Recovery Plan for Marsupial Moles
Notoryctes typhlops and *N. caurinus*, 2005-2010

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ANANGU•PITJANTJATJARA•YANKUNYTJATJARA•LAND•MANAGEMENT

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Cover: Ilawanti Ken holding an Itjaritjari in the A<u>n</u>angu-Pitjantjatjara/Yankunytjatjara Lands, SA

Photo: Joe Benshemesh (2001)

Contents

Acronyms

APIA	Australian Pipeline Industry Association
APYLM	Anangu-Pitjantjatjara/Yankunytjatjara Land Management
ASDP	Alice Springs Desert Park
BFC	Bushfire Council (NT)
CALM	Department of Conservation and Land Management (WA)
CLC	Central Lands Council (NT)
CLMA	Central Land Management Association (NT)
DBIRD	Department of Business, Industry and Resource Development (NT)
DEH SA	Department of Environment and Heritage (SA)
DIPE	Department of Infrastructure, Planning and Environment (SA)
EA	Environment Australia
EPA	Environment Protection Agency (QLD)
EPBC	Environment Protection and Biodiversity Conservation Act (1999)
GIS	Geographic Information System
NLMU	Ngaanyatjarra Land Management Unit (WA)
NPWS	National Parks and Wildlife Service (NSW)
NSW	New South Wales
NT	Northern Territory
NTMU	Northern Territory Museum
OE	Office of Energy (WA)
PIRSA	Department of Primary Industries and Resources South Australia
QLD	Queensland
SA	South Australia
SAM	South Australia Museum
TSN	Threatened Species Network
WA	Western Australia
WAM	Western Australia Museum

Summary

Current Taxon Status

Both the Kakarratul (*Notoryctes caurinus*) and the Itjaritjari (*N. typhlops*) are listed as Endangered under the EPBC Act 1999, and IUCN criteria A1c,2c (Maxwell et al. 1996). However, an accurate assessment of the conservation status of marsupial moles is difficult due to the paucity of information (Maxwell et al. 1996) and taxonomic uncertainties.

The Itjaritjari occurs in South Australia, Northern Territory and Western Australia. In SA, Itjaritjari is listed as Endangered under the *National Parks and Wildlife Act 1972 – Schedule 7*, but a change to Vulnerable has been proposed (Department of Environment and Heritage 2003). In the NT, Itjaritjari is listed as Vulnerable under the *Territory Parks and Wildlife Conservation Act 2000*. In WA both Kakarratul and Itjaritjari occur and both are listed as Fauna that is rare or is likely to become extinct under Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2003*.

The available evidence does not provide a clear indication of the current status of marsupial moles, and a major thrust of this recovery plan is to obtain information in order to make a more accurate classification in terms of IUCN criteria within 5-10 years.

Habitat Requirements and Limiting Factors

Very little is known about the habitat requirements of either species of marsupial mole. They are most often recorded in sandy dunes habitats supporting various acacias and other shrubs, and often but not always in association with spinifex. Such habitat is widespread in and typical of the sandy deserts. Marsupial moles may also occur in some sandy plains, and might also occupy sandy river flats, especially in areas where aeolian dunes also occur. Marsupial moles are not capable of travelling far across hard ground and continuity of suitable habitat is also likely to be important for the occurrence of marsupial moles in an area.

It is not known what factors limit marsupial mole populations. Marsupial moles remains occur frequently in the scats of introduced foxes, and to a lesser extent dingos and feral cats, and it is possible that these predators may be having an adverse affect on populations. Other concerns include changed fire regimes, and trampling and habitat changes caused by introduced cattle and burgeoning camel populations. These factors have the potential to greatly modify the vegetation of habitats, and thus the availability of invertebrate prey for marsupial moles. Current predictions of climate change for Australia also provide considerable cause for concern and projected changes in rainfall and temperatures, and concomitant changes in biota, might threaten marsupial moles over their entire range.

Recovery Plan Objectives and Actions

Describe the distribution of the distinct lineages of marsupial moles

1. Resolve the taxonomy and determine appropriate management units.
2. Describe the distribution and provide indices of the abundance of the distinct lineages of marsupial moles

Determine trends in populations

3. Determine population trends of the distinct lineages of marsupial moles

Provide preliminary information on threats

4. Provide preliminary information on the threat of fire, introduced predators such as foxes and cats, and grazing.

Learn about the ecology

5. Describe activity patterns and ranging behaviour
6. Obtain ecological information from Aboriginal elders
7. Examine the diet, reproductive state and general condition of surfacing animals.
8. Prepare for captive individuals brought to Desert Park

Manage the recovery process

9. Manage the recovery process through a recovery team
10. Downlist species from endangered to a lower category of threat

Estimated Costs of Recovery

Five year Budget ($000s)

Action		1	2	3	4	5	Total
1a	Map and model habitat	10	0	0	0	0	10.0
1b	Survey	73	73	0	0	0	145.0
1c	Collect and analyse scats	23	21	21	21	21	106.0
1d	Solicit records	10	2	2	2	2	18.0
1e	Inspect pipeline trenches	2	0	0	0	0	2.0
2	Monitor	64	0	43	0	43	148.5
3	Taxonomy	31.5	0	0	0	0	31.5
4a	Fire, grazing, predation	46	0	15	0	15	76.0
4b	Surfacing & predation	46	36	37	36	36	189.3
5	Activity and ranging	37.1	37	0	0	0	74.2
6	Aboriginal knowledge	28	28	0	0	0	56.0
7	Diet and condition	20	0	0	0	0	20.0
8	Captive preparations	4	0	0	0	0	4.0
9a	Coordinate Plan	28.7	14.9	9.8	5.6	5.6	64.6
9b	Recovery team	2	2	2	2	2	10.0
10	Re-evaluate status	0	0	0	0	4	4.0
		426.3	215.9	132.8	70.6	133.6	959.1

Part A Species information and general requirements

Species

Marsupial moles have been known to science for over a century, and to indigenous peoples for many thousands of years, but they remain amongst the least known and elusive animals in Australia (Benshemesh & Johnson 2003). Occurring in remote areas and characterised by extreme morphological specialisation, an elusive nature and extraordinary habits, marsupial moles continue to intrigue people of all ages and backgrounds.

Marsupial moles have a head and body length of up to 140 mm and weigh from 30 g to 60 g. They show the typical characteristics of fossorial mammals including a tubular body form, an absence of ear pinnae, heavily keratinised skin on the snout, a reduced tail, and short dense fur. In common with most burrowing marsupials, the pouch opens posteriorly as a protection against the incursion of soil. They are the most fossorial of the marsupials, only rarely venturing to the surface.

Two species are currently recognised, *Notoryctes typhlops* or Southern Marsupial Mole from central Australia, and *Notoryctes caurinus* or Northern Marsupial Mole from north western Australia. Given these unimaginative common names for these extraordinary species, Maxwell et al. (1996) proposed the adoption of Aboriginal names: Itjaritjari for *N. typhlops*, and Kakarratul for *N. caurinus*. These names have been widely accepted.

Taxonomy

Marsupial moles are not closely related to any other taxa and comprise their own unique marsupial order, the Notoryctemorphia, which may have branched off from other lineages as much as 64 million years ago (Kirsch et al. 1997). Stirling (1891a) described *N. typhlops* from the first specimen collected in south east NT in 1888. Thomas (1920) described *N. caurinus* based on several features including its smaller size than *N. typhlops*. Later authors suppressed this species but it has gained widespread currency in recent years based in part on as-yet unpublished morphological studies by Ken Aplin formerly of the Western Australian Museum and van Oosterzee at Alice Springs (K. Aplin, pers. comm.; P van Oosterzee pers. comm.). These workers also recognised morphological differentiation between northern and southern forms of *N. typhlops*, and more recently this division has been supported by genetic analyses (S. Donnellan pers comm.; S Fuller pers. comm.). These southern populations seem to be larger-bodied on average than those from the central part of the species' range, but are otherwise consistent with *N. typhlops* in cranio-dental morphology (K. Aplin pers. comm.). The taxonomic and biogeographical implications of these differences have yet to be fully resolved.

Conservation status

Both the Kakarratul and the Itjaritjari are listed as <u>Endangered</u> on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and in the Action Plan for Australian Marsupials and Monotremes (Maxwell et al. 1996). The Itjaritjari occurs in South Australia, Northern Territory and Western Australia. In SA, Itjaritjari is listed as <u>Endangered</u> under the *National Parks and Wildlife Act 1972 – Schedule 7*, but a change to <u>Vulnerable</u> has been proposed following IUCN guidelines (Department of Environment and Heritage 2003). In the NT, Itjaritjari is listed as Vulnerable under the *Territory Parks and Wildlife Conservation Act 2000*. Kakarratul has not been recorded in the NT, or at least not recognised, and is not listed under NT legislation. However, it is possible that the species does occur in the NT given the proximity of Kakarratul records across the border in WA. In WA both species of marsupial moles are listed as Fauna that is rare or is likely to become extinct under Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2003.*

An accurate assessment of the conservation status of marsupial moles is difficult due to the paucity of information (Maxwell et al. 1996) and taxonomic uncertainties. Indeed, it was this paucity of information that led Maxwell et al. (1996) to list Itjaritjari and Kakarratul as Endangered (A1c,2c; IUCN 1994) by invoking a precautionary approach (Annex 1, IUCN 2000) due to concerns of potential predation by foxes and cats, apparently declining acquisition rates, and changed fire regimes. Since then some studies have shown high predation rates on Itjaritjari by foxes and cats (Paltridge 1998, 2002), reinforcing the concern that these recently introduced predators may threaten the survival of marsupial moles as they have other medium sized mammals in central Australia.

Examination of the available records does not suggest a decline in collections and sightings in recent decades, a conclusion previously reached by Pearson and Turner (Pearson & Turner 2000), although the significance of this is open to question. Relatively high numbers of marsupial moles were collected in the early 1900s when collectors employed the skills of hundreds of traditional aboriginal people and paid high prices to obtain specimens (see, for example, (Mulvaney et al. 2000). An anecdotal account of an extensive fur trade in marsupial mole pelts (Johnson and Walton 1989, (Kimber 1985); R Kimber pers. comm.) might may have its origin in this trade for specimens; no other evidence for a trade in pelts has been documented. More recently, while increased recreational and scientific interest in the sandy deserts has probably increased opportunities for sightings, the changed lifestyles of Aboriginal people has decreased the rate at which they encounter marsupial moles and bring them to the attention of authorities. The general paucity of records and changing nature of opportunities for observations makes it difficult to interpret the ecological significance in the rate at which records have been obtained. Similarly, the available data are inadequate to determine whether there has been any change in the area of occupancy (IUCN 2001). Indeed, recent records have clearly shown that even the extent of occurrence of marsupial moles is poorly known. For example, three records in the past decade have increased the parts of the confirmed range of *N. typhlops* by 500km to the south west, 200km to the north, and 100 km to the west.

In short, the available evidence does not provide a clear indication of the current status of marsupial moles. IUCN rules governing the transfer of taxa between categories (IUCN 2001) are not satisfied for either species of marsupial moles, and there is no justification at this stage in changing their status from Endangered A1c,2c.

A major thrust of this recovery plan is to obtain information in order to make a more accurate classification of marsupial moles in terms of IUCN criteria within 5-10 years.

International obligations

The species are not listed under any international agreements.

Affected interests

Marsupial moles have a huge potential range and occur on a variety of land tenures primarily comprising Aboriginal Land, pastoral leases, and State and Federal Government controlled land in the form of National Parks and reserves and uncommitted/unallocated Crown Land (Table 1).

All of these interested parties will be involved in the implementation of this plan to some degree. For Aboriginal communities and organisations, planned recovery actions include employment of traditional owners in field work and site clearances for survey locations, as well as the recording of traditional knowledge. Pastoralists and the general public will be encouraged through local media to lodge sighting records and other information with wildlife authorities. State and Federal government agencies will be involved in every stage of implementing the plan, especially in National Parks and reserves.

