National Multi-species Recovery Plan
for the

Carpentarian Antechinus *Pseudantechinus mimulus*, Butler's Dunnart *Sminthopsis butleri*, and Northern Hopping-mouse *Notomys aquilo*

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Cover photograph
Butler's dunnart *Sminthopsis butleri*, Melville Island, NT. (photo: Damian Milne)

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SUMMARY

This Recovery Plan considers three species of small native mammals occurring in northern Australia, the carpentarian antechinus *Pseudantechinus mimulus* (occurring in Northern Territory and Queensland), Butler's dunnart *Sminthopsis butleri* (Northern Territory and Western Australia) and northern hopping-mouse *Notomys aquilo* (Northern Territory and Queensland). All three species are considered Vulnerable at national level.

Much or most of the distribution of all three species is on Aboriginal lands. Only two of the species are known to be represented in conservation reserves, and in each case this is in one reserve only: carpentarian antechinus in Barranyi National Park and northern hopping-mouse in Nanydjaka IPA.

There is remarkably little known about each of the three species. There are a total of only 9 records of Butler's dunnart, 19 records of carpentarian dunnart; and the northern hopping-mouse is known only from several collections on Groote Eylandt and two specimens from elsewhere. In each case, there have been no records of the species in the region around their type localities since the initial collections. There have been no substantial ecological studies conducted on any of the species. This limited information base is a substantial impediment to management planning for these species.

Largely because of this information deficiency, this Recovery Plan includes a set of actions that describe additional survey and research activities. These are aimed to refine and more closely target management actions, but until such refinement is possible, a set of broad management actions is proposed for more immediate implementation. This set includes fire management to maintain and enhance habitat suitability, and control of feral cats.

PART A: SPECIES INFORMATION AND GENERAL REQUIREMENTS

Introduction

This plan jointly considers three native mammal species from northern Australia. While the three species share some similarities in ecology, status and conservation management requirements, there are also distinct differences among them in these and other features. Recognising both these similarities and differences, this plan follows the standard overall framework for single species Recovery Plans, but provides specific information for each of the three species whenever relevant throughout, and wherever possible pools information from each of the three species accounts to derive commonalities and to highlight management issues and actions that may apply for all three species.

Descriptions

The carpentarian antechinus *Pseudantechinus mimulus* is a small (*ca*. 15-20 g.) terrestrial carnivorous marsupial. It is closely related to and superficially similar to a set of dasyurids typically occupying rocky areas in northern and central Australia, including the sandstone antechinus *Pseudantechinus bilarni*, ningbing antechinus *P. ningbing*, fat-tailed antechinus *P. macdonellensis* and Woolley's antechinus *P. woolleyae*, but is slightly smaller than these others. All have a somewhat flattened head and pointed muzzle, large ears, and are generally brown above and pale below. The carpentarian antechinus has a patch of reddish fur around the ears. *Pseudantechinus* species can store fat in their tail, and this becomes carrot-shaped when food is plentiful.

Carpentarian Antechinus (photo Kym Brennan)

Butler's dunnart *Sminthopsis butleri* is another small (*ca*. 10-20 g.) terrestrial carnivorous marsupial, finer of features than for the carpentarian antechinus. It too is similar in general appearance to a range of small dasyurids occurring across Australia, including the Kakadu dunnart *S. bindi* and red-cheeked dunnart *S. virginiae* in northern Australia. All are generally grey-brown above and pale below, with large ears and eyes, and sharply pointed muzzle.

The northern hopping-mouse *Notomys aquilo* is a medium-sized (25-50 g.) terrestrial granivorous rodent. It has features typical of hopping-mice in general, with very long narrow hindfeet, large ears and eyes, and very long partly tufted tail (about 150% of head-body length). It is the only representative of its genus in northern Australia, thus, in this area, its morphology is highly distinctive. It is sandy-brown above and paler below. Hopping-mice move with a distinctive gait, such that the bipedal tracks may provide the most conspicuous signs of its presence.

Taxonomy

The three species each have a somewhat complicated taxonomic history, notable for single puzzling early records followed by a long period before any subsequent specimens.

carpentarian antechinus

The carpentarian antechinus *Pseudantechinus mimulus* (Thomas, 1906) was originally named (as *Phascogale mimulus*) from one specimen collected by W. Stalker at Alexandria, NT, in 1905. The distinction of this species was subsequently largely unrecognised, with most authors including it within *P. macdonnellensis* (e.g. Mahoney and Ride 1988), and with the generic name of these and allied species being variably changed from *Antechinus, Parantechinus* to *Pseudantechinus*. The placement of *mimulus* was hampered by the lack of specimens other than the type (Kitchener and Caputi 1988) until 1967, when three individuals caught on North Island (Sir Edward Pellew group, NT) were included in a re-recognition and redescription of *P. mimulus* (Kitchener 1991). A complex set of morphological criteria (notably in skull and dentition characters) was used to separate *P. mimulus* from its congeners, notably *P. ningbing, P. bilarni* and *P. macdonnellensis* (Kitchener 1991). Recent genetic analyses have supported this classification, but these are not yet published (M. Westerman, Genetics Department, LaTrobe University *pers. comm*.).

Some sources give the vernacular name for this genus as "false antechinus" (e.g. Menkhorst 2001), thus carpentarian false antechinus for *P. mimulus*. This formation provides somewhat greater taxonomic precision but is unnecessarily cumbersome.

butler's dunnart

Butler's dunnart *Sminthopsis butleri* Archer, 1979 was described relatively recently (Archer 1979*a*) (with the vernacular name Carpentarian Dunnart: Archer 1979*b*), on the basis of one specimen collected on "Cape York" in 1898 and three specimens from Kalumburu WA collected in 1965 and 1966.

A further historical record (previously mis-identified as *S. virginiae*), collected on Melville Island in 1913, was subsequently assigned to this species (Woinarski *et al*. 1996). Since the original description, examination of additional specimens from Cape York Peninsula and New Guinea resulted in a taxonomic split of *S. butleri*, with that taxon now referring to only those populations from the northern NT and Kimberley, and the Queensland and New Guinea population defined as the Carpentarian Dunnart *S. archeri* (Van Dyck 1986). Given this treatment, the listing of "Carpentarian Dunnart *Sminthopsis butleri*" as a threatened species under the *EPBCA* is invalid and confusing. The listing should be of Butler's Dunnart *S. butleri*.

northern hopping-mouse

The northern hopping-mouse *Notomys aquilo* Thomas 1921 was described from a single specimen collected around the 1870s from "Cape York". The species was not reported again until Johnson (1959, 1964) named *N. carpentarius* from 13 specimens collected on Groote Eylandt, Northern Territory in 1948. In this description, Johnson did not compare this series with the type of *N. aquilo*, and he was apparently also unaware that Donald Thomson had also collected hopping-mice on Groote Eylandt some five years previously (i.e. 1943-1944: with these records not documented until much later: Dixon and Huxley 1985). Subsequent comparisons revealed the conspecificity of *N. carpentarius* with *N. aquilo* (Ride 1970).

