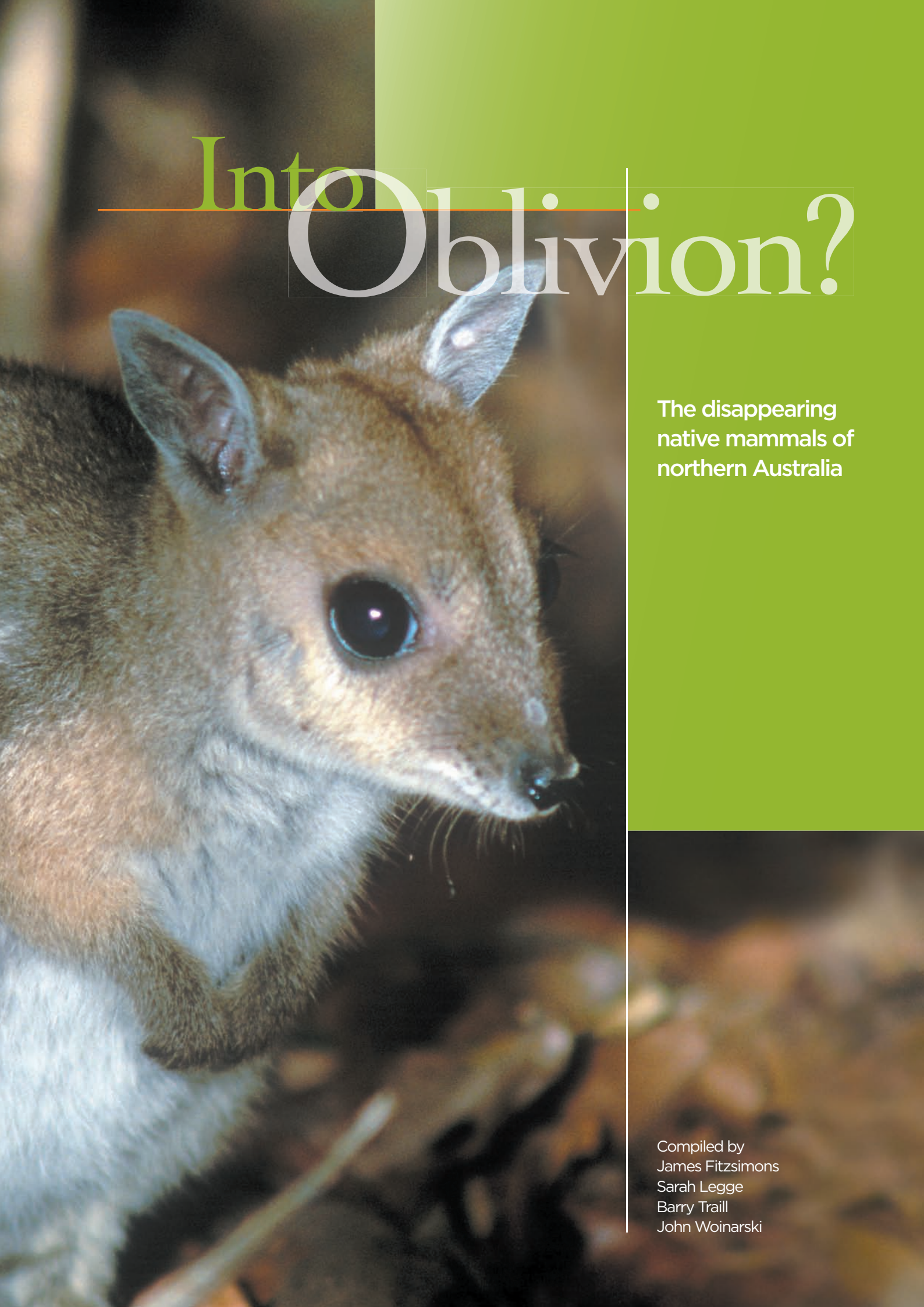

Into Oblivion?

The disappearing native mammals of northern Australia

Compiled by
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Sarah Legge
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John Woinarski

SUMMARY

Since European settlement, the deepest loss of Australian biodiversity has been the spate of extinctions of endemic mammals. Historically, these losses occurred mostly in inland and in temperate parts of the country, and largely between 1890 and 1950. A new wave of extinctions is now threatening Australian mammals, this time in northern Australia. Many mammal species are in sharp decline across the north, even in extensive natural areas managed primarily for conservation. The main evidence of this decline comes consistently from two contrasting sources: robust scientific monitoring programs and more broad-scale Indigenous knowledge. The main drivers of the mammal decline in northern Australia include inappropriate fire regimes (too much fire) and predation by feral cats. Cane Toads are also implicated, particularly to the recent catastrophic decline of the Northern Quoll. Furthermore, some impacts are due to vegetation changes associated with the pastoral industry. Disease could also be a factor, but to date there is little evidence for or against it.