In addition, marsupial moles are known to occur on Aboriginal and Crown land leased by mining companies (eg Newmont Pty Ltd in the Tanami, Birla (Nifty) Pty Ltd and Newcrest Mining Limited in the Great Sandy Desert) and tourism operators (eg. Voyagers Ayers Rock Resort). These interests are not likely to be deleteriously affected by actions developed in this plan. While mining and tourism interests operate on a very small proportion of the distribution of marsupial moles, these are strategically important areas because the existing infrastructure at these localities could facilitate local survey and monitoring and thus benefit the recovery program.

Table 1. The estimated likely range of all species of marsupial mole in regard to land tenure (Australian Land Tenure 1993) in each state and nationally (bracketed values). Range was estimated as a polygon including all records and extended to the edges of aeolian sand deposits in central Australia. Note that there are no confirmed records from QLD or NSW.

Tenure	Description	NSW	NT	QLD	SA	WA	Total
Aboriginal	Aboriginal freehold, reserve or leasehold over 100kmsq	-	47.6% (15%)	-	33.6% (7%)	23.9% (10%)	33.0%
Private	Freehold land other than Aboriginal land	-	-	-	1.9% (<1%)	-	0.4%
Private	Leasehold land other than Aboriginal land	89.4% (<1%)	40.7% (13%)	79.9% (2%)	36.0% (8%)	8.6% (4%)	27.3%
Public	Defence land	-	-	-	0.6% (<1%)	-	0.1%
Public	Nature conservation reserve	10.2% (<1%)	0.3% (<1%)	20.1% (<1%)	27.3% (6%)	7.0% (3%)	9.7%
Public	Other Crown land	0.5% (<1%)	0.6% (<1%)	-	0.1% (<1%)	1.2% (<1%)	0.7%
Public	Aboriginal freehold-national park	-	0.2% (<1%)	-	-	-	0.1%
Public	Uncommitted/unallocated Crown land	-	10.7% (3%)	-	0.5% (<1%)	59.4% (25%)	28.6%
	Total Area (10^3 km^2)	17.3	758.1	51.6	519.9	980.9	2,327.9

Role and interests of indigenous people

A substantial portion of the range of Itjaritjari and Kakarratul occurs on Aboriginal land, and Aboriginal peoples throughout the sandy deserts have known of marsupial moles for thousands of years and know the species by a variety of names (Burbidge et al. 1988). In regard to scientific inquiry, Aboriginal people have collected most specimens and their involvement has been instrumental in much of what has been learnt about the species.

As major stakeholders in marsupial mole conservation, Aboriginal landholders and traditional owners will be invited onto the recovery team and be part of the decision making process.

Considering the elusiveness of the species and the paucity of information on their ecology, it is likely that continued efforts to understand and manage marsupial moles will benefit from Aboriginal involvement. Aboriginal people can also make a substantial contribution to conserving marsupial moles through their traditional knowledge, skill, and management practices, and their proximity to sites of particular interest. In particular, the plan aims to involve Aboriginal communities by:

- Collecting traditional ecological knowledge (Action 6)
- Soliciting sightings (Action 1d)
- Involving indigenous communities in field actions such as collecting predator scats (Action 1c) and tracking (Action 6), and

- Providing community education and information in regard to marsupial moles and the recovery process (Action 1d and 9b).

In addition to the recovery process, it is also recognised that marsupial moles feature in Aboriginal mythology and are associated with certain ‘Dreaming’ sites and trails in central Australia. Such sites occur at Uluru (Mountford 1948; Baker et al. 1993), Watarrka (P Laughton per. comm.), Ooldea (Berndt & Berndt 1992) and in the Anangu-Pitjantjatjara Lands (R Kankanpakantja pers. comm; Bernard pers. comm.). While recording these stories and songs may not be essential to the recovery process, knowledge of these is often held by people who are likely to be interviewed due to their traditional ecological knowledge. These people will be invited to record their stories and songs and the recordings will be archived appropriately according to their wishes.

While a number of actions include Aboriginal involvement, it should be noted that the capacity of Aboriginal people to contribute is dependent on there being a core of infrastructure and project management expertise on Aboriginal Lands. This is provided by land management units of land holding organisations, community ranger programs and other structures, but these are not well established in all areas and often lack secure funding for their basic infrastructure and staffing, and frequently rely on inputs of CDEP programs for their operational capacity.

Benefits to other species or communities

Marsupial moles are primarily predators of underground invertebrates, and possibly also of smaller vertebrates, and they occupy a vast range in the sandy deserts. Their role in the ecology of these deserts is not understood, but it may be important in regard to controlling numbers of these animals.

It is also possible that marsupial moles benefit plant and animal communities by changing soil dynamics and redistributing materials. Where marsupial moles are still known to occur, their underground backfilled tunnels are often very common and these may represent an important source of soil disturbance or biopedturbation (Whitford & Kay 1999). Evidence of 30-60 kilometres of backfilled tunnel per hectare is usual in these areas (JB unpublished), representing about 40-80 m^3 of turned-over soil per hectare, or up to 1% of the soil within one metre of the surface.

Social and economic impact

This plan aims to contribute positively to communities within the range of marsupial moles, especially those that are actively involved in implementation of the plan. There are unlikely to be any adverse social or economic impacts of this recovery plan as most of the on-ground actions proposed at this stage involve the collection of information rather than management treatments. Unforseen adverse effects will be avoided through consultation with interested parties.

Part B Distribution and location

Distribution

The distribution of Notoryctes spp. is known from scattered records throughout the sandy deserts of inland Australia. Most of these records derive from specimens or traditional information provided by Aboriginal people to collectors. Although there are about 300 specimens of Notoryctes in Australian Museums and wildlife databases, only 194 of these have locations recorded in some form (coordinates or localities). However, as most specimens were obtained from Aboriginal people whose information on the source of the specimens often could not be understood, the accuracy of many location records is poor. In many cases the place at which specimens were received from Aboriginal collectors has been recorded as the location, whereas the actual collecting point may have been 50-100km away.

In addition to these specimens and observations, Burbidge et al. (1988) collected anecdotal information from Aboriginal traditional owners on the occurrence of marsupial moles within living memory in areas they visited. These records are of great value in estimating the original distribution of marsupial moles in some of the most remote parts of the continent, but are also likely to be of low accuracy in date and location due to difficulties in cross-cultural communication of site names and concepts.

Notwithstanding these caveats on the accuracy of many of the location records, the available records are of great importance in defining the regional areas in which marsupial moles occur. These sources suggest the range of the genus is largely coincident with the extent of sandy soils in the central desert region (Johnson & Walton 1989). These arid regions include the Great Sandy, Little Sandy, Gibson, Tanami, Great Victoria and western Simpson Deserts. Figure 1 shows the distribution of records in relation to surficial sand coverage as well as the distribution of aeolian dunes across Australia (Bretan Clifford, pers. comm.). While surficial sand deposits are extensive across Australia, marsupial mole records of both species of *Notoryctes* tend to occur within the distribution of non-coastal aeolian dunes.

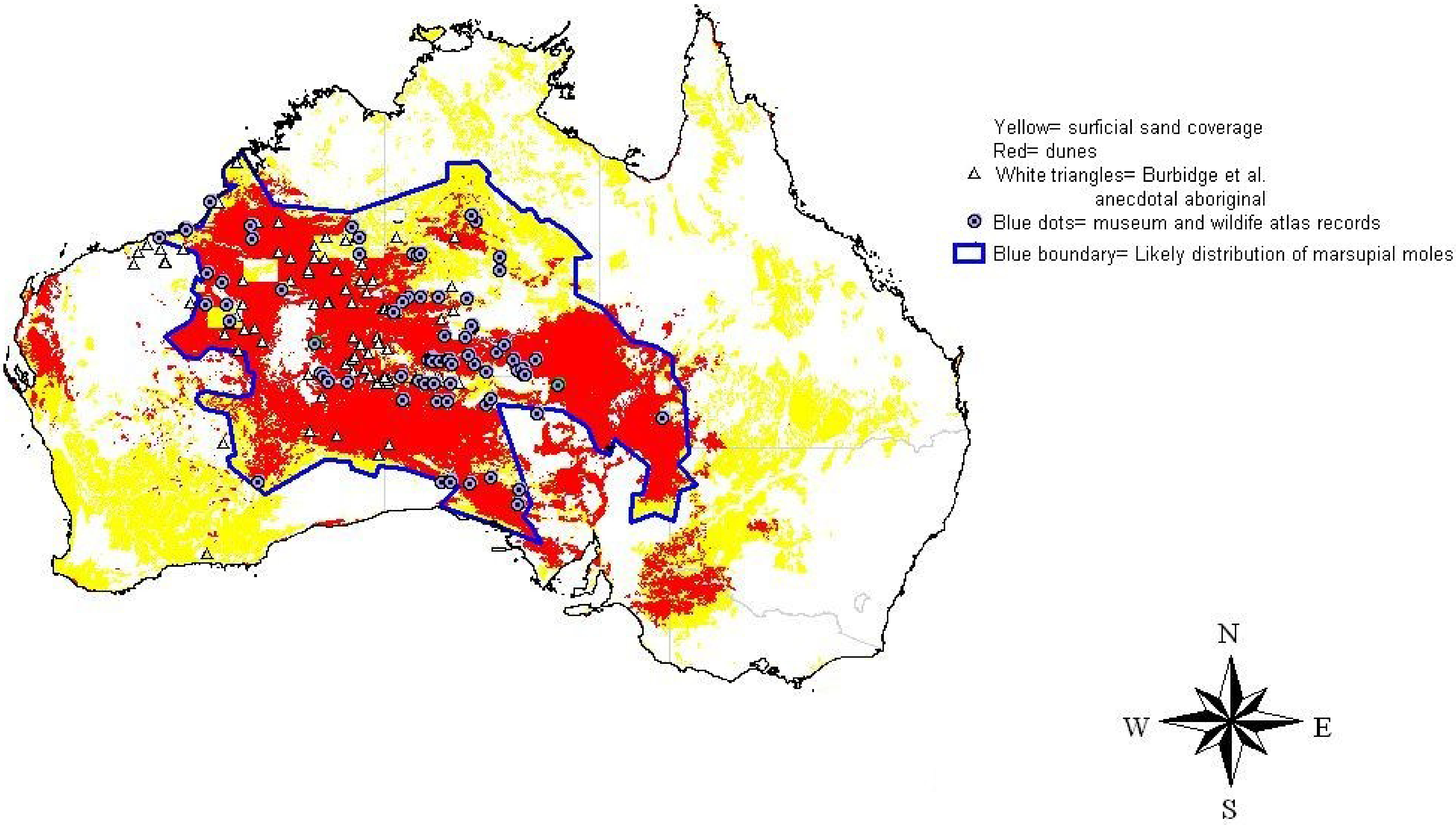
Ranges of individual species and distinct forms

Recent genetic (S Donnellan and S Fuller, unpublished) and morphological analyses (K Aplin and P van Oosterzee, unpublished) suggest there are three distinct lineages of marsupial moles: *N. caurinus*, and a southern and northern form of *N. typhlops*. This taxonomic work is still in progress and both approaches are in general agreement. There is uncertainty about the limits of the ranges of these lineages although they appear to occupy broadly different areas. The following summary draws largely from the combined results of morphological and genetic studies, although the genetic analysis has looked at a wider range of specimens to date and is used here to distinguish forms of *N. typhlops*.

Specimens of *N. caurinus* have been collected from twelve localities in the Great Sandy, Little Sandy and Gibson Deserts of WA. Most recently a live specimen was collected in 1998 on the surface at Punmu in Rudall National Park and kept briefly in captivity (Withers et al. 2000), and in 2000 specimens were also collected at Wallal Downs on the coast between Broom and Karratha, and at Kunawarritji Community (-22.33° S, 124.72° E) on the edge of the Gibson Desert and Great Sandy Deserts. Both *N. typhlops* (southern form) and *N. caurinus* have been recorded in the vicinity of Warburton and may be sympatric there. Otherwise, specimens north of Warburton and west of the NT border have all been identified as *N. caurinus* (K Aplin, pers. comm.; S Donnellan pers. comm.).