Conservation Status

As at December 2003,

the Carpentarian Antechinus *Pseudantechinus mimulus* is listed as:

- *Vulnerable* in Australia, under the *EPBCA*;
- *Endangered* in the Northern Territory, under regulations of the *Territory Parks and Wildlife Act 2000* (by the IUCN criteria B2ab (i, ii, iii, iv, v) - area of occupancy < 500 km^2; severely fragmented or known to exist at no more than five locations; and continuing decline, observed, inferred or projected);
- *Common Wildlife* in Queensland, under the Nature Conservation Regulations 1994.

Butler's Dunnart *Sminthopsis butleri* is listed as:

- *Vulnerable* in Australia, under the *EPBCA*;
- *Vulnerable* in the Northern Territory, under regulations of the *Territory Parks and Wildlife Act 2000* (by the IUCN criteria B1ab (i, ii, iii, iv, v) - extent of occurrence < 20,000 km^2; severely fragmented or known to exist at no more than ten locations; and continuing decline, observed, inferred or projected);
- *Schedule 1 - Fauna that is rare or likely to become extinct* in Western Australia, under the Wildlife Conservation (Specially Protected Fauna) Notice 2003 (Wildlife Conservation Act 1950).

Northern Hopping-mouse *Notomys aquilo* is listed as:

- *Vulnerable* in Australia, under the *EPBCA*;

- *Vulnerable* in the Northern Territory, under regulations of the *Territory Parks and Wildlife Act 2000* (by the IUCN criteria B2ab - area of occupancy < 2000 km^2; severely fragmented or known to exist at no more than ten locations; and continuing decline, observed, inferred or projected);
- *Vulnerable* in Queensland, under the Queensland Nature Conservation Act 1992.

In each case, the NT status is based on evaluations made in 2003. The national status typically follows assessments made in the Action Plans for Australian rodents (Lee 1995) and Marsupials and Monotremes (Maxwell *et al*. 1996).

Affected interests

The primary affected interests for all three species are the Australian and State/Territory conservation agencies, and particularly that of the Northern Territory, in which the bulk of the range for all three species occurs.

Much of the range of all three species is on Aboriginal lands: indeed, all recent records of butler's dunnart and northern hopping-mouse are on Aboriginal lands. In the Northern Territory, the interests managing these lands are the Tiwi Land Council (Butler's dunnart), Anindilyakwa Land Council (northern hopping-mouse), Northern Land Council (northern hopping-mouse and carpentarian antechinus), Dhimurru Aboriginal Land Management Corporation (northern hopping-mouse) and Mubanji Aboriginal Resource Association (carpentarian antechinus).

In Western Australia, the Kimberley Land Council and Wunambal-Gaambera Aboriginal Corporation manages those lands near Kalumburu on which Butler's dunnart was recorded.

In Queensland, the provenance of the single old record of northern hopping-mouse is so vague that it cannot be assigned with any confidence to any land tenure category, but may be in either Aboriginal lands, pastoral lands, conservation reserves and/or lands managed by Defence. The few recent records of carpentarian antechinus from Queensland are in pastoral leasehold and freehold lands.

None of the species is commercially exploited.

On Melville Island, Butler's dunnart occurs in sites either in or around a developing major forestry venture (oprated by Sylvatech) that replaces native vegetation with short-rotation exotic plantation species.

Parts of the range of the northern hopping-mouse occurs on lands subject to extensive strip-mining, for bauxite at Gove, and for manganese on Groote Eylandt. The first records of the carpentarian antechinus in Queensland were during a survey of the impacts of sulphur dioxide emissions around the Mt Isa mine (Griffiths 1998).

Role and interests of indigenous people

As noted in the above section, much of the range of all three species occurs on Aboriginal lands. However none of the species is known to have special significance to Aboriginal people for cultural reasons or for food resources. The two dasyurids, carpentarian antechinus and Butler's dunnart, are small and typically occur at low density, such that they would have been unlikely to have been harvested for foods. In contrast, the northern hopping-mouse is a colonial nester and may have been targeted for occasional gathering. Thomson (in Dixon and Huxley 1985) noted that Aboriginal people on Groote Eylandt sometimes excavated burrow systems of hopping-mice and collected large numbers for food. Northern hopping-mice were named *wurrendinda* by Aboriginal people (Anindilyakwa language) on Groote Eylandt (Waddy 1988). Other names used for the species by Aboriginal people in Arnhem Land included *djirrkin, wara, hudinwara, nik-nik, dayhdayh, kidjikidjidayhdayh* and *kilki* (Woinarski *et al* 1999), but in most cases these names apparently also refer to a range of other rodent species.

Thomson (in Dixon and Huxley 1985) also noted that many Aboriginal people appeared to have very little knowledge of northern hopping-mouse, even in sites where it appeared to be relatively common.

Aboriginal rangers from Dhimurru Aboriginal Land Management Corporation have conducted searches for northern hopping-mice at Nanydjaka (Cape Arnhem) IPA.

In November 2003, Aboriginal rangers from Mubanji participated in collaborative surveys for carpentarian antechinus with scientists from the NT Department of Infrastructure Planning and Environment.

Benefits to other species

The three species considered here overlap in range and habitat requirements with a diverse assemblage of native mammals, many of which are declining across extensive areas of northern Australia (Woinarski *et al*. 2001). Such declining species include northern brush-tailed phascogale *Phascogale (tapoatafa) pirata*, brush-tailed tree-rat *Conilurus penicillatus*, black-footed tree-rat *Mesembriomys gouldii*, northern quoll *Dasyurus hallucatus*, northern brown bandicoot *Isoodon macrourus* and common brushtail possum *Trichosurus vulpecula*. Three of these species (northern quoll, brush-tailed tree-rat and northern brush-tailed phascogale) are classified as vulnerable in the Northern Territory.

