) RECOVERY TEAM

Establish a recovery team for threatened Arid Zone fauna found mainly in South Australia, with representatives from SA DEWNR, the Biodiversity Conservation Division and the Parks Division of the NT Department of Natural Resources, Environment, the Arts and Sport (NRETAS), Queensland Department of Environment and Heritage Protection (DEHP), the South Australian Arid Lands (SAAL) NRM Board, state pastoral boards, mining company (BHP Billiton), research institutes and private landholders. The recovery team should provide advice on the design of research projects and oversee the implementation of the recovery plan. Other species to be addressed by the team could include the Fawn Hopping Mouse (*Notomys cervinus*), Dusky Hopping Mouse (*Notomys fuscus*), Kowari (*Dasyuroides* byrnei) and Thick-billed Grass-wren (*Amytornis modestus*).

- Twice-yearly meetings, travel $ 20 000 annual

10) ENGAGEMENT, INVOLVEMENT AND PROMOTION

As the majority of extant Plains Mouse population records occur on private pastoral and mining leasehold land, the awareness and involvement of lessees, indigenous communities and other land managers is essential for the recovery of this species, through the behaviours they adopt and support.

Foster the interest of the landholders through dissemination of information about the species and its protection and encourage involvement during monitoring surveys.

- Develop and print brochure on Plains Mouse $ 10 000 Year 1

Evaluation of success or failure

Once established, the recovery team will be responsible for the implementation of this plan. Performance criteria are listed under each objective, and will be assessed and reported on at appropriate timeframes. An independent review and evaluation of the success of the recovery implementation will be undertaken in five years following the adoption of this recovery plan.

PART E: MANAGEMENT PRACTICES

Though the threatening processes to the Plains Mouse are not clearly understood, there is sufficient information/data to implement adaptive management actions/practices to protect the species. Several actions likely to improve the survival of the Plains Mouse, along with a precautionary approach, include:

- Discourage the construction of new watering points in areas of occupied or apparently unoccupied habitat critical for survival of the Plains Mouse until the impacts of stock grazing are known.

- Implement effective feral predator control at and around key populations and establish the role that dingoes play in controlling introduced predators. Dingo management requires careful consideration as the dynamics between dingoes, introduced predators and Plains Mice are not yet understood.

- Ensure grazing pressure from domestic stock is kept at a level that does not lead to degradation of gilgais (extensive removal of perennial vegetation, trampling and siltation of cracks).

- Monitoring research by Read and Cunningham (2010) suggested that suppression of cattle grazing alone was insufficient and that recovery depends upon management of both total grazing pressure and predation.

PART F: DURATION OF RECOVERY PLAN AND ESTIMATED COST

Duration and estimated costs

This recovery plan details actions and estimated costs for a five-year period. However, some actions and research require monitoring over both wet and dry periods, and the exact timing of these actions will be dependent on climatic conditions. Actions 1, 2, 3 and 7 should be completed within two years and Actions 4, 5, 6, 8 and 9 within five years. The total estimated cost over five years is $930 000.

Actions	Year 1	Year 2	Year 3	Year 4	Year 5	Priority
1) Mapping	$ 15 000					High
2) Detection Methods	$ 15 000					High
3) Define Range Extremities	$ 30 000					High
4) Monitoring to identify habitat critical for survival during dry periods	$ 70 000	$ 70 000	$ 70 000	$ 70 000	$ 70 000	High
5) Determine grazing impacts (establishment cost only – annual costs included in Action 4)	$ 50 000	see Action 4 above	see Action 4 above	see Action 4 above	see Action 4 above	High
6) Determine predation impacts	$ 15 000	$ 15 000	$ 15 000	$ 15 000	$ 15 000	Medium
7) Interim protection for habitat critical for survival	$ 10 000	$ 20 000				High
8) Long term protection for habitat critical for survival	$ 15 000			$ 40 000	$200 000	High
9) Recovery team	$ 20 000	$ 20 000	$ 20 000	$ 20 000	$ 20 000	Medium
10) Engagement	$10 000					High
TOTAL	**$250 000**	**$125 000**	**$105 000**	**$145 000**	**$305 000**	

Recovery allocation

All actions would require assistance and partnership with pastoral lessees and other land managers.