It is unclear which species inhabits much of the Tanami Desert, or if there are zones of overlap. *N. caurinus* has been collected in the western Tanami near Balgo (-20.15, 127.98) and identified as such by its morphology (K Aplin pers. comm.), whereas *N. typhlops* (northern) has

Figure 1. Likely distribution of marsupial moles



been recorded 300 km SW from the Kintore Ranges (-23.30, 129.40) and Waite Creek/Nyirripi (-22.65, 130.05) areas (S Donnellan pers. comm.). Notoryctids have also been recorded from the central, northern and eastern Tanami Desert in the NT and attributed to *N. typhlops*, but this classification was based on supposed range rather than taxonomic examination. Tracks of a marsupial mole (-20.87, 130.27) from the Sangster's Bore area in the NT were photographed by Pip Masters in 1988, and appear to be those of *N. typhlops* rather than *N. caurinus* (JB, unpublished). A specimen simply labelled "Tanami Desert, NT", but otherwise without information on locality or date, has also been shown to be the northern form of *N. typhlops* (S Donnellan pers. comm.). Thus, it seems likely that *N. typhlops* occurs in the eastern Tanami Desert, and *N. caurinus* in the western Tanami, but whether these forms are sympatric or not is uncertain.

The distinct lineages of *N. typhlops* also appear to overlap in distribution. The northern form of *N. typhlops* occurs in the NT from the Tanami Desert south to the SA border, while the southern form appears to extend from southern WA and SA as far north as Hermannsburg in the NT. Northern and southern forms thus appear to overlap between the MacDonnell Ranges and the SA border.

The occurrence of marsupial moles records in biogeographical regions of Australia (Thackway & Cresswell 1995) is described in Appendix 1**.**

Range of the genus Notoryctes

Many distribution records of Notoryctes have relied on sightings of the animals or their signs and identification to the level of species has not been possible. Moreover, not all specimens have been examined in light of the differences between species or lineages, and in many cases specimens have been attributed to a species by default. While a distinction between the forms of *Notoryctes* is not possible with these records, these data are nonetheless valuable in circumscribing the likely range of the genus.

In the North, *N. caurinus* has been collected within 100km south of Broome, at Sturt Creek (19.68° S, 127.65° E) near Balgo Mission, and *N. typhlops* has been collected as far north as Barrow Creek (21.53° S, 133.88° E). Marsupial moles attributed to *N. typhlops* have been observed at both Sangster's Bore (-20.87° S, 130.27° E) and 70 km north of Barrow Creek (20.97° S, 133.92° E). Signs of marsupial moles have also been recovered from predator scats west-north west of Tennant Creek (about 19.21° S, 132.67° E) (Paltridge 1998).

The western edge of the range of marsupial moles follows the coast between Broome and Pardoo Station (20.17° S, 119.58° E) east of Port Headland. Several specimens have been collected south east of Pardoo Station as far as Lake Disappointment (23.5° S, 122.75° E). Anecdotal records from Aboriginal informants (Burbidge et al. 1988) suggest marsupial moles may occur up to 200km south of Lake Disappointment, but there are no records between there and Warburton (26.1° S, 126.6° E) 300km to the south west, or Laverton (28.6° S, 122.4° E) over 400km to the south. A single specimen and sightings of tracks from Queen Victoria Spring Nature Reserve (30.48° S, 123.68° E) is particularly interesting because it is recent and extended the confirmed range of marsupial moles by several hundred kilometres (Pearson & Turner 2000).

In the South, Aboriginal informants suggest that marsupial moles occurred in the Great Victoria Desert (Burbidge et al. 1988; Pearson & Turner 2000), but none have been collected in the Great Victoria Desert north of the Nullarbor Plain between Queen Victoria Springs and Ooldea (30.45° S, 131.83° E). Over 30 specimens have been collected from near Ooldea, most of which were collected between 1920 and 1952 and only once since then (in 1992). Several specimens have been collected east of Ooldea as far as Lake Everard on the eastern edge of Yellabinna Nature Reserve (31.42° S, 134.67° E).

The eastern extent of the distribution of *N. typhlops* is uncertain and is apparently bounded by the vast aeolian dunefields of the Simpson and Strzelecki Deserts. The most eastern specimens lodged in museums have come from Barrow Creek in the north through to the western edge of the Simpson Desert (New Crown and Charlotte Waters) near the SA and NT border where numerous specimens were brought in by Aboriginal people in the early 1900s. Specimens have also been collected from the north-eastern edge of the Great Victoria Desert (Granite Downs and Mintabie), but there are no records between there and the southern Great Victoria Desert.

A single specimen collected in the early 1900s suggests the species may occur in the vicinity of Oodnadatta (this record is doubtful; C Kemper, pers. comm.), and another specimen collected in the early 1980s, allegedly from the vicinity of Innamincka, suggests that *N. typhlops* may even occur in the Strzelecki Deserts, a range extension of over 500km. The Innamincka specimen is not recorded in museum records and the specimen appears to have disappeared, but genetic samples were collected by CSIRO and these have confirmed it was of the same genotype as *N. typhlops* from northern South Australia (S Donnellan, pers comm.). There have also been anecdotal accounts of tracks that might be of marsupial moles in the dune country north of Innamincka (G Armstrong, pers. comm.). If marsupial moles do inhabit the NE corner of SA, the species might also occur in the north western corner of NSW, and in the south western corner of QLD.

Anecdotal accounts also suggest the species may inhabit the eastern Simpson Desert in south western QLD (Duncan-Kemp 1933; Johnston & Cleland 1943), however no confirmed records have been obtained. Little information appears to have been documented from Aboriginal informants concerning the eastern part of the range of *Notoryctes*, except that Finlayson (1943) found no knowledge of marsupial moles amongst Aborigines east of the Simpson Desert between the Diamantina and Barcoo rivers.

Habitat critical for survival

Very little is known about the habitat preferences of either species of marsupial moles. They are most often recorded in sandy dunes with various acacias and other shrubs (Corbett 1975; Johnson & Walton 1989), and often but not always in association with spinifex (*Triodia* spp.) (JB Unpublished). Such habitat is widespread in and typical of the sandy deserts. While there are no clear indications of the vegetation types required by marsupial moles, underground signs of Itjaritjari tend to be most common on well-vegetated dunes (JB unpublished).

Aboriginal people from WA, NT and SA associate marsupial moles in general with sand dunes and swales (Burbidge et al. 1988; Baker et al. 1993). Likewise, Pitjantjatjara people from south west NT and northern SA frequently claim that Itjaritjari requires soft sand and that they are unable to tunnel through hard or loamy substrate which occurs in swales between widely spaced dunes. The frequency of underground signs of marsupial moles lend support to this. In the Anangu-Pitjantjatjara/Yankunytjatjara Lands, remnant backfilled tunnels are much more common on the slope and crest of dunes than in the harder sand at their base, and are usually absent from the hard and loamy “mulga earth” that often occurs between dunes (JB unpublished). Where the substrate between dunes is deep sand rather than loam, Itjaritjari backfilled tunnels occur but less frequently than on dunes, and marsupial moles have been recorded in swales and flats in other areas (Pearson & Turner 2000).

While marsupial moles seem generally associated with dune habitats, they may also occur in some sandy plains. For example, surface and underground signs of Itjaritjari have been detected several kilometres away from the nearest mapped dunes near Nyapirri in northern SA (K Stevens pers. comm.; JB Unpublished). Interestingly, in underground signs were common in patches of mallee this flat habitat (*Eucalyptus gamophylla*) with an open understorey of spinifex (*Triodia basedowii*), but were absent in neighbouring areas of similar soils dominated by Desert Oak (*Allocasuarina decaisneana*) with a thick understorey of spinifex (*T. basedowii).*

Elsewhere, underground and surface signs of Itjaritjari have been recorded in Desert Oak habitat on or near dunes both in northern SA (P Copley, pers. comm.) and at Watarrka in the NT (JB Unpublished).

Continuity of suitable habitat is also likely to be important for the occurrence of marsupial moles in an area. For example, in the northern Great Victoria Desert, underground signs of Itjaritjari were not detected on dunes that were isolated from other similarly vegetated dunes by calcrete swales and outcrops (JB unpublished). Hard and rocky substrates such as calcrete probably represent an impenetrable barrier to marsupial moles that appear to mostly travel underground and are slow and clumsy on the surface.

River flats might be expected to be rich in food resources for marsupial moles, and conceivably might provide corridors for dispersal through otherwise inhospitable terrain.

Less is known about the habitat preferences of *N. caurinus* than of *N. typhlops*, and it is not known whether their preferences differ.

Mapping of habitat critical to the survival of the species

Marsupial moles occupy a range of sandy habitats over a vast area of central Australia. Figure 1 shows the distribution of records in relation to surficial sand coverage (AUSLIG), and aeolian dunes across Australia (extracted from 1:250,000 mapsheets; Bretan Clifford, pers. comm.). While surficial sand deposits are extensive across Australia, marsupial mole records of both species tend to occur within the distribution of aeolian dunes, or within 10 kilometres of dunes. Notable exceptions in which the location of a specimen or a sighting was apparently accurate yet distant from mapped dunes include an observation of a marsupial mole north of Barrow Creek (NT), and of several *N. caurinus* specimens collected from near the coast near Wallal (WA). In both these areas, dunes are apparent on satellite images even though they are not mapped as such on 1:250,000 mapsheets.

Various sources of information are likely to be useful to map the extent of suitable habitat for marsupial moles (Table 2).

Table 2. Existing mapping that would be useful in determining the extent of suitable habitat for marsupial moles.

Data Type	Relevance to marsupial mole	Resolution/accuracy	Availability
Surficial cover	Approximate extent of surface sand across Australia	Generally low accuracy and resolution	All Australia
Geological maps	Approximate extent of surface sand across Australia	Generally higher accuracy and resolution than surficial cover	All Australia, but not available as a single dataset
Dunes mapping	Dunes appear to be primary habitat	High resolution and accuracy in most areas, but only dunes >3m	All Australia (information extracted as part of this project by PWCNT)
Radiometrics imagery	Provides information on depth of sand, thus distinguishing between very shallow and deeper deposits which is likely to be important to marsupial moles.	High (100m pixels)	All of NT and some parts of SA and WA.
Vegetation mapping	Unclear, but associations are likely between marsupial mole prey and vegetation	Variable and at various scales ranging from local to continental. modis	

Important populations

Recent genetic and morphological studies suggest there are three distinct forms of marsupial moles comprising *N. caurinus* in north west WA, and a northern and southern form of *N. typhlops* in central Australia. The taxonomic status of the two forms of *N. typhlops* has yet to be clarified, but for conservation purposes these forms should be considered seperately.

Within the range of these forms, no particular populations or areas can be described as being of greater importance for the long-term survival of the taxa than any other at this stage.

Part C Known and potential threat

Biology and ecology relevant to threatening processes

General ecology

Food

Information on the diet of marsupial moles has been obtained by examining the gut contents of preserved specimens and from observations of the behaviour of captive animals when presented with different foods. Stirling (1891a) and Spencer (1896b) noted the presence of ants and their eggs as well as other insect debris in the guts of some of the first specimens dissected. Winkel and Humphrey-Smith (1988) examined the gut contents of ten museum specimens and found that predatory ants *(Iridomyrmex* sp.) and seed-eating ants (Myrmeciinae) were well represented, as were termites, and traces of a range of other arthropods were also encountered. Seed material was also regularly encountered in the guts, but it is unclear whether these are intentionally eaten or incidentally ingested in pursuit of seed-eating ants.

Various food items have been presented to *N. typhlops* in captivity and large items are sometimes taken underground to be consumed. Captive animals seem partial to the eggs, larvae and pupae of insects such as ants, beetles and moths, but less so to the adult insects (Stirling 1891b; Corbett 1975; Howe 1975; Johnson & Walton 1989). *N. typhlops* have also been known to take centipedes, spiders and geckoes in captivity (M. Gillam, pers. comm.). These prey items spend much of their lives in burrows underground and may be preyed upon by marsupial moles there. Various Aboriginal informants have commented that marsupial moles eat insects, seeds and lizards, and fungi (Johnson & Walton 1989; Baker et al. 1993).