There is some proximity in distribution between the three species considered here and the golden bandicoot *Isoodon auratus* and golden-backed tree-rat *Mesembriomys macrurus*, both considered vulnerable at national level.

Targeted management for northern hopping-mouse, carpentarian antechinus and Butler's dunnart will benefit these other mammal species. The management actions with broadest collateral benefit are:

- improved fire management, particularly involving imposition of fine-scale burning regimes, and minimisation of broad-scale uncontrolled late dry season fires;
- enhancing quarantining of islands to reduce likelihood of entry of new threats; and
- broad-scale management to reduce numbers of feral cats.

Such actions will benefit not only the three mammal species considered here and at least some of the other mammals listed above, but will also have benefits for some co-occurring bird species (such as the vulnerable partridge pigeon *Geophaps smithii*: Fraser *et al*. 2003) and, with less substantial evidence, a gamut of other plant and animal species that have been adversely affected by recent changes in fire regimes (e.g. Bowman and Panton 1993; Russell-Smith *et al*. 1998, 2002; Franklin 1999; Bowman *et al*. 2001; Yibarbuk *et al*. 2001).

Social and economic impacts

There are no clearcut and tightly defined social and economic impacts associated with this Recovery Plan. Much of the distribution of these three species is on Aboriginal land. Research on, and management of, these species may provide some limited contributions to these local economies. The three species each have some distributional overlap or convergence with large mining or forestry operations. Conservation management for the species may come at some costs to these ventures, but such costs are generally likely to be low because the disturbances are generally not on lands that provide high quality habitat to these species. A possible exception is for Butler's dunnart on Melville Island, where forestry development may occur on, or be proposed for, habitats that have high suitability for this species.

PART B: DISTRIBUTION AND HABITAT

Distribution

The core range of all three species appears to be in the "Top End" (the northern monsoonal tropics) of the Northern Territory, with disjunct populations in either Queensland or Western Australia. However, available information on all three species is remarkably limited, and the distributions cannot be tightly circumscribed.

The known range of all three species is largely unreserved. Butler's dunnart is known from no conservation reserve; and the northern hopping-mouse and carpentarian antechinus are each represented in only one conservation reserve (Nanaydjaka IPA and Barranyi NP respectively).

carpentarian antechinus

The carpentarian antechinus is known from three broadly-defined sites - Alexandria (Barkly Tablelands, NT), the Pellew Islands, and north-western Queensland (Fig. 1). The Alexandria record (from 1905) is particularly imprecise, and somewhat anomalous. As now defined, Alexandria station comprises almost entirely mitchell grasslands, with scattered bluebush swamps - environments highly unlikely to be suitable for this rock-dwelling (saxicoline) species. However, around the beginning of the twentieth century, the name Alexandria was loosely applied to a far greater area of north-eastern Northern Territory, and probably encompassed some rocky ranges, such as the Mittiebah Ranges and other rugged country in the Gulf Falls and Uplands bioregion. It is probable that the type specimen was collected in such ranges.

On the Pellew Islands, the carpentarian antechinus was recorded from rocky habitats on North Island (58 km^2: now Barranyi National Park) in 1967 (3 individuals: Kitchener 1991); subsequently on North Island (2 specimens) and also on Centre (84 km^2: 4 individuals) and South-west (95 km^2: 2 individuals) Islands in 1988 by Johnson and Kerle (1991); and on North and Vanderlin (262 km^2) Islands in 2003 (two captures of one individual on North Island, and four captures of three individuals on Vanderlin Island: Taylor *et al*. 2004). The only large island of the Pellew group on which the species has not been recorded is West Island, which has far smaller areas of rugged sandstone, which have not been adequately sampled. The species has not been recorded on several smaller sampled islands in the Pellew group (e.g. Skull (6 km^2), Watson (13 km^2), Black Craggy (4 km^2)), but the extent of this sampling has been limited (total of 500 Elliott trap-nights: Johnson and Kerle 1991).

In Queensland, the carpentarian antechinus is known from only four recent specimens. Three of these were collected near Mt Isa in 1997 (Griffiths 1998), and one at Selwyn mine site about 140 km SE of Mt Isa in 2000 (S. Van Dyck *pers. comm*.). These records have not been documented. Despite recent fauna survey, it has not been recorded in apparently suitable habitat on Lawn Hill (Boodjamulla) National Park, to the north of these isolated records.

Given the uncertainties about the distribution of this species, it is difficult to estimate the extent of occurrence or area of occupancy. A minimum area of occupancy can be calculated from the size of the islands from which the species is known (taking also into account the extent of suitable habitat on these islands), plus an estimate of the extent of suitable habitat around the two known Queensland locations.

This provides a very approximate lower estimate of about 400 km^2. Spanning the distance from the southernmost Queensland record to the northwest most Pellew Island record, the extent of occurrence can be estimated at approximately 16000 km^2.

butler's dunnart

Knowledge of the distribution of Butler's dunnart is similarly frustratingly limited (Fig. 2). Its sole records from Western Australia are three individuals collected (hand-caught under logs and other shelter) near Kalumburu in the north Kimberley in 1965-66. It has not been recorded from the Kimberley since, despite substantial general wildlife survey effort.

Butler's dunnart has not been recorded from the Northern Territory mainland, again despite considerable general wildlife survey effort over the last two to three decades. However, a total of six individuals have been collected from widely-scattered locations on Bathurst Island (1693 km^2) and the nearby Melville Island (5788 km^2) (together, the Tiwi Islands). One of these records was from 1913, two from 1991, and three between 1999 and 2002 (Woinarski *et al.* 2003). Building up information on the distribution of this species is hampered by its apparently low trappability, at least using conventional trapping techniques. The five records from the Tiwi Islands since 1990 came from a wildlife survey effort there that included over 33,000 Elliott trap-nights and 3,200 pitfall trap-nights, and one of these records was of an individual hand caught under a fallen log rather than trapped.

northern hopping-mouse

Knowledge of the distribution of northern hopping-mouse is also limited (Fig. 3), and constrained by its apparent low trappability using conventional techniques (Woinarski *et al*. 1999). There has been no confirmed record from Queensland since the very imprecise "Cape York" record of the 1870s, despite some limited searches in possibly suitable sites.