Based on current trends, many native mammals will become extinct in northern Australia in the next 10-20 years, and even the largest and most iconic national parks in northern Australia will lose native mammal species. This problem needs to be solved. The first step towards a solution is to recognise the problem, and this publication seeks to alert the Australian community and decision makers to this urgent issue. Targeted management of known threats, based on the evidence currently available, is urgently required to ensure the survival of northern Australian mammal species. In part, the answer lies in more rigour and accountability in the management of conservation reserves; but it also lies in seeking to identify and deliver more conservation outcomes from all other lands. In the shorter-term, there is also a need to strengthen the safeguards on islands off northern Australia, as a temporary refuge for 'at risk' species until a more comprehensive solution can be reached on the mainland.

Introduction

Twenty or so years ago, people camping in northern Australia were likely to witness bandicoots and quolls scampering around their campsites during the night. Scientists working in many areas of the north would regularly find a remarkably rich diversity and abundance of small native mammals. For native mammals, this was a land of plenty; one of the few remaining places with a fauna largely as it was at the time of European settlement. Much has changed since then, and the extremely diverse mammal fauna of northern Australia is now fading away. This is a pattern of loss witnessed previously elsewhere in Australia, largely before we could do anything about it. This document is prompted by concerns of not wanting a repeat of those losses, and by the hope that we have learnt to manage our environment with more care, concern and expertise.

In Australia we have a remarkable landscape, populated with and characterised by plants and animals unlike those anywhere else on the planet. It is a legacy that defines and distinguishes us. But it is a legacy at risk as we lose important components and introduce elements that blur the natural essence of our environments.

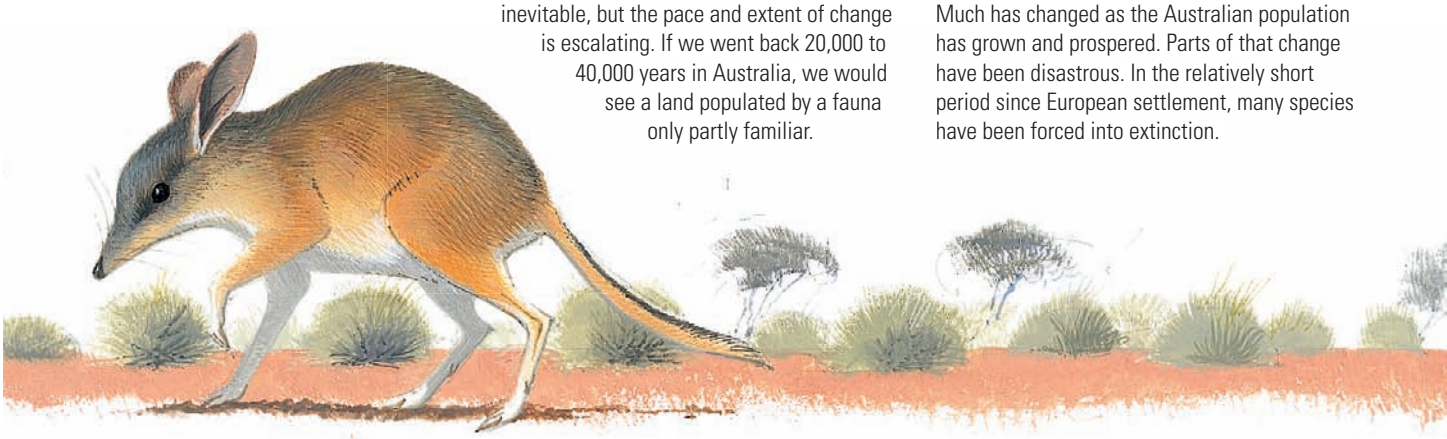
These environments, and the plants and animals that inhabit them, have changed. Change is inevitable, but the pace and extent of change is escalating. If we went back 20,000 to 40,000 years in Australia, we would see a land populated by a fauna only partly familiar.