Life History

Virtually nothing is known about reproduction or population structure of marsupial moles. Their anatomy conforms to the normal marsupial pattern, except that the testes are internal and lie between the skin and the abdominal wall at about the level of the anterior edge of the pubic bones, and the pouch opens backwards and contains two teats (Spencer 1896a; Sweet 1907). A pouch may be present in both sexes, but is only slightly developed and rudimentary in the male (Spencer 1896a; Sweet 1907). Single and twin pouch young have been recorded but pouch young appear very rarely in museum collections, and the external characteristics of small pouch young have been described from only one individual (Wood Jones 1921). A pregnant female from Ooldea was found to contain six sub-terminal embryos (K. Aplin pers. comm.), suggesting a degree of embryonic wastage in *Notorycte*s. On examination of “a considerable number of female specimens caught at various times”, Spencer (1896a) though that the breeding season was likely to be in or about November.

It is not known whether marsupial moles build a nest or form permanent burrows. Given their underground locomotion, females would presumably have great difficulty moving about underground with sizeable pouch young. Backfilled tunnels of Itjaritjari are common in dunes of the northern Great Victoria Desert (see below), but tend to be similar diameter (JB unpublished) suggesting either that young follow adults or remain in a nest of sorts until they are adult size.

Dispersal

Dispersal by marsupial moles probably occurs underground and requires suitable sandy habitat for tunnelling. Marsupial moles are slow, clumsy and vulnerable above-ground, and it is unlikely that they would travel far. Nonetheless, above ground dispersal might enable marsupial moles to occasionally cross between dunes where the swale substrate is inhospitable for tunnelling.

Sex ratio

Of the 300 records of marsupial moles in Australian museums and fauna atlases, only 113 have been sexed and these show a bias toward females (47 males: 66 females). However, males and females are difficult to distinguish by external examination unless a distinct pouch is evident, indicating a female. Thus, a bias toward females is not surprising, especially considering the low proportion of specimens for which sex has been determined. The best indication of sex ratio is perhaps from specimens at the National Museum of Victoria, almost all of which originated from the collection by Spencer and Byrne on around Charlotte Waters between 1894 and 1916. Of these 84 records, 65 have been sexed (77%) and the sex ratio is even (32 males: 33 females).

Of these sexed individual, only 16 (6 male:10 female) were recorded with accurate dates that range from February to October, and these do not indicate any difference in the month males and females were collected on the surface although sample size is small.

Underground ranging behaviour

Marsupial moles have been considered to virtually swim through the sand, their tunnels collapsing behind them, but recent work has shown that they are more accurately regarded as tunnellers that back-fill as they move along. After a marsupial mole has passed through the ground the sand-filled tunnels remain and are visible in cross-section. These signs are being used to develop survey techniques and describe the underground habits of Itjaritjari (*N. typhlops*) in the Anangu-Pitjantjatjara Lands of SA (J Benshemesh, unpublished). These underground tunnels appear common in suitable dune habitat (2-6 tunnels per m^2 of vertical trench face), although the age of these tunnels vary and many may be several years old. While some tunnels have been recorded more than two metres below the surface, most occur between 20 cm and 100 cm from the surface and are typically twice as common in the top metre (where most prey may be expected) as below this. Itjaritjari are probably only vulnerable to predators, such as foxes, within 20 cm of the surface, but the scarcity of tunnels at shallow depths does not necessarily mean that Itjaritjari spends little time in this zone. Tunnels degrade faster near the surface than at increasing depth (JB unpublished) and the relative abundance of shallow tunnels may grossly under-represent the time spent by marsupial moles within reach of their predators.

Surfacing

Apart from recent sub-surface tracking studies, almost all information on marsupial moles has been derived from animals observed or caught on the surface. The surfacing behaviour has important implications for conservation because when marsupial moles are at or near the surface they are vulnerable to a range of predators, particularly foxes and cats. However, it appears that marsupial moles rarely come to the surface, even in areas where they are considered common by local Aboriginal people and where their signs are abundant underground. Surface trails of *N. typhlops* are distinctive and those examined in the Anangu-Pitjantjatjara lands have shown no obvious clues to suggest animals were foraging or meeting conspecifics, or that marsupial moles may socialise on the surface (JB unpublished). Pearson and Turner (2000) record an incident where two marsupial moles were on the surface within five metres of each other, although their trails did not intersect and there was no indication that the animals were involved in social behaviour. One Aboriginal informant has been reported stating that male and females meet on the surface in spring (Copley et al. 2003), and other anecdotal accounts also suggest that marsupial moles may breed in late winter (Maurice in Gara 1996), but the veracity of these accounts is uncertain.

Most surface signs are of individuals that travel only a few metres before returning underground. Occasionally, these visits are numerous and extensive and it is clear that animals have spent many hours wandering on the surface during which time they would be highly vulnerable to predators. Information from Aboriginal sources suggests that while marsupial moles may surface at any time of day or year, they are more likely to do so after rain and in the cooler seasons (Spencer 1896b; Bolam 1927; Russell 1934; Burbidge et al. 1988; Baker et al. 1993). The reason for this is unclear and may be related to respiration or other factors. In any case, if they surface more frequently after rain and in cool seasons, marsupial moles could be especially vulnerable to predators at such times.

The tracks of *N. caurinus* and *N. typhlops* differ and may be distinguished by experienced observers. When Aboriginal people from north-west WA have been shown tracks of Kakarratul and Itjaritjari, they recognise the former but appeared baffled by the latter, and conversely, Aboriginal people from north-west SA recognised Itjaritjari, but not Kakarratul (JB unpublished). Photographs of surface tracks may thus be valuable clues to the species that occur in an area, and especially in the broad areas of uncertainty between the known ranges of these species.

Identification of threats

PREDATION

Recent studies suggest that marsupial moles may be common prey items of larger mammalian predators, especially the introduced fox. Paltridge (1998) found remains of *Notoryctes* sp. in predator scats at five of her six sites in the Tanami Desert. Her study revealed that 10% of fox scats, 3% of cat scats and 5% of dingo scats contained signs of moles (n= 82, 111 and 59 respectively). Signs of marsupial moles have also been found in fox and dingo scats from the Anangu-Pitjantjatjara/Yankunytjatjara Lands (APYL) in SA (J Benshemesh, unpublished), and in other areas of the NT (Paltridge 2002), although not as frequently. For example in the APYL, of 504 fox, 303 dog and 71 cat scats collected over five years in areas where marsupial moles were known to occur, only 1.4% contained marsupial moles signs and there was little difference between predators, although signs were slightly more prevalent in fox scats (1.6%).

It is uncertain whether these predators take marsupial moles on the surface or dig them up, or indeed whether they are actually killing moles or taking dead animals. Dead or severely debilitated moles have been recorded on the surface on several occasions (Maurice in Gara 1996; Read 1998; Pearson & Turner 2000, JB unpublished) but it seems most likely that these predators prey upon living moles that are on or just under the surface. R. T. Maurice, who travelled widely in the Great Victoria Desert between 1897 and 1903, reported that local Aboriginal people were able to capture moles after hearing them when they were under the surface (Gara 1996), and larger mammalian predators may do likewise. On the surface, marsupial moles are also vulnerable to butcherbirds and corvids (Calaby 1996), birds of prey, snakes and goannas.

Other potential threats

There is very little information on the conservation ecology of marsupial moles, and factors that may threaten the species are largely unknown. Accordingly, a major thrust of this recovery plan is to examine the stability of populations as a necessary step towards identifying threatening processes. Apart from predation, other factors that may threaten marsupial moles on a landscape scale include:

- Changed fire regimes, and trampling and habitat changes caused by introduced cattle and burgeoning camel populations. Changes to fire and grazing regimes have the potential to greatly modify the vegetation of habitats, and thus the availability of invertebrate prey for marsupial moles. Large fires, especially when followed by drought, have the potential to cause widespread declines in potential prey items for marsupial moles.
- Larger roads, railways and pipeline trenches would probably hinder dispersal of marsupial moles and might genetically isolate populations that were previously continuous, potentially leading to deleterious effects for small, localised populations in the long term.

However, such major linear disturbances are uncommon in the sandy deserts and are unlikely to pose a serious threat to populations.

- Current predictions of climate change for Australia (Pittock & Wratt 2001) provide considerable cause for concern and projected changes in rainfall and temperatures, and concomitant changes in biota, might threaten marsupial moles over their entire range. However, modelling the effects of climate change on populations is not likely to be instructive at this stage because little is known about the climatic responses of marsupial moles. Moreover, little can be inferred about climatic constraints from distribution as available records suggest that marsupial moles occupy most of the available sandy habitats and do not appear to be constrained by climate as much as by substrate. Thus, there is little basis from which to construct meaningful models at this stage.

Populations and areas under threat

There is no information to suggest that any particular population of marsupial moles is under more threat than another.

Existing conservation research and management

Conservation actions currently underway:

- Research into the conservation ecology of Itjaritjari has been ongoing since 1999 in the Anangu Pitjantjatjara/Yankunytjatjara Lands (SA) by J Benshemesh in collaboration with traditional owners. Between 2001 and 2004 Earthwatch volunteers were involved. The work has focused on developing methods for survey, monitoring, and research using a range of traditional and novel techniques involving tracking, underground excavation, predator scat analysis, and geophone technology. Notable achievements include the development of rapid and reliable survey and monitoring techniques, and the application of these at various locations in APL as well as Mt Willoughby (SA), and at Andado, Deep Well, Uluru and Watarrka in the Northern Territory. These underground tunnels are often common in suitable dune habitat (2-6 tunnels per m^2 of vertical trench face), and the technique is highly efficient at detecting the presence of marsupial moles in an area. For example, while there has been only one confirmed record of marsupial moles within 100km of Watarrka National Park over the past century, in 2004 underground signs were detected in 28 of 36 trenches (each about 0.8 vertical m^2) (JB unpublished). One unresolved aspect of the technique is that the age of these backfilled tunnels is usually unknown. These techniques have also been disseminated to others, and have been successfully used by DEH (SA) to detect marsupial moles on the western edge of the Simpson Desert, as well as by individuals to detect marsupial moles in the central Great Victoria Desert (M Schulz pers. comm.) and in the Tanami Desert (S Bazzacco pers. comm.; J Holmes pers. comm.; R Paltridge pers. comm.). This work has been primarily funded by NHT, DEH (SA), Earthwatch Institute (USA), Nature Foundation (SA) and the Rio Tinto Aboriginal Foundation.

- A Mole Patrol project has raised awareness and the importance of reporting sightings of marsupial moles. Mole Patrol information kits have been distributed to teachers, mining companies, ecotourism operators, pastoral landcare and catchment management groups, 4WD tourists, field naturalist and NRM groups and other interested parties in the NT, WA, SA and Qld.

- The South Australian Museum (Dr S Donnellan and Dr S Fuller) have begun to examine the genetic differentiation of marsupial moles, following on from earlier morphological work (unpublished) by K Aplin and P van Oosterzee. The genetic work has focussed on using existing museum specimens, but new techniques have also been developed that enable marsupial mole DNA to be amplified from hair and skin fragments extracted from predator scats.

- Dr Bretan Clifford (NTPWS) has collated sand dune coverages across Australia in preparation for habitat modelling of the range of marsupial moles. This work is especially important for looking at discontinuity in habitat suitability that might relate to the different taxa and forms of marsupial moles, and for identifying new areas where marsupial moles may occur.
- On Aboriginal lands, several small-scale fauna survey and monitoring projects involving traditional owners have collected data on surface signs of a range of species, including marsupial moles, at various sites in the Great Victoria, Great Sandy, Tanami and Gibson Deserts. Apart from providing distribution records of marsupial moles, these projects are important in providing work for people on their traditional lands, and for maintaining traditional tracking skills.
- Dr Rachel Paltridge has been working on predator-prey interactions in the Tanami Desert (NT) and has collected data on the frequency of marsupial mole fur in predator scats. She has also been working with Aboriginal people in the Tanami and recorded marsupial mole tracks on numerous occasions.
- Monitoring sites for Itjaritjari have been established at Uluru Kata-Tjuta NP (45 trenches in 6 areas) and Watarrka NP (36 trenches in 6 areas), and at simulated molehole trenches have been installed at both Ulura and Watarrka to measure the decay of backfilled tunnels. This work was initiated as part of this recovery plan.
- The management of fire, and feral predator baiting, throughout the sandy deserts might have benefits for the conservation of moles.

Part D. Objectives, Criteria and Actions

Recovery objectives and criteria

Overall objectives

Downlist species from endangered to a lower category based on knowledge of species and its conservation status.