In the Northern Territory, with one exception, the only specimen records of northern hopping-mouse are from Groote Eylandt (2260 km^2). The single exception is a specimen from the Upper Caddell River area of central Arnhem Land, in 1973 (Calaby 1983). Nonetheless, there are sight records and plausible records based on the species' distinctive tracks and burrow systems, from a number of other locations in and around the Arnhem Land mainland, especially in coastal sand dunes at Nanydjaka (Cape Arnhem) IPA (Woinarski *et al*. 1999). Records from Groote Eylandt have been widespread, but concentrated particularly on coastal dunes and sandsheets (Woinarski *et al*. 1999).

There is circumstantial but not substantial evidence suggesting that the current distribution of each of these three species is reduced from that of 200 years ago. For the northern hopping-mouse, there have been no records from Cape York Peninsula since the single original record more than 120 years ago, notwithstanding some extensive wildlife surveys in the general area. Likewise, for the carpentarian antechinus, there have been no records from the region around the type locality since the original collection (nearly 100 years ago), nor from elsewhere on the mainland of the Northern Territory, again despite some extensive wildlife surveys in apparently suitable habitat. Similarly, for Butler's dunnart, there have been no subsequent records from the region around the type locality (Kalumburu) since the original collections nearly 40 years ago, again despite some extensive wildlife surveys in the general area.

The reality and extent of such apparent regional loss is clouded by some possible doubts about the type localities for northern hopping-mouse and carpentarian antechinus, and the difficulty of sampling northern hopping-mouse and Butler's dunnart using conventional wildlife survey techniques.

Habitat critical to the survival of the species

Again, given the limited information base, it is difficult to describe habitat preferences for any of the three species with any confidence.

carpentarian antechinus

The habitat of the carpentarian antechinus is probably the most readily determined. All but one of the 19 known records of this species are from rocky areas. On the Pellew Islands, these comprise mostly sandstone boulders, pavements and outcrops, typically supporting a ground layer of hummock grasses *Triodia* spp., with a scattered low woodland or shrubland including such species as *Eucalyptus aspera, E. kombolgiensis, Acacia latifolia, A. multisiliqua, Bossiaea bossiaeoides* and *Calytrix* spp.

The historic Alexandria record of Carpentarian Antechinus may, on face value, represent a very dissimilar habitat, but there were no habitat details given for this record (Thomas 1906), and the provenance of the record is at best imprecise.

The habitat of three of the four records from north-west Queensland was described briefly by Grifffiths (1998) as comprising rocky (sandstone) ridges supporting open woodland (of *Eucalyptus leucophloia, E. normantonensis, Corymbia terminalis, Atalaya hemiglauca* and *Acacia* spp.) over hummock grassland.

butler's dunnart

The total of nine records of Butler's dunnart show no consistent tightly-defined habitat (Woinarski *et al*. 1996, 2003). Most are from eucalypt open forest (typically dominated by Darwin stringybark *Eucalyptus tetrodonta* and Darwin woollybutt *E. miniata*) on sandy substrates, but the records also include *Melaleuca* woodlands, coastal shrublands and "blacksoil sandplain ... heavily vegetated with eucalypt and grass" (Archer 1979*a*).

northern hopping-mouse

The habitat for northern hopping-mouse comprises a broad range of grassland, shrubland and open forest habitats, typically in sandy substrates in coastal or near-coastal areas (Woinarski *et al*. 1999). From an extensive search on Groote Eylandt (Woinarski *et al*. 1999), it was recorded most frequently in open shrubland dominated by either *Acacia* spp., *Hakea arborescens* or *Banksia dentata*, especially where these overtopped hummock grasses *Triodia stenostachya* and where there was high species richness of native peas (including *Tephrosia, Cajanus, Boassiaea* and *Jacksonia* species).

Given the apparently relatively broad habitat range used by each species, it is not possible to tightly define any habitat that is "critical" for the survival of any of the species.

Mapping of habitat critical to the survival of the species

Not applicable.

Important populations

All species are characterised by highly disjunct populations and, given the limited known occurrence of each species, it could be argued that each of these disjunct populations is important for the maintenance of these species. However, some populations may be more substantial than others, and some may be more likely to be managed successfully.

For the carpentarian antechinus, the populations on the Pellew Islands (Centre, North, South-west and Vanderlin) may be recognised as most important, because their isolation provides them some - fragile - protection against processes that may affect much of their mainland populations. The thinness of this protection is evident from the advent of cane toads and feral cats to each of these islands over the last two to three decades.

Similar arguments may be made for the special importance of island populations of Butler's dunnart (Bathurst and Melville Islands) and northern hopping-mouse (Groote Eylandt), again with the same caveats about the weakness of the assumed quarantining.

PART C: KNOWN AND POTENTIAL THREATS

Biology and ecology relevant to threatening processes

Limited knowledge of the ecology and general biology of all three species is a major constraint on conservation planning, identification of threats and management of those threats.

Based mainly on detailed studies of its close relatives (e.g. Watts and Aslin 1981), the northern hopping-mouse is probably mostly granivorous, taking seeds of grasses, herbs and shrubs. Many granivorous birds are known to have declined extensively across northern Australia (Franklin 1999), largely because this resource has been affected by vegetation change caused by altered fire regimes, grazing by livestock and incursions by exotic weed species (particularly pasture grasses). Many granivorous rodents have probably suffered similar patterns of decline for similar reasons, although the information available is generally more sparse (Woinarski 2000).

For granivorous animals, the most critical resource changes appear to be related to spatial heterogeneity, with seed resources most likely to be available year-round if the consumer can access a broader range of variability (such as that created or enhanced by fine-scale burning) (Fraser *et al*. 2003; Woinarski *et al*. in press, *a*). Seed availability is also affected by changes in phenology, vegetation structure and floristic composition, with each of these capable of being affected by imposed fire regimes, grazing and occurrence of exotic plants (Crowley and Garnett 1999, 2001; Woinarski *et al*. in press, *a*).

The northern hopping-mouse is also highly communal, with many individuals occupying a single burrow system. This characteristic may render the species particularly susceptible to predation by feral cats, which may wait at burrow entrances and over several nights consume entire colonies. To some extent, this threat may be partly limited by the explosive exit of hopping-mice from their burrows and some degree of concealment of burrow entrances (Johnson 1964; Dixon and Huxley 1985).

The two other species considered here are more solitary, and probably consume a broad variety of invertebrate and small vertebrate food, and hence may be somewhat less affected by habitat change and predation. The very limited information available suggests that Butler's dunnart shelters, at least at times, under fallen woody debris. This may render the species susceptible to direct mortality in hot fires, and to a reduction in suitable shelter sites following extensive hot fires.