- Action 1 could be undertaken by SA DEWNR; the Biodiversity Conservation Division and the Parks Division of the NT Government; and the Department of Environment and Heritage Protection in Queensland if funding could be secured.
- Action 2 could be completed by partnering the relevant divisions of the state government agencies with NRM Boards and research students from Universities.
- Action 3 could be completed by state Threatened Species Officers or an independent contractor experienced in survey methodology.

- Actions 4 to 6 are the most difficult and time consuming and would require a project officer and assistance from all stakeholders, including Arid Recovery Project staff.
- Action 7 will require a partnership approach between SA DEWNR, the Pastoral Board, pastoral lessees and the Biodiversity Conservation Division of the NT Government.
- Action 8 should be implemented through guidance of the recovery team formed during Action 9.
- Action 9 will include representatives from SA DEWNR, the Biodiversity Conservation Division and the Parks Division of the NT Government, Queensland Department of Environment and Heritage Protection (DEHP), South Australian Arid Lands NRM Board, states pastoral boards, mining company (BHP Billiton), research institutes and private landholders.
- Action 10 could be completed by SA DEWNR, the Biodiversity Conservation Division and the Parks Division of the NT Government, Queensland DEHP, South Australian Arid Lands NRM Board, states pastoral boards and research institutes.

Benefits to other species

The nationally threatened Thick-billed Grasswren (nationally – Vulnerable (EPBC Act); SA - Rare (SA NPW Act); NT – Endangered (NTWC Act)); Kowari (nationally – Vulnerable (EPBC Act); Qld – Vulnerable (Qld NC Act)) and Greater Bilby (nationally – Vulnerable (EPBC Act); Qld – Endangered (Qld NC Act)) occupy similar habitat to Plains Mice and could potentially benefit from recovery actions implemented under this plan. There are five other species known to be endemic to cracking gypseous clay habitat which could also benefit from this plan: Gibber Dragon (*Ctenophorus gibba*), Woomera Slider (*Lerista elongata*), Johnston's Slipper-plant (*Embadium johnstonii*) (SA – Vulnerable), Gypsum Groundsel (*Senecio gypsicola*) (SA - Rare) and Haegi's Stemodia (*Stemodia* sp. *Haegii*) (SA - Rare). The Bronzeback Legless Lizard (*Ophidiocephalus taeniatus*) (nationally - Vulnerable; SA - Vulnerable; NT - Data Deficient) and Chestnut Breasted Whiteface (*Aphelocephala pectoralis*) (SA - Rare) also occur within the range of the Plains Mouse (although in different habitat) and could also potentially benefit from the implementation of recovery actions outlined in this plan.

Interests that will be affected by recovery plan's implementation

Plains Mice occur across a range of land tenures with a variety of land uses. Implementation of this recovery plan could potentially involve a range of land managers, leaseholders, government agencies and researchers, including the following:

- South Australian Arid Land Natural Resources Management Board
- South Australia Department of Environment, Water and Natural Resources
- Northern Territory Department of Natural Resources, Environment, the Arts and Sport including the Biodiversity Conservation Division and the Parks Division
- Qld Department of Environment and Heritage Protection

- Arid Recovery Program
- pastoral lessees
- SA Pastoral Board (part of DEWNR)
- Irrwanyere Aboriginal Corporation
- Department of Defence
- mining lessees, e.g. BHP Billiton
- Research institutions

Any management actions required under this recovery plan would need the consultation and involvement of pastoralists and other land managers and ideally would involve them in assisting with on-ground monitoring programs or threat abatement actions on their properties.