Specific Objectives

1. Describe the distribution of the distinct lineages of marsupial moles
    - Resolve the taxonomy and determine appropriate management units.
    - Describe the distribution and provide indices of the abundance of the distinct lineages of marsupial moles
2. Determine trends in populations
    - Determine population trends of the distinct lineages of marsupial moles
3. Provide preliminary information on threats
    - Provide preliminary information on the threat of fire, introduced predators such as foxes and cats, and grazing.
4. Learn about the ecology
    - Describe activity patterns and ranging behaviour
    - Obtain ecological information from Aboriginal elders
    - Examine the diet, reproductive state and general condition of surfacing animals.
    - Prepare for captive individuals brought to Desert Park
5. Manage the recovery process
    - Coordinate and manage the recovery process
    - Downlist species from endangered to a lower category of threat

Performance criteria

The following performance criteria relate to the objectives above:

1.1 Likely distribution of marsupial moles is described based on physical and climatic data

1.2 Actual distribution is described and compared with historical records

1.3 Benchmark abundance indices established

1.4 Predator scats are collected

1.5 Genetic lineage of marsupial moles at strategic locations is determined

1.6 Land managers invited to become involved

1.7 Actual population sizes estimated

2.1 Monitoring manual produced

2.2 Population trends for distinct populations are quantified from at least 2 locations in each of the three genetically distinct populations

3.1 Taxonomy is resolved

3.2 Population units appropriate for management are described

4.1 Effect of grazing is quantified

4.2 Effect of fire is quantified

4.3 Effect of predator removal is quantified

4.4 Seasonality of predation is described

4.5 Seasonality of marsupial moles surfacing is described

4.6 Significance of predation is assessed in light of general ecology

5.1 Activity cycles described

5.2 Underground rate of movement described

5.3 Decay rates of underground signs is described

6.1 Interviews recorded, translated, and archived

6.2 Ecological information extracted

7.1 Museum specimens examined in regard to diet, reproductive state and general condition

8.1 Suitable enclosures filled with dune sand and encouraged to re-cement

8.2 Detailed plan for managing marsupial moles in captivity developed

9.1 Recovery process is coordinated effectively

9.2 A recovery team is established

10.1 Submission made to reclassify taxa to lower category if appropriate

The relationship between objectives, performance criteria and actions is shown in Appendix 2.

Recovery Actions

The following actions are described from a national perspective. Some of these actions involve fieldwork over vast distances and are costed as single actions even though they could be subdivided and implemented as a series of related parts. For most actions described below, details of how each action was costed is provided to facilitate subdivision of the actions.

Action 1 Distribution of marsupial moles

Action 1a Map and model potential habitat

Justification

The distribution of marsupial moles is poorly known, but their potential habitat can be mapped at fine resolution using known habitat requirements, existing remotely sensed data, digital cartography (GIS), and climate data (BIOCLIM). These data will provide the basis for a testable model of the likely distribution of the species and greatly assist conservation by guiding the survey and monitoring efforts.

Methods

Available data sets that describe the likely physical requirements of each form or taxa of marsupial moles will be collated. This information includes spatial data such as sand cover, dune size and patterning, vegetation classification, and radiometric imagery (Table 3). BIOCLIM analyses will define the climatic envelope in which each form or taxa of marsupial moles occur. These data sets will be combined and tested against the existing distribution data to provide:

1) an assessment of the relative importance of each variable,

2) an indication of areas where the taxa/forms of marsupial moles may divide or be sympatric, and

3) an initial set of predictions of where marsupial moles may be found

Radiometric imagery is not available for all of Australia, but coverage is available for most of the NT and northern SA and this should be sufficient for assessing the utility of this data type. Existing continental scale vegetation maps will be used to avoid differences in classification in different regions. Classification of vegetation by Modis imagery may also be useful, and this imagery may also identify sub-surface paleo-drainage patterns that might be important as past or current barriers to the range of distinct genetic populations.

Stakeholders

DIPE or consultant

Costs ($000's)

Yr1	Yr2	Yr3	Yr4	Yr5	Total
10.0	0	0	0	0	10.0

Action 1b Survey underground signs of marsupial moles at strategic localities

Justification

Understanding the distribution and abundance of marsupial moles is critical to determining their conservation status. The existing records of marsupial moles do not adequately define the distribution of species, and where records are available these are often from many decades ago and there is no recent information to confirm that the species still occurs in the area. A strategic approach to survey will greatly increase our understanding of the distribution and abundance of marsupial moles, landscape features that provide continuity or barriers to populations, and the spatial relationship between the taxa. This work will also provide a firm basis for subsequent monitoring (see below).

Methods

Field surveys will be guided by historical records and the results of Action 1a (map and model habitat) to:

a) Determine whether marsupial moles still occur in the vicinity of historical sightings,
b) Describe the current range of marsupial moles by conducting surveys at key locations,
c) Identify areas that may geographically separate genetically distinct populations/taxa,
d) Assess the degree to which marsupial moles use river flats and sand plains, in contrast to dunes, especially where these might provide continuity between otherwise geographically separate populations, and
e) Test the veracity of the model developed in Action 1a.

A new technique has been developed that enables reliable and relatively rapid survey and is based on revealing the backfilled tunnels made by the animals' underground. The technique has been used to assess Itjaritjari distribution in the Anangu-Pitjantjatjara/Yankunytjatjara Lands, and at Uluru and Watarrka National Parks, and would probably work with Kakarratul as well. The technique is efficient and quantitative, and with appropriate controls would allow comparisons between areas, but is more rapidly used qualitatively to detect the presence of marsupial moles. The species/forms of marsupial moles cannot be distinguished by this technique.

Specific sites for surveys will be selected in light of the findings of Action 1a and in consideration of Actions 1c and 1d, and Action 2 (monitoring) to maximise the benefits of the fieldwork in engaging local participation. It is expected that 6 fieldtrips each of a fortnight duration over a period of two years would be required to provide data to determine the extent of the range of marsupial moles.

Stakeholders

NT: DIPE, CLC, possibly Birds Australia (Newhaven), Newmont (The Granites)
SA: DEH, APYLM and other Aboriginal Land Management organisations
WA: CALM, NLMU and other Aboriginal Land Management organisations and possibly Birla (Nifty)
QLD: EPA, University of Sydney (Ethabuka)
NSW: NPWS

Costs ($000's)

Funding is required to cover salaries, vehicle and travel costs.

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Scientific Salaries (1)	54.5	54.5	0	0	0	109
Vehicles (1)	12.0	12.0			0	0
Traditional Owner consultations (1)	6.0	6.0			0	0
Total	72.5	72.5				109

Notes on Costing: 1) Based on 3 field trips per year, each 2 weeks plus 2 weeks preparation and 4 weeks analysis and report= 24 weeks/yr. For 2 people (60k +40k) plus 18% oncost= 54.5k. 2) Rental about 8k for 3 trips, plus 4k fuel and travelling costs= 12k. 3) 40 days of Traditional Owner consultations per year @$150/day.

Action 1c Collect predator scats to obtain marsupial mole DNA at strategic localities

Justification

While three genetically distinct populations of marsupial moles have been identified, including the two currently recognised species, the distribution of each of these is only coarsely known. However, this information is crucial for management as each of these populations will need to be managed as separate entities if differences are found in the conservation status of each. Specimens of these populations are extremely difficult to obtain due to the elusive nature of marsupial moles, but new techniques have shown that marsupial mole DNA can be obtained from the scats of predators such as dogs, foxes and cats. Information on the distribution of the individual taxa/forms can thus be obtained most reliably by collecting large numbers of predator scats. The frequency of marsupial mole signs in predator scats will also provide information on predation rates and thus the degree of threat.

Methods

Predator scats will be collected by employing local traditional owners or contractors, especially in areas thought to represent genetic boundaries. The occurrence of marsupial moles remains in predator scats typically varies between 1-5% in areas in which marsupial moles are known. However, scats of foxes and dogs are usually abundant along rarely used tracks and are easy to collect, and marsupial mole remains within scats are easily and inexpensively identified. Scats of cats are usually more difficult to obtain, but are equally valuable. Scats will preferentially be collected in late winter or spring, and in the weeks following heavy rains, when marsupial moles are said to be most likely to be on the surface and vulnerable to predation.
The success of this project will require coordination between the geneticists, who will determine the regions from which DNA samples would most profitably be obtained, and the land managers primarily on Aboriginal lands.

Stakeholders

Genetics: SAM
Fieldwork NT: PWSNT; CLC; Parks Australia North
Fieldwork SA: DEH; APYLM and other Aboriginal Land Management organisations
Fieldwork WA: CALM; NLMU and other Aboriginal Land Management organisations

Costs ($000's)

Funding is required to cover salaries of collectors, sorting samples, and genetic analysis. Budget based on total 1000 scats/yr from 5 sites. Sites may change from year to year, depending on results of genetic analysis.

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Equipment (1)	3	0.5	0.5	0.5	0.5	5
Collect (2)	10	10	10	10	10	50
Process (wash and separate marsupial mole material) (3)	4	4	4	4	4	20
Genetic identification of 15 specimens per year(4)	6.2	6.2	6.2	6.2	6.2	31
Total	23.2	20.7	20.7	20.7	20.7	106

Notes on Costing: 1) 5 palms-gps units at 0.5k each, paper scat bags and postage. 2) 2 aboriginal people at $150/d each should be able to average 40 scats per day. Thus 1000 scats would cost a maximum 7.5k to collect, plus 2.5k vehicle costs ($100/day in field). 3) Based on flat rate of $4 per sample (excludes microscopic hair analysis). 4). $2700 materials plus $3500 for 3wks salary (@50.5k/yr +18% oncost). Assumes in kind from SAM for lab and supervision/report by senior scientist (about $1750)

Action 1d Solicit records and specimens and otherwise engage landholders and land managers.

Justification

Most records and specimens of marsupial moles have originated from traditional owners and pastoralists, and it is likely that most future specimens will similarly depend on the goodwill and involvement of such people. The importance of specimens, sighting records and photographs should thus emphasised to landholders and land managers, and clear and simple instructions should be made available to them regarding collecting information about signs and specimen.

Methods

Interpretive materials on marsupial moles and the recovery project will be produced and targeted to both Aboriginal and Western communities and schools. "Mole Patrol" information kits have already been produced and mailed to teachers, mining companies, ecotourism operators, pastoral landcare and catchment management groups, 4WD tourists, field naturalist and NRM groups and other interested parties in the NT, WA, SA and Qld. However, these kits were targeted at people with a high level of literacy. The current action will focus on providing and distributing information in the form of story-books, posters, PowerPoint presentations and radio segments in Aboriginal languages of the central sandy deserts. The distribution of Mole Patrol information to interested parties will also be continued.

Stakeholders

TSN, CLMA, CLC, NLMU, APYLM, and other Aboriginal Land Management organisations, possibly also State/Territory Departments of Employment and Education, CAAMA Radio

Costs ($000's)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Salary (1)	3.6	0.8	0.8	0.8	0.8	6.8
Translation (2)	2.7	0	0	0	0	2.7
Printing and distribution to communities	3.7	1.2	1.2	1.2	1.2	8.5
Total	10	2	2	2	2	18

Notes on Costing: 1) 1st year 4 weeks salary @ 40k plus 18% oncost= 3.6k, subsequent years= 1 weeks salary @ 40k plus 18% oncost= 0.8k. 2) Translation services @450/day for a total of 6 days = 2.7k.

Action 1e Inspect Pipeline trenches for signs of marsupial moles

Justification

Continuous trenches are occasionally dug through potential marsupial mole habitat in order to lay pipes for gas, oil and water to service the mining industry and communities. These trenches are often left open for several days and provide an opportunity to detect marsupial moles signs underground, and thus provide information on the distribution of these animals.

Methods

Environmental impact monitoring of open pipeline trenches already occurs, and examination of the walls of trenches will not add significant costs to this process. An illustrated guide to detecting underground signs of marsupial moles will be produced, and a sampling strategy will be developed in conjunction with environmental consultants regularly employed to monitor the impact of open trenches.