We would marvel at kangaroo species far larger and more varied than today's. We could see and perhaps be terrified by *Thylacoleo* the "marsupial lion". We would see the Tasmanian Devil and Thylacine prowling across all of Australia. This "megafauna" has been lost from our heritage, ghosts now only evident in a meagre collection of fossils and cave paintings.

If we went back just 100 to 150 years, to a colonial era, top hats and stage coaches, we could venture to the fringes of settlement and see the now-lost Paradise Parrots and Toolache Wallabies; we would see acclimatisation societies zealously introducing European plants and animals, shaping the environment to appear more familiar, somehow more gentle; the first herds of cattle and sheep sweeping across the novel landscapes; and a thriving Koala pelt industry. Back just 50 years, we would still find quolls around Melbourne; and Pig-footed Bandicoots, Crescent Nailtail Wallabies and Desert Rat-kangaroos in central Australia[1]. Those animals have gone, in a timeframe that in an evolutionary context is the merest of blinks. Species that had thrived on the Australian landscape for hundreds of thousands, even millions of years disappeared in just a few decades – ironically coinciding with the development of our sense of responsibility for the Australian environment.

Much has changed as the Australian population has grown and prospered. Parts of that change have been disastrous. In the relatively short period since European settlement, many species have been forced into extinction.

Two species, formerly widespread in arid and semi-arid Australia, now extinct: the Pig-footed Bandicoot (below) and Crescent Nailtail Wallaby (opposite above). [Illustrations: Frank Knight]



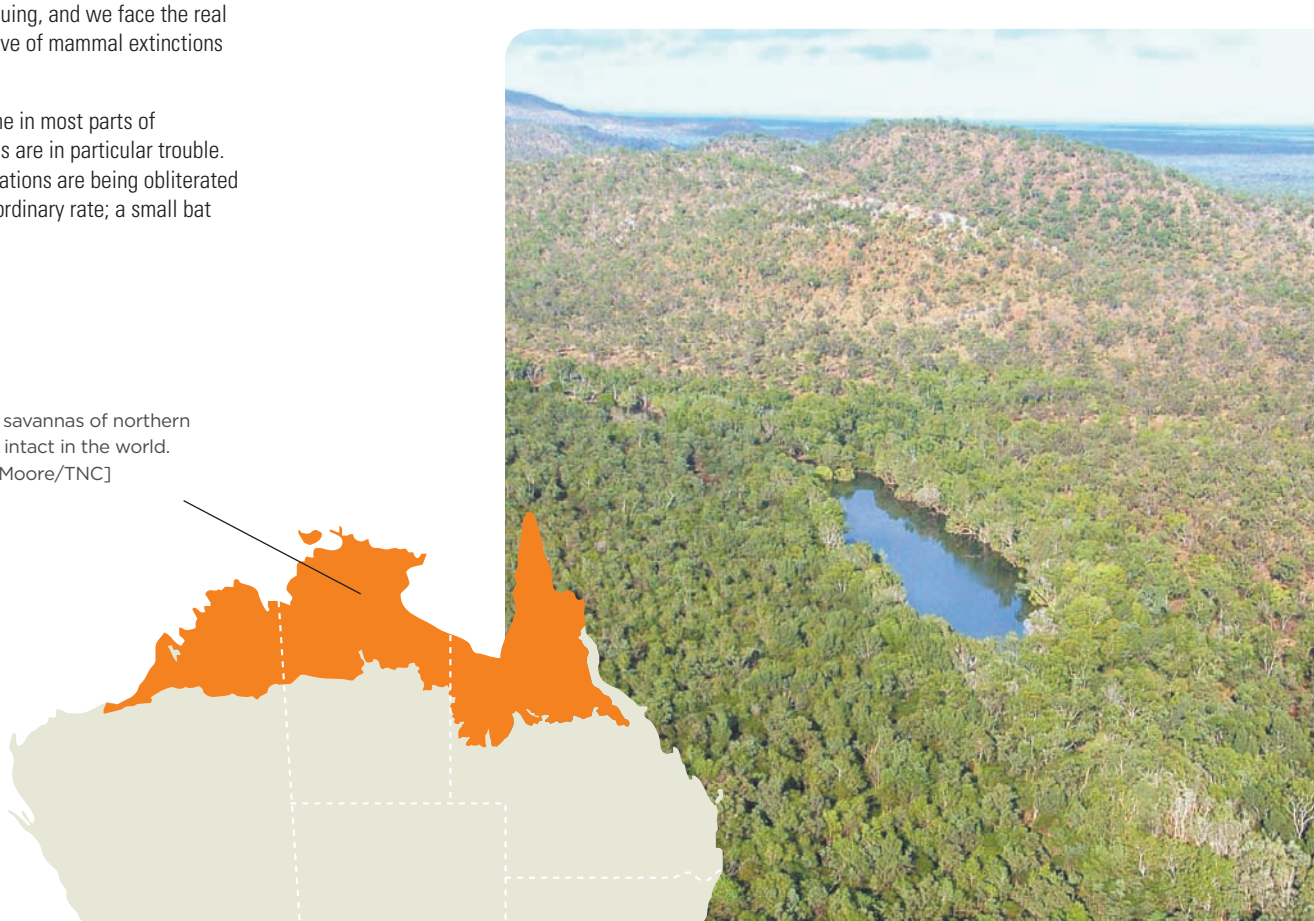
Such a fate has befallen plants, invertebrates and birds, but by far the most affected have been Australia's native mammals. Over the last 200 years, more mammal species have become extinct in Australia than anywhere else on Earth: Australian mammal extinctions account for about one-third of all mammals that have disappeared from the world over the last 500 years. The roll call of Australian mammal extinctions includes 22 species from continental Australia and a further five species from offshore islands[2]. There is a recency to these extinctions that is remarkably affecting and tantalising. Many almost come alive in the paintings from John Gould and others, or in the vivid descriptions of unusual traits or captivating behaviours, by early explorers and naturalists. We could have so nearly saved them.