The SAAL NRM Board currently employs a Threatened Fauna Officer who is responsible for implementing management actions for threatened species including the Plains Mouse.

The Alice Springs Desert Park (NT) maintains a captive colony of Plains Mice where the species is on display in the nocturnal house.

Roles and interests of indigenous people

Plains Mice or 'Palyoora' are found within Witjira National Park which is partly managed by the Irrwanyere Aboriginal Corporation. Although the majority of current records are on pastoral leases, sub-populations are likely to be present in areas such as Finniss Springs station and the Mt Willoughby Indigenous Protected Area in South Australia that are owned by indigenous groups. The vast majority of the range of the Plains Mouse on Andado Station and Mac Clark Conservation Reserve occurs within an area that is of immense religious significance to Lower *Arrente* people (Nano *et al.* 2008). The species may possibly also occur on the currently unsurveyed Pmer Ulperre Ingwemirne area in the Northern Territory owned by the Aboriginal Land Trust to the east of Andado Pastoral Lease.

This plan aims to ensure that the role and interests of Aboriginal people are considered in implementing recovery actions. DEWNR, DEHP and NRETAS have consulted with the relevant Aboriginal nations and communities about their interests in the Plains Mouse and their involvement in recovery planning and implementation. In South Australia, the process was undertaken by the Aboriginal Partnerships Section of DEWNR who contacted each of the relevant Aboriginal communities. In Queensland and the Northern Territory, the process was undertaken through consultation with the Kirrendirri Cultural Resource and Family Research Aboriginal Corporation (Qld) and through the Central Lands Council to the Pmer Ulperre Ingwemirne Aboriginal Lands Trust (NT). For this recovery plan no comments had been received from the relevant Aboriginal nations and communities in South Australia, Queensland or the Northern Territory. However, as and when actions of this plan are implemented, relevant Aboriginal interests will be engaged with.

This recovery plan will be adopted and released subject to any Native Title rights and interests that may continue in relation to the land and/or waters. Nothing in the plan is intended to affect Native Title. The Commonwealth

Native Title Act 1993 should be considered before undertaking any future acts that might affect Native Title.

Social and economic impacts

Economic impacts include a potential reduction in pastoral production if some Plains Mouse habitat is protected from cattle and sheep grazing. Consultation will be undertaken with relevant land managers to minimise adverse economic or social impacts in the implementation of the Recovery Plan. The potential use of market-based incentive mechanisms, such as through an environmental stewardship program, should also be investigated.

Acronyms

EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
IUCN	International Union for Conservation of Nature and Natural Resources
Qld NC Act	Queensland *Nature Conservation Act 1992*
NPW Act	*National Parks and Wildlife Act 1972*
NRM	Natural Resource Management
NT	Northern Territory
Qld	Queensland
SA	South Australia
SAAL NRM Board	South Australian Arid Lands Natural Resource Management Board
SA DEWNR	Department of Environment, Water and Natural Resources (South Australia)
TPWC Act	*Territory Parks and Wildlife Conservation Amendment Act 2000*

Glossary

Colony (sub-population)- A group of occupied burrows or cracks located in close proximity in suitable habitat. Individuals can move freely within a colony between more or less continuous patches of suitable habitat. Colonies are surrounded by unoccupied habitat. Colonies can range in size from less than 1 ha to more or less linear areas of suitable habitat more than 40 km in length (historical records only). Colonies may be temporary and become locally extinct during dry conditions.

Gilgai – A natural soil formation occurring extensively in inland Australia, characterised by an undulating surface sometimes with mounds or depressions caused by the swelling and cracking of clays during alternating wet and dry seasons. Gilgais support higher shrub densities than the surrounding run-off gibbers.

Population (meta-population)- A number of colonies within a geographic range. Transfer of genetic material (individuals) within a population is common but rare between populations. Location of colonies within a population may change depending on local rainfall conditions. Populations may be separated by large areas of unsuitable habitat.

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