Identification of threats

Given the lack of specific information, some assessment of threats likely to be affecting these three species may be interpolated from evidence of a more general decline in native mammal assemblages across much of northern Australia (Woinarski *et al*. 2001; Watson and Woinarski 2003; Pardon *et al*. 2003; McKenzie and Burbidge 2002). Such declines appear to be affecting species with very diverse ecologies. Given the extensiveness of the patterns of decline and the broad range of mammal species involved, the causes of decline must also be extensive and non-specific. There are three processes that may fit this bill: predation by feral cats; altered vegetation patterning (of floristic composition, structure and patchiness, and due to either changed fire regimes or the impacts of feral or managed livestock); or disease. There is no evidence that points conclusively to the primacy of any of these factors.

Of these three putative threatening processes, there is by far the most information available about the impacts of fire. Recent studies have shown that mammal communities in northern Australia can be readily moulded by variation in fire regimes (e.g. Woinarski *et al*. in press, *b*), with many species showing very marked responses to fire frequency, fire intensity and fire scale, mediated through direct impacts upon vegetation patterning. There is now much evidence showing that current fire regimes are markedly dissimilar to those that were probably most pervasive under Aboriginal land management (Bowman 1998; Vigilante 2001; Yibarbuk *et al*. 2001; Preece 2002), and hence that there has been broad-scale change in habitat suitability for many mammal species across northern Australia.

However, there is little or no specific information about the response of the three mammal species considered here to individual fires or fire regimes, because these species have been subject to so little research. A limited correlative study of the northern hopping-mouse suggested that it preferred spatially heterogeneous heathlands, with such patchiness probably promoted largely by fine-scale burning (Woinarski *et al*. 1999). In other heathlands in northern Australia, frequent fire (typically with recurrence of less than 4-5 year intervals) has been shown to reduce floristic diversity, and particularly so for the shrubby native pea species (Russell-Smith *et al*. 1998, 2002), with which the northern hopping-mouse appears to be associated. Hence, a preferred fire regime for this species may be fine-scale burning with return intervals of at least 5 years, and the extent of any departure from this regime will be related to the extent of detrimental impact.

However, this conclusion is tentative and needs to be examined through more rigorous study. There are no data on the responses of carpentarian antechinus and butler's dunnart to fire. Other ground-dwelling dasyurids in northern Australia have been shown to be disadvantaged by frequent extensive hot wildfires (e.g. Oakwood 2000). On such slight evidence, a conservative fire management (infrequent fires and/or fine-scale "cool" fires) may be preferred by butler's dunnart and carpentarian antechinus, but such a presumption should be subject to more rigorous study.

There is no information on the impacts of predation by cats upon these three species. Such impacts may be expected to be most severe on the colonial burrow-nesting northern hopping-mouse rather than the solitary Butler's dunnart and carpentarian antechinus, with the latter probably given some additional protection from predation because of its preferred rugged rocky habitat.

There is no information on any impacts of disease upon any of the three species considered here.

Grazing by livestock and/or feral stock may have some impact upon these three species, but there are no data to evaluate such a claim. Neither the northern hopping-mouse nor butler's dunnart is known from any lands used for pastoralism, but feral stock (cattle, buffalo and pigs) occur, generally at low densities, across much of their known range. The apparent stronghold of carpentarian antechinus (the Pellew islands) is largely free of stock, except for Vanderlin Island (where cattle occur at generally low densities). The few recent records of carpentarian antechinus in Queensland occur largely on pastoral lands, but pastoralism is unlikely to affect this species, even on such properties, given that it is largely restricted to rugged rocky areas.

In contrast to the pervasive threats of altered vegetation patterning, predation by feral cats and disease, more acute factors may (also) threaten the northern hopping-mouse and carpentarian dunnart. The largest known populations of northern hopping-mouse occur on Groote Eylandt and the mainland of north-eastern Arnhem Land. Broad-scale strip-mining occurs in both areas, for manganese and bauxite respectively, and this mining probably affects some populations of northern hopping-mice. However, in both regions, the mining activity is concentrated mainly away from the sandy substrates preferred by northern hopping-mouse; and on the mainland of north-eastern Arnhem Land, a population of northern hopping-mouse is protected from mining within the Nanydjaka IPA. All recent records (i.e. since 1966) of Butler's dunnart have been from the Tiwi Islands. Over the last decade, an extensive forestry operation has been developed on the larger of these islands, Melville, with approval for clearing 25,000 ha of native forest for plantation of exotic timber species. This constitutes about 3% of these islands, and may be expected to have a similarly proportioned impact on the population of Butler's dunnart.

The carpentarian antechinus was first recorded from Queensland during a study of the impacts upon biota of sulphur dioxide emissions from the Mt Isa copper smelter (Griffiths 1998). In that study, capture data were too few to derive any relationship with emission levels, but captures of carpentarian antechinus occurred only in the two sites with lowest levels of emissions (>20 km from emission source), and not in similar environments at four sites with higher emission levels.

Populations and Areas under threat

All populations of each of the three species are subject to at least some of the pervasive threatening processes of vegetation change through altered fire regimes (and/or impacts of livestock) and/or predation by feral cats.

Populations of northern hopping-mice are subject to some impacts from strip-mining on north-eastern Arnhem Land and Groote Eylandt. Populations of Butler's dunnart are subject to some impacts of vegetation clearance for forest plantation on Melville Island.

PART D: RECOVERY OBJECTIVES, CRITERIA, ACTIONS AND COSTS

[Note on costs: Each species occurs mainly at sites remote from major population centres. Some of the most important populations are on islands for which transport of personnel and equipment is expensive. In most activities described below some component of the estimated cost includes payments to Aboriginal landholders as collaborators in the research and management activities.]

1. Enhance communication about the status of these species, and establish a Recovery Team of interested stakeholders

Objective
To better communicate information about these species amongst interested stakeholders, and coordinate the implementation of recovery planning.

Criteria
- formation and operation of a Recovery Team that includes representation of stakeholder groups;
- high levels of awareness of the threatened status of these species amongst stakeholder groups, and substantial involvement of those groups in recovery management.