Stakeholders

APIA; CALM, OE in WA; DEH, PIRSA in SA; DIPE, DBIRD in NT

Costs ($000's)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Develop guide	2					2

Action 2 Monitor population trends

Justification

Populations of marsupial moles must be monitored in order to establish trends, and to provide the data required for an accurate assessment of their conservation status. While monitoring has not been possible in the past, new techniques have been developed and will provide information on the activity of marsupial moles in selected areas through time.

Methods

Monitoring will involve similar methods to survey of underground signs, but with some additional components. These underground signs (ie. backfilled tunnels) persist in the soil profile for years, and their decay is probably influenced by rainfall and depth. As it is unclear whether marsupial moles avoid disturbed sand, new trenches should be excavated for each monitoring effort, although these should be arranged to sample the same general area and microhabitat.

Monitoring sites will be selected from survey sites (Action 1b) and with regard to accessibility to provide a representative sample of each genetically distinct population, and will occur biennially at each site. Strategically important areas include mining sites, national parks, reserves and tourism centres because the existing infrastructure would facilitate monitoring and increase opportunities for in-kind contributions, local involvement and ownership. Other strategically important areas include sites at which introduced predators (foxes and cats) are controlled as marsupial mole population trends in these areas may demonstrate the effects from these predators, especially in comparison with similar areas where predators are not controlled. Monitoring marsupial moles by their underground signs is a new technique and, to fully understand and develop its application, monitoring should be associated with two avenues of further study. Firstly, the rate at which tunnels decay needs to be measured in order to interpret results and understand the frequency with which monitoring should occur. This can be achieved most efficiently by routinely examining the decay of real and simulated marsupial mole signs previously made in the walls of trenches, and correlating these results with rainfall and soil moisture (using dataloggers). Secondly, it will be necessary to understand, and where possible control, the variability between recorders due to different skill levels, as well as variability from environmental sources. This variability will make trends in populations more difficult to detect. Careful training and perhaps calibration may reduce the variability in results amongst recorders.

An illustrated monitoring manual will be produced to disseminate techniques, and local involvement of Departmental staff and volunteers will be encouraged with a long-term view of local ownership of the monitoring sites. Funding will be required for a consultant to develop the monitoring manual, and for ongoing monitoring salaries and transport.

Stakeholders

NT: PWSNT, Parks Australia North (Uluru-Kata Tjuta), and possibly Birds Australia (Newhaven), Newmont (The Granites), Voyagers Hotels and Resorts (Yulara)
SA: DEH, APYLM
WA: CALM, and possibly Birla (Nifty)

Costs ($000's)

Budget based on total of 5 monitoring sites across Australia.

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Monitoring Salaries (1)	27.5	0	27.5	0	27.5	82.5
Travel (2)	15	0	15	0	15	45
Simulated molehole trenches (3)	16	0	0	0	0	16
Monitoring instruction (4)	5	0	0	0	0	5
Total	63.5	0	42.5	0	42.5	148.5

<u>Notes on Costing</u>: 1). Monitoring trenches dug and inspected will take 6 days at each site, plus another 2 days for travel, totalling 8 field days @400/d = 3.2k per site. It is anticipated that local staff/volunteers will also be available at most sites. Preparation and report 2 weeks per site @50k/yr plus 18% = 2.3k. (5.5k= 27.5 for 5). 2) Estimated to average 3k for a vehicle incl. fuel and travel for each 8d field trip. (15k for5) 3) Establish simulated molehole trenches at each monitoring site would an extra 3d per site @400/d= 1.2k in the first year, plus soil moisture dataloggers (2k each site), totalling 3.2k per site (16k for 5). Sets of 3 simulated molehole trenches have already been set up at four sites (Uluru, Watarrka and at 2 sites in the APYL), and if these sites were used for the monitoring program some setup costs could be reduced.

Action 3 Resolve taxonomy

Justification

The taxonomy and distinctiveness of different populations of marsupial moles is unclear, but needs to be resolved so that appropriate units for conservation and management can be identified. This work is of high significance for understanding the systematics and conservation status of marsupial moles. The project will also develop a suite of molecular markers and non-invasive sampling techniques to enable genetic studies of these rarely encountered and elusive taxa without the need to directly capture marsupial moles.

Methods

Mitochondrial DNA and morphology is currently being used to examine the distinctiveness of marsupial mole populations represented in museums. This analysis is limited in scope and needs to be expanded to include more DNA sequence data for each specimen and better representation of samples from the known range of marsupial moles, especially areas where the forms may be in contact or sympatric. Morphological analysis of the differences between the three forms currently identified also has to be completed, and nomenclature of existing museum specimens updated as appropriate. Obtaining many new entire specimens from the field is unlikely, but genetic samples can be obtained from the remains of marsupial moles in predator scats (see Action 1c above), and possibly from hair shed within the animals' backfilled tunnels. This would provide information on the genotypes of the marsupial moles that occur in the area, as well as the sex of the animals preyed upon which is relevant to their conservation ecology. The information on the distinctiveness of populations would then be related to Action 1a data to determine the geographic separation of forms.

Stakeholders

SAM

Costs ($000's)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Salaries: Morphology (1)	5					5
Genetics (2)	18.5					18.5
Materials (3)	8					8
Total	31.5					31.5

Notes on Costing: 1). 4 weeks @60k plus 18% oncosts. 2) 13.75k for 12 weeks researcher @50.5k plus 18%=, plus 4.75k for 3 weeks senior scientist @69.8k plus 18%. 3) 4k for nuclear markers 4k plus for mitochondrial DNA (50 loci @$80 each).

Action 4 Assess the threats imposed by fire, grazing and predation, particularly by introduced foxes and cats

Action 4a Conduct pilot studies on the effects of predators, fire and grazing on marsupial moles abundance

Justification

Threats to marsupial moles are largely unknown. Introduced predators are implicated as a threatening process due to the occurrence of marsupial moles remains in their faeces, although the degree to which predators impact upon marsupial moles populations is unknown. Similarly, fire and grazing may influence marsupial moles numbers by modifying habitat and ultimately food sources, and stock may also trample substrate, although the degree to which these factors impact on marsupial moles abundance is unknown. This action will compare indices of the abundance of marsupial moles in areas that are differentially affected by introduced predators, fire and grazing as a means of providing correlative information on the likely effects of these factors.

It should be noted that this study is intended as a preliminary examination of these complex issues in order to assess their gross effects on marsupial moles. Considerably more elaborate studies would be required to more fully understand the effects of predation, fire and grazing, but such a commitment is not warranted at this stage.

Methods

Underground signs will provide an index of the abundance of marsupial moles in different areas. The effect of foxes and cats will be measured by comparing marsupial mole abundance in and out of fenced exclosures where foxes, cats and dogs have been removed. A suitable exclosure has already been established at Watarrka National Park (NT), and another is planned at Uluru- Kata Tjuta National Park. In both cases exclosures are one kilometre square and contain suitable habitat for marsupial moles (*N. typhlops*, southern form). Biennial monitoring of marsupial mole tunnels inside and outside these enclosures will provide preliminary information on the effects of these predators on marsupial moles abundance. Monitoring, rather than one-off survey is advisable because this will provide a before/after contrast (temporal control), as well as the in/out contrast (spatial control). The exclosures at Watarrka and Uluru will not restrict the movements of marsupial moles, and it is possible that dispersal of marsupial moles will mask any positive effects of removing predators. For this reason it will be desirable to locate monitoring sites in the centre of exclosures, and to interpret the results of this experiment in light of the ranging habits of marsupial moles (Action 5) as well as habitat changes that may occur in the exclosures. Whereas an increase in marsupial mole tunnels inside the exclosures relative to numbers outside would suggest predators have the potential to suppress marsupial mole numbers, a lack of difference should not be regarded as evidence that predators have no impact.

Comparing the abundance of marsupial moles tunnels in areas that have been subjected to fire and grazing will provide preliminary information on the overall effect of these factors on the species. In this case, one-off survey would be sufficient to detect gross differences in marsupial moles abundance in areas burnt or grazed compared with similar and nearby areas not subjected to these factors. Marsupial mole tunnels may persist underground for several years and thus provide an index of the accumulated abundance of the species over this timeframe, a fact that will be taken into consideration in the design of this study and in particular in the selection of age classes. The contrasts (recently burnt/unburnt, and grazed/ungrazed) will be appropriately designed and replicated at least six times to provide statistical validity.

Apart from changes in the activity of marsupial moles, differences in the number of underground signs between fire age classes, or the grazed/ungrazed contrast, might be due to increased compaction in the case of grazing, and increased infiltration of water through the soil in the case of burnt habitats. Where possible, these factors should be measured in the field. If significant differences in marsupial mole signs are detected between burnt/unburnt sites, or grazed/ungrazed sites, the difference in the decay rate of tunnels at these sites will be examined biennially by measuring the persistence of simulated moleholes at a selection of these sites.

Stakeholders

NT: DIPE, Parks Australia North (Uluru-Kata Tjuta), Desert Knowledge CRC and possibly Birds Australia (Newhaven),
SA: DEH, APYLM and other Aboriginal Land Management organisations, and
WA: CALM, NLMU and other Aboriginal Land Management organisations.

Costs ($000's)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Fire (1)	20 (1)		5 (2)		5 (2)	30
Grazing (2)	20 (1)		5 (2)		5 (2)	230
Predation (3)	6 (3)		5 (2)		5 (2)	11
Total	46		15		15	76

Notes on Costing: 1). 6 trenches (half burnt, half unburnt) at 8 sites= 48 trenches. With travel and reading trenches this may take up to 13d total in the field. Setup of 6 simulated molehole trenches (3 Bnt + 3 Unb)= 6d. Total= 19d field @400/d =$7600, plus 2 week prep and 3 weeks report @60k/yr plus 18% = $7000. Total salary= 14.6k. Vehicle=3.5k plus 2k fuel and travel costs= 5.5k. Total initial 14.6k+5.5k= 20 k. 2). Read 6 simulated molehole trenches = 5 d field plus 1 week preparation and 1 week report= 3k, plus vehicle for 6 days= 2k incl. fuel and travel= 5k. 3). Total salary= 2.4k (6d field @400/d), plus vehicle 2.2k (1.4k plus .8 fuel), plus 1 week report (@60k+18% oncosts)=1.4k. Total = 6k.

Action 4b Determine the seasonality of surfacing by marsupial moles and the relative abundance of predators and other animals

Justification

Regular tracking at the same locations over several years will provide information on the times of year that marsupial moles are most likely to surface, and thus become vulnerable to predation. Tracking will also provide information on the abundance of predators and other introduced and native animals.

Regular scat collections at the same locations several times a year and over several years will provide information on the times of year that marsupial moles are most vulnerable to predation, and the influence of rainfall on predation.

This action will link in with recovery work on other species and a multi-species approach is strongly recommended.

Methods

Local traditional owners or contractors will be employed to regularly track animal signs in at least one location. An effort will be made to standardise the search effort and restrict searching to in predetermined areas or transects. Tracking should be conducted at least four times a year to sample the seasons equally, but more frequent samples would be an advantage. This action would suit traditional owners who are local to areas of interest and have good tracking skills, or young people who are keen to learn tracking skills from their elders. Issues of literacy, data standardisation and collation can be solved by using handheld computers linked to GPS units, and software specifically designed for this purpose (e.g. Cybertracker; see www.cybertracker.co.za). The tracking program will operate for five years.

Local traditional owners or contractors will be employed to regularly collect predator scats at least four times a year along transects. Predator scats are usually abundant along rarely used tracks, and marsupial mole remains within scats are easily and inexpensively identified. An effort will be made to collect all scats along these transects so each scat can unambiguously be ascribed to a seasonal interval. The influence of rain on predation rates will be determined by analysis of the frequency of marsupial mole signs in scats in relation to local rainfall.

Stakeholders

NT: PWSNT; CLC; Parks Australia North,
SA: DEH; APYLM and other Aboriginal Land Management organisations, and
WA: CALM; NLMU and other Aboriginal Land Management organisations.

Costs ($000's)

Funding is required to cover salaries for TOs, equipment, and for developing and maintaining a cybertracker database. The budget is based on six locations at which a total of about 1000 scats are collected per year.