The loss of these mammals has diminished our heritage and stained our stewardship of this land. We can look back on the lost opportunities with some regret but regard it as the unintended consequence of the environmental ignorance of earlier generations. We can assume that we now have a greater sense of environmental responsibility – we have better environmental legislation, more national parks, and a far greater knowledge of Australian ecology. We can assume that future generations will commend our environmental responsibility rather than lament our inaction. But such assumptions are flawed; for the declines are continuing, and we face the real likelihood of a new wave of mammal extinctions on our watch.

Biodiversity is in decline in most parts of Australia, but mammals are in particular trouble. Tasmanian Devil populations are being obliterated by disease at an extraordinary rate; a small bat endemic to Australia's Christmas Island became extinct in 2009[3]; possums are in rapid decline in south-western Australia; and rock-rats have again disappeared from central Australia. But it is in northern Australia that the native mammal fauna is facing its largest and fastest decline, and it is there that this document is focused. It is the strangeness of this situation that is most arresting. Worldwide, extinction is mostly the lot of animals and plants that unhappily occurred in areas subject to the most marked environmental change, of broad-scale clearing and intensive development, of very high human population density, or of direct unsustainable hunting pressure[4]. But these are not characteristics of northern Australia, which remains spectacularly natural in appearance and essence, with remarkably few people, relatively little intensive development, and extensive areas protected in conservation reserves. Indeed, northern Australia claims the title of the world's largest intact tropical savanna. These are characteristics that should serve to maintain and offer refuge to biodiversity. It is this apparent paradox that we explore here, with the particular concern that we must change our conception of what constitutes conservation security, and must instead more clearly recognise the need for more active and intensive management of those factors that are currently driving our fauna to extinction.

Most Australians will be unaware this crisis exists. Most will be unaware that many species are in unchecked decline. Indeed, with the exception of koalas, kangaroos and flying-foxes, and perhaps possums in some urban parks, most native mammals are largely invisible, with a very low profile on our national awareness. Compared with the strikingly obvious and often common large mammal fauna of other continents, Australia's native mammals are mostly small, nocturnal and shy. And so their decline escapes public attention and risks silently passing us by.

This document aims to alert us to what we are now losing. It aims to sketch an approach that will stop the loss. It focuses particularly on the mammal fauna of northern Australia, because this is where the problem may be most immediate.



Right:
The extensive tropical savannas of northern Australia are the most intact in the world.
[Photo: Geoff Lipsett-Moore/TNC]

Above:
The Burrowing Bettong, a "critical weight range" species, once widespread in parts of the mainland, now confined to islands off Western Australia. [Photo: Jiri Lochman/Lochman Transparencies]

The Australian mammal fauna

At the time of European settlement, the native land mammal fauna of Australia and its offshore islands comprised 308 species. This mammal fauna consisted of two monotremes (the Short-beaked Echidna and the Platypus), 159 marsupials including thylacines, bandicoots, kangaroos and wallabies, dasyurids (carnivorous marsupials), marsupial moles and possums, 79 bats, 66 rodents, a shrew and the Dingo[5]. By far the majority of these species (86%) occur (or occurred) only in Australia, making it an extraordinarily distinctive fauna.