Action 1.1. Establish and operate a Recovery Team
There are at least three options for composition of a Recovery Team relevant to these three species. These are:
- a specific Recovery Team for each species.
    - For northern hopping-mouse, this may include NT Department of Infrastructure Planning and Environment, Queensland Environment Protection Agency, Anindilyakwa Land Council, Northern Land Council, Threatened Species Network, Dhimurru Aboriginal Land Management Corporation, GEMCO, Nabalco and Cape York Land Council;
    - For Butler's dunnart, this may include NT Department of Infrastructure Planning and Environment, WA Department of Conservation and Land Management, Tiwi Land Council, Kimberley Land Council, Wunambal-Gaambera Aboriginal Corporation, Sylvatech and Threatened Species Network;
    - For carpentarian antechinus, this may include NT Department of Infrastructure Planning and Environment, Queensland Environment Protection Agency, Northern Land Council, Threatened Species Network and Mabunji Aboriginal Resource Association.
- a combined recovery team that considers together all three species; and/or
- a recovery team for threatened native mammals generally across northern Australia.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
operate Recovery Team	5	5	5	5	5

2. **Undertake studies necessary to refine management advice**

Objective
To undertake sufficient research to allow a reasonably informed assessment of the total population, population trends, distribution, habitat suitability, and susceptibility to threatening processes for each of the three species.

Criterion
- Knowledge gained will have been sufficient to substantially refine management priorities and guidelines

Action 2.1. Evaluate options for increasing efficiency of sampling protocols for northern hopping-mouse and Butler's dunnart at sites of known occurrence

Sampling techniques used in conventional wildlife survey appear to be unsuitable for these two species. To detect the species reliably, more targeted sampling will be required. The action described here involves experimentation with a range of different sampling procedures (including different sizes and shapes of pitfall traps, and different baits) to attempt to identify a sampling protocol for these two species that can be used to reliably detect presence and can provide an index of relative abundance.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
assess sampling techniques for northern hopping-mouse	8	5	0	0	0
assess sampling techniques for Butler's dunnart	8	5	0	0	0

Action 2.2. Advance knowledge of the geographic distribution of each species, particularly with reference to persistence in regions around the type locality
In part based on improvements in sampling methodology developed in Action 2.1, this action seeks to better circumscribe the known distribution of each species, and particularly to evaluate whether the species continue to be found around their type localities (north Kimberley for Butler's dunnart; Cape York Peninsula for northern hopping-mouse, and Alexandria for carpentarian antechinus), and other potentially suitable sites (e.g. coastal north-west NT mainland for Butler's dunnart, rocky ranges of the NT Gulf mainland for carpentarian antechinus, islands around Groote Eylandt for northern hopping-mouse)

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
distributional survey for northern hopping-mouse	0	20	10	0	0
distributional survey for Butler's dunnart	0	15	10	0	0
distributional survey for carpentarian antechinus	0	10	10	0	0

Action 2.3. Undertake detailed autecological study of each species in order to more specifically identify impacts of threatening processes
There have been no substantial ecological studies undertaken on any of these species, consequently the information currently available on diet, habitat requirements, resource availability, breeding biology and responses to putative threatening processes is insufficient to prescribe management actions with any confidence. This action describes basic autecological study for each species, with that study considering each of the aspects listed above.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
assess diet, habitat, resource availability, breeding biology and threats for northern hopping-mouse	0	35	35	35	0
ditto Butler's dunnart	0	35	35	35	0
ditto carpentarian antechinus	0	35	35	35	0

Action 2.4. Establish monitoring programs to report on trends in the abundance of each species, and responses to management actions.
In at least one site for each species, establish and implement a monitoring program that provides sufficient information to describe long-term trends in abundance and responses to management actions. Until such time that distributions are better known (Action 2.2 above), the most suitable such sites are probably North Island (Barranyi NP) for carpentarian antechinus, Melville Island for Butler's dunnart and Groote Eylandt and/or Nanydjaka IPA for northern hopping-mouse. Monitoring activity should be every two years, except where additional monitoring may be advantageous in order to describe short-term responses to management actions (e.g. experimental fires).

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
establish monitoring program for northern hopping-mouse	0	15	0	10	0
ditto Butler's dunnart	0	15	0	10	0
ditto carpentarian antechinus	0	15	0	10	0

3. Manage populations (or threats to those populations) of each of the three species such that the conservation status of the three species becomes secure (not threatened)

Objective
To implement management that results in substantial benefit to populations of these species.

Criteria
- Threatening processes are ameliorated, and management implemented to benefit each species;
- Conservation status of all three species is improved, to not threatened status.

Action 3.1. Maintain and enhance habitat suitability, through fire management
For each of the three species, the preferred fire regime is not known with any certainty. However, by analogy with better known species with similar ecologies, it is likely that frequent, extensive, hot (late Dry season) fires reduce habitat suitability and may result in increased direct mortality. Small fires that promote a mix of burnt patches and patches unburnt for various ages are more likely to increase habitat suitability. Most conservation reserves in northern Australia, and many Aboriginal lands, are now being managed to attempt to implement such fine-scale regimes and minimise risks of extensive destructive fires. As such, fire management specifically for these three species should be capable of being insinuated into existing management planning that applies more broadly for conservation reserves and Aboriginal lands in much of northern Australia.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
implement fire management programs for northern hopping-mouse	0	10	10	10	10
ditto Butler's dunnart	0	10	10	10	10
ditto carpentarian antechinus	0	10	10	10	10

Action 3.2. Minimise impacts of predation by feral cats
Currently, there is no broad-scale application of control mechanisms for feral cats in northern Australia, and there is some uncertainty about whether such control is practical. While it is desirable for biodiversity conservation to control feral cats in northern Australia, a more practical immediate action would be to maintain the cat-free status of some existing sites (islands) and attempt to eliminate cats from sites where this is most achievable. All three species considered here occur on islands but, unfortunately cats are known to occur on most of these islands (Bathurst and Melville Islands, on which Butler's dunnart occurs; Vanderlin, Centre and South-west Islands on which the carpentarian dunnart occurs; and Groote Eylandt on which the northern hopping-mouse occurs). Of the known range of these species, this leaves only one island, North Island (on which carpentarian antechinus occurs), that is possibly cat-free (although even this status is uncertain). This action seeks to:

- assess whether cats are present on North Island;
- if not, to communicate widely with residents of, and visitors to, North Island about the detriment posed by introduction of cats;

- attempt to control cats on at least the smaller islands that are known to support populations of any of these three mammal species (Vanderlin, South-West and Centre); and
- examine whether northern hopping-mouse occurs on any cat-free islands around Groote Eylandt.