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Equipment (1)	5	0	1	0	0	6
Salaries and operating for TOs (2)	29	29	29	29	29	145
Process scats (wash and separate marsupial mole material) (3)	4	4	4	4	4	20
Developing and maintaining a cybertracker database, training in its use, and annual data report (4)	7.5	2.7	2.7	2.7	2.7	18.3
Total	45.5	35.7	36.7	35.7	35.7	189.3

Notes on Costing: 1) 6 palms-gps units at 0.5k each (incl. all necessary software), plus 6 digital cameras at 0.3k each. 2) estimated as $100/ person/day top-up for 2 people for 4 days at 6 locations, 4 times per year. Operating estimated as $100 per day for vehicle incl fuel. 3) Based on flat rate of $4 per sample (excludes hair analysis). 4) Based on 4 weeks work (@60k/yr plus on-costs) in the 1st year plus 2k travel, and 2 weeks thereafter with no travel.

Action 5 Describe the activity and ranging behaviour of Itjaritjari

Justification

An understanding of the activity patterns and ranging behaviour of marsupial moles is essential for their conservation, yet nothing is known of these basic aspects of behaviour from free-living animals. In particular, methods of assessing the abundance of marsupial moles are crucial for both survey and monitoring. A study in the Anangu-Pitjantjatjara lands of SA has provided a number of insights into the ecology of *N. typhlops* and developed two new techniques for assessing the abundance of marsupial moles based on their underground signs, and the sounds they make as they tunnel. While measuring underground signs is currently the most efficient way of conducting surveys, there are still questions regarding the rate of decay of tunnels that need to be addressed in order to interpret survey and monitoring results. Geophone technology has also been developed to track marsupial moles underground, and automatic systems have been built but not yet deployed. This technology provides an opportunity to describe the activity budgets, ranging behaviour and rate of tunnelling which are crucial data for converting the abundance of tunnels to estimates of population size. This work should be continued both to describe the underground habits of *N. typhlops*, and because development of this technology may lead to cost effective methods of automatically detecting marsupial moles and measuring their abundance in remote areas.

Methods

Researcher will determine the best approach to provide the following information:

- Diurnal and season activity budget and cycles
- Average rate of movement in different seasons
- Decay rates of underground signs in different soil conditions

This information will be collected and used to gain a better understanding of the ecology of marsupial moles, and specifically to enable estimates of abundance and population density to be developed. This work will involve developing software that enables 1) recognition of marsupial mole sounds from geophone signals, and 2) triangulation of the location of these sounds within a grid of geophones. The ability to automatically recognise marsupial moles using geophones would potentially be of great value for monitoring of marsupial mole abundance, and the researcher will report the feasibility and likely costs of such technology to the recovery team.

Stakeholders

Universities, DEH (SA), APLYM, DIPE.

Costs

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Support research and report [1]	23.6	23.6				47.2
Signal processing consultant [2]	7.5	7.5				15
Operating (vehicle plus expenses) [3]	6	6				12
Total	37.1	37.1				74.2

Notes on Costing: 1) 16 weeks @60k plus 18%= 21.8k plus 14 d in field @additional $130/d=1.8k. 2) Signal processing consultant @500/d for 15 d= 7.5k. year. 3). 4 field trips/yr of 5d duration= 6k for vehicle including fuel.

Action 6. Obtain ecological information from Aboriginal elders

Justification

The traditional knowledge of Aboriginal peoples about their environment is extensive and it is important for the conservation of marsupial moles to tap into this while it is still available. It is likely that new and important insights into the species will be obtained from detailed discussions with such people. This knowledge includes ecological knowledge, personal experience, and mythological knowledge in the form of stories. In particular, older Aboriginal people who walked the country in their youth often have a perspective on rarer events, such as surfacing by marsupial moles, that would take many years of study to reproduce. It should be emphasised that the opportunity to collect such traditional information about marsupial moles is rapidly diminishing due to the ageing population and will not be present in years to come.

Methods

Knowledgeable Aboriginal people will be located with the assistance of local land councils, anthropologists and other sources and invited to be interviewed to record their knowledge about marsupial moles. In the Anangu-Pitjantjatjara Lands, these interviews are recorded on minidisk or digital video and while the interviewer speaks in English (which is broadly understood), the interviewee is encouraged to answer in their own language so that the nuance of their information is preserved. The recordings are then concisely translated in the form of an index, and any potentially useful ecological information translated in full. While interviewees are encouraged to talk on any issue regarding marsupial moles, they are prompted by photos and a set of six standard questions regarding surfacing behaviour:

- When do marsupial moles occur on surface? (ie. winter/summer, dry/wet, hot/cold, night/day)
- What sort of country do marsupial moles occur in?
- Where and when have you seen them?
- Why do they come to the surface? (m/f)
- Are the marsupial moles on the surface healthy or sick?
- Do they come to the surface alone, in pairs, or in groups?

Ecological interviews regarding a range of species have previously been conducted with the involvement of translators by Uluru Kata-Tjuta National Park (P. Hookey, pers. comm.) and DEH SA (P Copley pers. comm.). However a more detailed and goal orientated approach is needed to clarify what Aboriginal people have witnessed in regard to the surfacing behaviour of marsupial moles.

Recordings of this nature will be regarded as copyright to the interviewee and relevant community or council, and permission sought to extract ecological information. Also, any restricted information (eg. “not for men”, etc) will be identified in the recording and on the labels. All recordings will be lodged in appropriate anthropological archives (eg. Ara Irititja archive for Pitjantjatjara/Yankunytjatjara).

Stakeholders

CLC, APYLM, NLMU, and other Aboriginal Land Management organisations.

Costs ($000s)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Informant wages (1)	5	5				10
Translator/interpreter wages (2)	15	15				30
Operating (3)	8	8				16
Total	28	28				56

Notes on Costing: 1) 40 person days @$125/d=5k. 2) 20 days of wages $500/d in field=10k, plus transcription and report 5k. 3). 4 field trips/yr of 5 d duration= 8k for vehicle incl fuel and expenses

Action 7 Refine knowledge of diet and determine sex, reproductive state and general condition from museum specimens

Justification

The ecology of marsupial moles is poorly known, but some important ecological information could be obtained by analysis of museum specimens. In particular, the diet of marsupial moles has so far only been examined from ten specimens (Winkel & Humphrey-Smith 1988) and many more specimens need to be examined in order to refine this knowledge and inform field studies. Almost all specimens in museums have been obtained from the surface, and knowledge of the general health and sex of these animals is important both for understanding surfacing events and for assessing the significance of predation.

Methods

Marsupial mole diet will be analysed by microscopic exanimation of gut contents of museum specimens. In many cases the sex of specimens can only be determined by internal examination. General body condition will be assessed by fat storage, weight (where possible), parasite load and tooth wear. A pilot study will also examine the feasibility of determining diet from molecular analysis of gut or scat contents, which may more reliably identify prey whose remains are not easily identifiable by microscopic techniques.

Stakeholders

NTMU, SAM, WAM

Costs

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Salary (1)	13.6					13.6
Pilot genetic analysis of gut contents (2)	6.4					6.4
Total	20					20

Notes on Costing: 1) 12 weeks @40k plus 18%= 13.6k. 2). DNA extraction, PCR cloning and sequencing, and four weeks technical salary (@40k plus 18%) to genetically process four gut contents.

Action 8. Prepare for captive individuals

Justification

An understanding of marsupial moles ecology and reproduction would be greatly assisted if there were a captive population. While it is not recommended that an attempt be made to capture a marsupial mole, the preparation of appropriate captive conditions would be advantageous for an already captured animal and increase the chance of learning about its habits and requirements. *N. typhlops* are occasionally captured by aboriginal people and offered to wildlife authorities. In the past, such animals have not lived long, probably due to a combination of stress and inappropriate captive conditions that have been prepared in haste. However, the likelihood of keeping a marsupial mole alive and well would be greatly increased if captive conditions closely mimicked those in the field, and appropriate food was made available (this has not been the practice in previous attempts to keep marsupial moles in captivity).

Methods

The Alice Springs Desert Park is the ideal location for keeping marsupial moles in captivity. The park is central to the range of marsupial moles and is thus climatically suitable, a variety of live foods are available for feeding other animals, and there is a high level of expertise regarding captive populations.

Four large circular tubs (about 2.5m diameter by 1m deep) have already been set aside by the Alice Springs Desert Park for preparation as a marsupial moles enclosure. These will be filled with dune sand of a consistency similar to that in which marsupial moles occur (in terms of particle size distribution and pH). Management of the enclosure will aim to mimic the natural environment of marsupial moles. In particular, thorough drainage of the sand mass will be provided, the light cementation of sand that is characteristic of stable dunes will be promoted by a series of wet-dry cycles, and sand temperatures will be monitored and manipulated as required.

A captive management plan will be produced by ASDP to guide all aspects of the preparation and development of the enclosures, release of a marsupial mole into the enclosure and subsequent management.

Stakeholders

ASDP

Costs ($000s)

ASDP will cover on-site costs, but funds will be required to develop a plan for the preparation of the enclosure and for subsequent management

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Document plan of preparation of enclosure and subsequent management	4.0					4.0

Action 9a Co-ordinate the recovery process

Justification

The actions described will occur over a vast area and involve a wide range of people and organisations. Implementation of this plan will benefit from a part time coordinator who will facilitate communication between stakeholders, provide training where needed, and .

Methods

A part time coordinator will be employed to:

1) Facilitate communication between stakeholders, especially between Aboriginal fieldworkers and lab based scientists (eg. actions 1c, 1d, 4b),
2) Provide training to fieldworkers in data collection processes, and in the use of equipment (such as GPS and Cybertracker),
3) Develop processes for the handling of data to ensure that all data collected in the field is lodged in appropriate databases, and that simple reports describing these data are routinely provided to fieldworkers and supporting organisations,
4) Ensure that information that arises from actions in this plan is made available to the recovery team within a reasonable period of time.
5) Facilitate communication between recovery teams and explore opportunities for common ground and joint actions. In particular, actions involving tracking and collection of predator scats have relevance and application to other threatened species recovery and a multi-species approach is strongly recommended.

Costs ($000s)

A declining workload for the coordinator is anticipated over the duration of this plan for two reasons. Firstly, the workload of a coordinator will depend on the schedule of implementation and is greatest in the first year of this plan. Secondly, processes put in place during the first year will lessen the coordinators role thereafter.

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Coordinator salary [(1)]	22.7	10.9	7.3	3.6	3.6	48.1
Travel and other expenses	6	4	2.5	2	2	16.5
Total	28.7	14.9	9.8	5.6	5.6	64.6

Notes on Costing: 1) 25, 12, 8, 4, and 4 weeks work for years 1-5 respectively @40k plus 18%.

Action 9b Manage the recovery process through a recovery team.

Justification

A recovery team containing people of relevant qualifications and interested parties is the appropriate body to oversee implementation and review this recovery plan.

Methods

The recovery team will meet every 12 to 18 months and consist of representatives of funding bodies, land management agencies, other land managers, the community and others with relevant expertise or interest. Organisations that will be represented include Conservation and Land Management (WA), Ngaanyatjarra Land Management Unit (WA), Department of Environment and Heritage (SA), Anangu-Pitjantjatjara Land Management (SA), Dept Infrastructure, Planning and Environment (NT), Central Land Council (NT), Alice Springs Desert Park (NT), Centralian Land Management Association (NT), Parks Australia, and Threatened Species Network (WWF) (this list is not comprehensive).
The recovery team will oversee the implementation of this plan and review progress of the program in the fifth year of the plan. If required, a funding submission will be made to rewrite the plan at the end of five years.

Costs ($000s)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Travel assistance	2	2	2	2	2	10

Action 10. Downlist from endangered to lower category

Justification

If species/lineages of marsupial moles are widespread and relatively abundant (Actions 1a, 1b, and 1c, Action 3) and monitoring does not indicate declines (Action 2), then it should be possible to downlist some or all of the species/lineages from Endangered to a lower category in five years.

Methods

A submission to the Threatened Species Scientific Committee will be made to reclassify species/lineages of marsupial moles as appropriate in light of the findings of the recovery program.