Results from these actions will be reviewed in 2008, to examine the need for and practicality of more extensive campaigns of cat control.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
assess whether cats are present on North Island	5	0	0	0	0
communicate widely with Aboriginal land-owners and others about risks posed by cats to the conservation values of the Pellew Islands	10	5	5	5	5
cat control on Pellew Islands	0	20	20	15	10
survey for occurrence of cats and hopping-mice on satellite islands around Groote Eylandt	0	15	15	0	0

Action 3.3 Minimise impacts of acute land-use factors

There is some risk of at least localised detriment to northern hopping-mouse and carpentarian antechinus from mining activities and to Butler's dunnart from land clearing and forestry activities. Assessing and minimising such risks requires improved communication with, and participation of, the industry groups, fine-scale distributional information, and provision of specific management advice to these ventures, appropriate for inclusion within the environmental management planning process for the operations. This action recognises that the existing ventures have been approved appropriately under a range of impact assessment regulations, and does not propose to revisit such assessment. Rather, it seeks to provide the tailored advice that is needed to minimise such impacts, and enhanced consideration of the conservation status and requirements of these species in any further related development proposals.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
assessment of fine-scale distributional patterning and habitat use for northern hopping-mouse in and around development areas of Groote Eylandt and NE Arnhem Land	0	20	20	10	10
ditto for Butler's dunnart on Melville Island	0	20	20	10	10
ditto for carpentarian antechinus around Mt Isa	0	20	20	10	10

Action 3.4. Monitor management actions and the responses of these species to those actions, and thence adapt and refine management practices

The set of recovery actions described above are those considered most appropriate for recovery, but this is based on the very limited information currently available. There is a need to monitor how these actions are implemented and then to measure the extent of response to these actions from the three mammal species; for such evaluation is necessary to continually improve management practice.

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**
parameterise management actions, and record management actions appropriately	5	5	5	5	5
assess improvements in habitat quality or threat abatement arising from each management action	10	10	10	10	10
assess changes in abundance and/or distribution arising from each management action	10	20	20	20	20

Total costs for all described Actions

cost ($000)

activity	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
for northern hopping-mouse	8	120	90	65	20	303
for Butler's dunnart	8	100	75	65	20	268
for carpentarian antechinus	15	125	100	85	35	360
for generic activities	30	40	40	40	40	190
Total	*61*	*385*	*305*	*255*	*115*	*1121*

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Abbreviations

EPBCA	*Environment Protection and Biodiversity Conservation Act 1999*
GEMCO	Groote Eylandt Mining Company Ltd
IPA	Indigenous Protected Area
IUCN	International Union for the Conservation of Nature
NP	National Park
NT	Northern Territory
WA	Western Australia

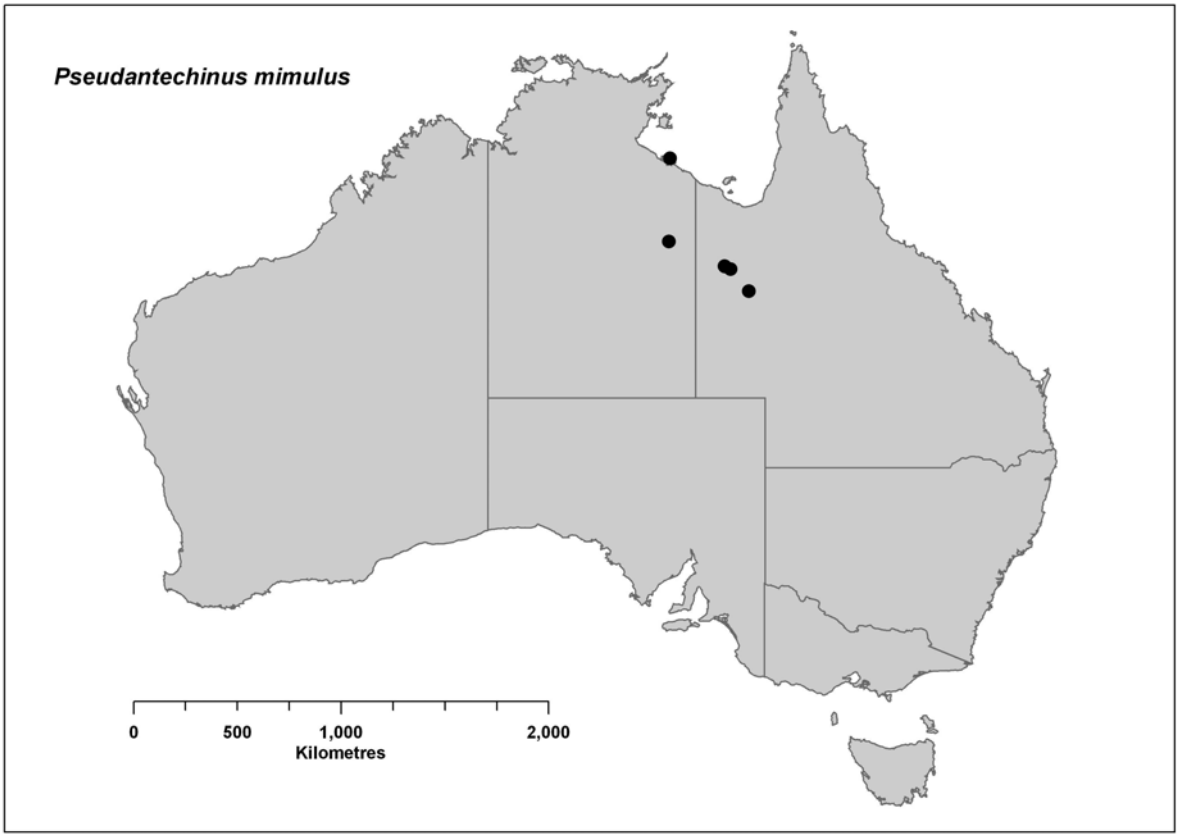

Figure 1. Known distribution of carpentarian antechinus. Note that the record from Alexandria (the southernmost of the NT records) has little geographic precision.

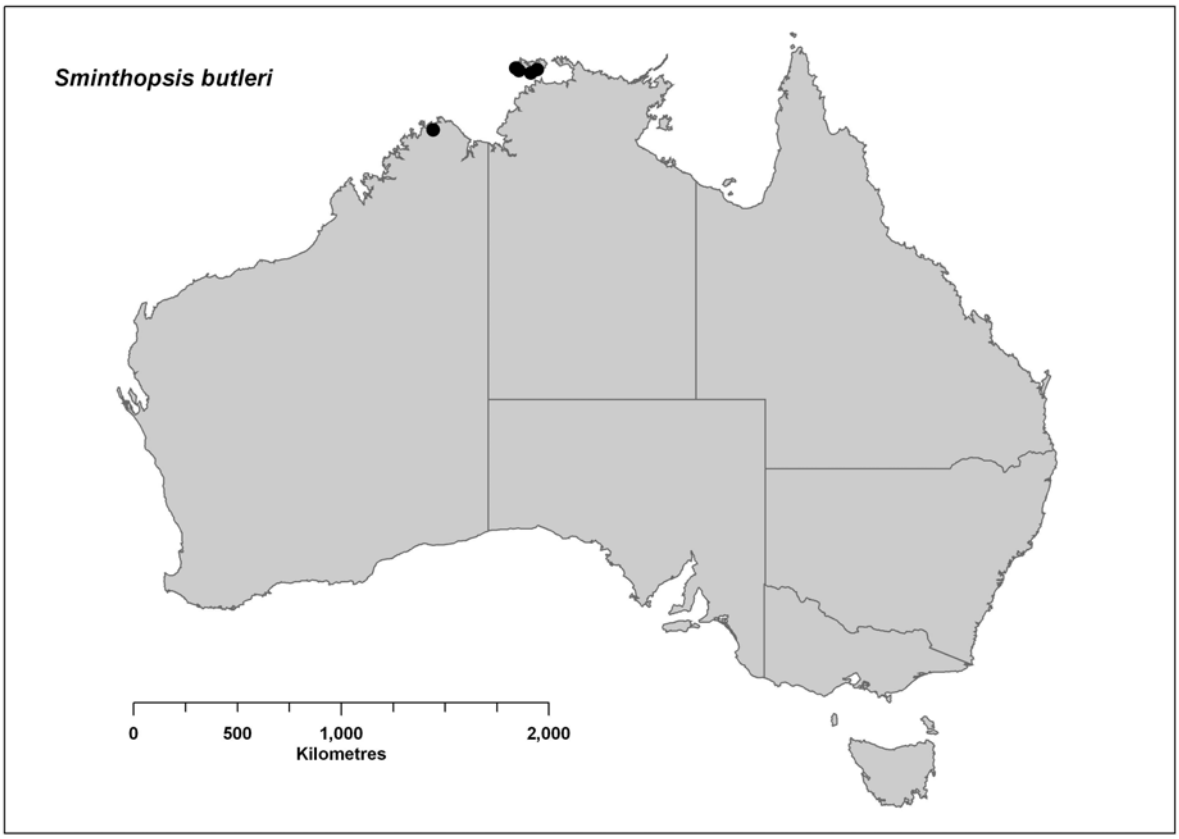

Figure 2. Known distribution of Butler's dunnart.

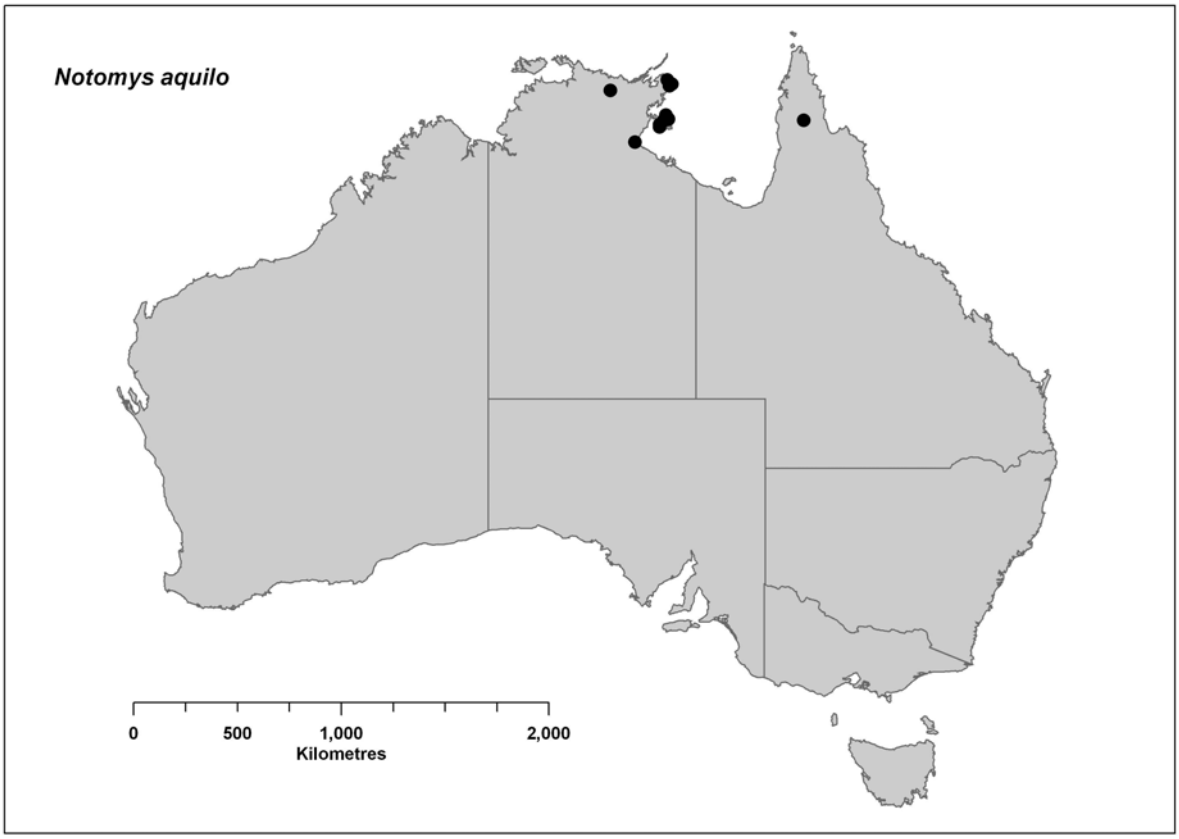

Figure 3. Known distribution of northern hopping-mouse. Note that the record from Queensland cannot be attributed to any more specific location than "Cape York".