Stakeholders

Marsupial mole recovery team, DEH (ACT)

Costs ($000s)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Prepare submission						4.0

E Management practices

There are no specific management actions that are known to benefit or harm marsupial mole populations, although this is due to a paucity of information rather than a known lack of effect. There are reasons to be especially concerned about threats that operate on a landscape scale such as predation by introduced animals, habitat changes and trampling caused by grazing, and changes to fire regimes. Where populations are small and localised, there is also reason for concern regarding large roads, railways and pipelines which may fragment and isolate populations. High levels of ground-propagated noise might also deleteriously affect nearby populations.

While significant impacts of these factors cannot be demonstrated, proposed developments could make a substantial contribution to marsupial mole conservation by developing monitoring programs in conjunction with the recovery team, and where possible designing these to monitor the effects of potential threats such as those outlined above.

F Duration and costs

Duration

This recovery plan outlines actions for improving the conservation status of marsupial moles for a five-year period, starting in 2005.

Five year Budget ($000s)

Action		1	2	3	4	5	Total
1a	Map and model habitat	10	0	0	0	0	10.0
1b	Survey	73	73	0	0	0	145.0
1c	Collect scats	23	21	21	21	21	106.0
1d	Solicit records	10	2	2	2	2	18.0
1e	Inspect pipeline trenches	2	0	0	0	0	2.0
2	Monitor	64	0	43	0	43	148.5
3	Taxonomy	31.5	0	0	0	0	31.5
4a	Fire, grazing, predation	46	0	15	0	15	76.0
4b	Surfacing & predation	46	36	37	36	36	189.3
5	Activity and ranging	37.1	37	0	0	0	74.2
6	Aboriginal knowledge	28	28	0	0	0	56.0
7	Diet and condition	20	0	0	0	0	20.0
8	Captive preparations	4	0	0	0	0	4.0
9a	Coordinator	28.7	14.9	9.8	5.6	5.6	64.6
9b	Recovery team	2	2	2	2	2	10.0
10	Re-evaluate status	0	0	0	0	4	4.0
		426.3	215.9	132.8	70.6	133.6	959.1

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Appendix 1. Notoryctes records in bioregions

Representation of marsupial moles records in biogeographical regions of Australia (Thackway & Cresswell 1995; Environment Australia 2000).

Bioregion	Spp	Last Record	Summary of records
Dampierland (WA)	*N. caurinus*	2000	Collected on several occasions along the coastal strip south of Broome. Anecdotal Aboriginal records from the vicinity of Beagle Bay.
Great Sandy Desert (WA, NT)	*N. caurinus* in WA;	2003	In WA, numerous anecdotal Aboriginal records but only four specimens, mostly from the northern and southern edges of the bioregion. All specimens regarded as *N. caurinus*.
	N. typhlops (n) in NT	2004	In NT, 11 specimens and several observations from at least 7 locations. Those in north have been determined as *N. typhlops* (northern), but otherwise simply regarded as *N. typhlops*.
Little Sandy Desert (WA)	*N. caurinus*	1999	Collected on several occasions north west of Lake disappointment, and numerous anecdotal Aboriginal records from the east side of the bioregion
Gibson Desert (WA)	*N. caurinus*	1968	*N. caurinus* recorded on NW and SE edges, plus several anecdotal Aboriginal records throughout the sandy eastern side of the bioregion.
	N. typhlops (s)	1999	*N. typhlops* (s) on SE edge near Warburton
Tanami	*N. caurinus* in WA;	1964	In WA, *N. caurinus* identified on western edge of bioregion, and several Aboriginal records
	N. typhlops? in NT	1990	In NT, observed at five widely separated locations and attributed to *N. typhlops*.
Burt Plain (NT)			Single record from Barrow Creek in 1901, probably brought in from surrounding

			Tanami
Great Victoria Desert (WA, SA)	*N. typhlops* (s)	2003	Collected at several locations in SA and in the far south western corner of the bioregion. Most specimens have been examined and all are *N. typhlops* (southern). Several anecdotal Aboriginal records from the centre of the bioregion.
Gawler (SA)	*N. typhlops* (s)	1977	Record from Wilgena Station near Tarcoola in or before 1926, and another west of Lake Everard in 1977. Both near dunefield incursions on the western edge of the bioregion.
MacDonnell Ranges	*N. typhlops* (s)	1998	Five specimens from near Hermannsburg, and also from Watarrka and Tempe Downes. All of those examined (3) have been *N. typhlops* (southern)
Central Ranges (WA, SA, NT)	*N. typhlops* (s) *N. caurinus*	1997	Numerous Aboriginal records, and specimens of *N. typhlops* (southern), A single record of *N. caurinus* on the western edge of the bioregion near Warburton
Finke (NT)	*N. typhlops (s)* *N. typhlops (n)*	1966 1960	Several records of *N. typhlops* (southern) through NT, and two records of *N. typhlops* (northern) at the eastern and western edges of the bioregion. On the SA side, a record from Granite Downs probably came from surrounding dunes of the Finke bioregion.
Simpson Strzelecki Dunefields (NT, SA, QLD)	*N. typhlops (s)* *N. typhlops (n)*	2003	Both southern and northern forms of have been recorded on the western edge of the bioregion near the NT SA border. Underground signs of marsupial moles have also been recorded at Andado (NT) and Purnie Bore (SA) in 2003. A record of the southern form from Innamincka probably came from the surrounding dune country of this bioregion.
Stony Plains	*N. typhlops (s)*	1963	Two records from Granite Downs and Oodnadatta probably came from surrounding dune country of the Finke and Simpson bioregions. (C Kemper considered the Oodnadatta record to probably be erroneous)
Pilbara			Several Aboriginal records located in stony habitat probably refer to the Great Sandy Desert region to the north

Appendix 2 Objectives, criteria and actions

Relationships between objectives, actions and performance criteria involved in the marsupial moles recovery program.

Objectives		Actions		Performance Criteria
Describe the distribution and abundance of the distinct lineages of marsupial moles	→	Action 1a Map and model potential habitat	→	Likely distribution of marsupial moles is described based on physical and climatic data
	→	Action 1b Survey underground signs of marsupial moles at strategic localities	→	Actual distribution is described
			→	Benchmark abundance indices established
	→	Action 1c Collect predator scats to obtain marsupial mole DNA at strategic localities	→	Predator scats are collected and analysed
	→	Action 1d Solicit records and specimens and otherwise engage landholders and land managers	→	Land managers informed of importance of reporting records
	→	Action 1e Inspect pipeline trenches	→	Pipeline trenches inspected in likely habitat
	→	Action 3 Resolve taxonomy	→	Taxonomy is of forms resolved
			→	Genetic lineage of marsupial moles at strategic locations is determined
	→	Action 5 Describe the ecology and ranging behaviour of Itjaritjari	→	Actual population sizes estimated
Determine population trends of the distinct lineages of marsupial moles	→	Action 2 Monitor population trends	→	Monitoring manual produced

				→	Population trends for distinct populations are quantified from at least 2 locations in each of the three genetically distinct populations
				→	Effect of predator removal is quantified
3. Provide preliminary information on threats	→	Action 4a Assess the threats imposed by fire, grazing, predation, and climate change		→	Effects of grazing is quantified
				→	Effects of fire is quantified
				→	Effect of predator removal is quantified
	→	Action 4b Determine seasonality of predation and surfacing		→	Seasonality of predation is described
				→	Seasonality of marsupial moles surfacing is described
	→	Action 5 Describe the ecology and ranging behaviour of Itjaritjari		→	Significance of predation is assessed in light of general ecology
4. Learn about the conservation ecology	→	Action 5 Describe the ecology and ranging behaviour of Itjaritjari		→	Activity cycles described
				→	Underground rate of movement described
				→	Decay rates of underground signs is described
	→	Action 6. Obtain ecological info from Aboriginal elders		→	Interviews recorded, translated, and archived
				→	Ecological information extracted
	→	Action 7 Determine diet, reproductive state and		→	Museum specimens examined in regard to

		general condition of museum specimens		diet, reproductive state and general condition
	→	Action 8. Prepare for captive individuals brought to Desert Park	→	Suitable enclosures filled with dune sand and encouraged to re-cement
			→	Detailed plan for managing marsupial moles in captivity developed
5. Manage the recovery process	→	Action 9a. Coordinate the recovery process	→	Coordinator employed
			→	Communication between stakeholders facilitated
			→	Reliable field and data handling processes developed
	→	Action 9b. Manage the recovery process through a recovery team	→	Recovery team established in which major interested parties are represented
	→	Action 10. Downlist from endangered to lower category	→	Submissions made to reclassify marsupial mole taxa to lower category if appropriate

Appendix 3. Recommended procedures in the event of encountering a marsupial mole

Marsupial moles and their signs are rarely encountered and every record is important for understanding the species distribution and habits. The following guidelines are designed to maximise the amount of information that can be obtained from your record while disturbing the animal as little as possible.

Records and specimens should be sent to regional government wildlife authorities, State/Territory Museums, or the Threatened Species Network.

1. Tracks and other signs

The tracks of marsupial moles are observed much more frequently than the animals themselves. Tracks are distinctive to the trained eye and can even be used to distinguish Itjaritjari (*N. typhlops*) and Kakarratul (*N. caurinus*).

- <u>Record the date time and location</u>. If using a GPS, indicate the datum used if known. Describe the topography (eg. dune crest/slope/base/swale/on flat)
- <u>Photograph</u> the tracks if you have a camera, and include a scale (matchbox, pen etc).
- <u>Follow trail</u> to find where the animal may have come up or gone down into the ground. <u>Describe</u> the distance that the animal moved on the surface and how many times it tunnelled down or came up. Provide a sketch if you can, and photos of any interesting signs.
- <u>Search</u> the surrounding area (100m or so) for any further signs of marsupial moles. If more tracks are found, note whether they seem older or more recent than those already found.

2. Marsupial moles found on surface

In addition to the points raised above, animals that are captured provide an opportunity to collect further information and samples from the animal. <u>Note that marsupial moles are easily stressed and may die if handled for extended periods. Handling and captivity should be kept to a minimum.</u>

Where possible and without unduly stressing the animal the following procedures are recommended:

- DNA samples can be easily obtained by <u>pulling a few hairs</u> from the animals rump. To collect hairs, use forceps/tweezers to grasp a small clump of hair (up to 10 hairs) and pull sharply. The aim is to collect a few follicles as these contain a rich supply of DNA. Be careful not to handle the hairs, especially the follicles, to avoid contaminating the sample. All hair should be collected and stored in a labelled vial* in 70% alcohol. If vials are not available, store the hairs in a dry paper envelope or equivalent.
- DNA samples may also be obtained by gently <u>swabbing the mouth</u> between the teeth and gums with a cotton tip. Being careful not to touch the tip, cut the tip off and store in a labelled vial* in 70% alcohol.

- The body of the animal should be inspected and any injuries or external parasites noted. Parasites should be collected and stored in a labelled vial* in 70% alcohol.
- The weight of the animal should be recorded if suitable scales are available.
- Scats should be collected and stored in a labelled vial* in 70% alcohol, or in an empty vial once they are completely dry.
- If the animal is held captive for more than a few minutes, it should be housed in a container with at least 10cm of sand. Sand temperature should be kept in the mid-20°C, and the container kept out of the sun in a quiet area. Preferably, the sand should be sieved before the animal is introduced to the container, and sieved again once it is removed, in order to collect scats (usually firm, dark and about 4mm long).
- The animal should be released where it was found or, in the case of hard pan areas or roads, at the nearest dune or deep sandy area.

3. Dead marsupial moles

Dead marsupial moles are occasionally encountered, and should be forwarded to State museums as soon as possible. Unless specialist assistance is available, the specimen should be kept cold but not frozen (ie on a bed of ice) until it is delivered to the museum. If the animal is already dry and desiccated, it can be wrapped in paper and transported in this form without ice.

At the museum, or where specialists are available in the field, the following treatment is recommended:

- Tissue samples (muscle) should be collected for DNA analysis and stored in 70% alcohol.
- Abdominal and thoracic cavities should be opened and the specimen infused with 10% buffered formalin. For more efficient preservation of the brain, a small part of skull can be removed on one side to allow formalin to penetrate.

* Vials pre-filled with 70% alcohol, suitable for storing DNA samples, can be obtained from the South Australian Museum; contact Dr Steve Donnellan by email donnellan.steve@saugov.sa.gov.au or phone (08) 8303-4855.