For Australian species, loss and extinction has happened within most major groups, but the proportional loss has been far greater for mammals than for birds, reptiles or plants (Fig. 1). Within mammal groups, the losses have been far greater for marsupials and rodents than for bats (Fig. 2). The mammal losses have also been somewhat size-dependent, with extinction and decline most likely for medium-sized mammals – those with a body weight between 35 grams and 5.5 kilograms – the so-called "critical weight range". These include bandicoots, possums, quolls, small macropods (wallabies, potoroos, bettongs and rat-kangaroos) and large rodents[6]. In contrast, larger mammals (such as the big kangaroos) and smaller mammals (such as many small rodents and small dasyurids including planigales, dunnarts, ningauis and antechinuses) have proven relatively resilient.

Fig. 1. Comparisons of the conservation status of Australian plants and animal groups.

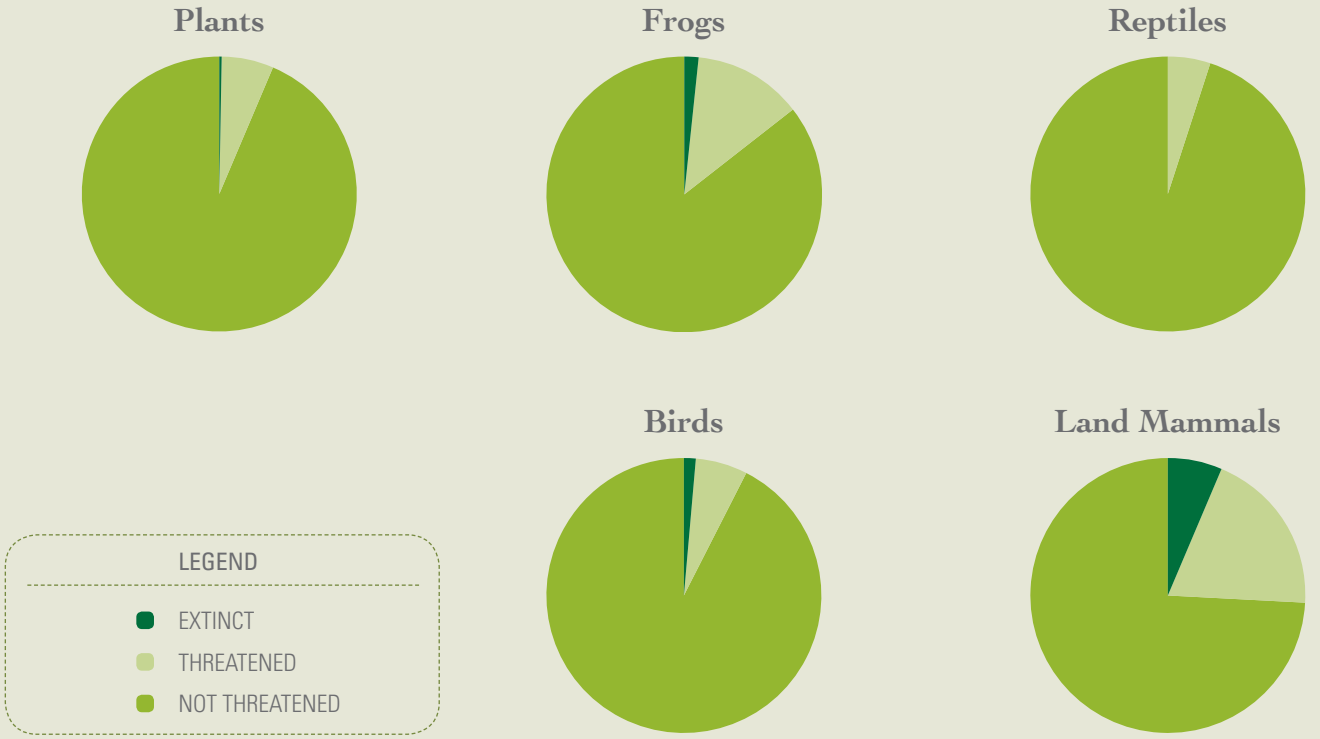
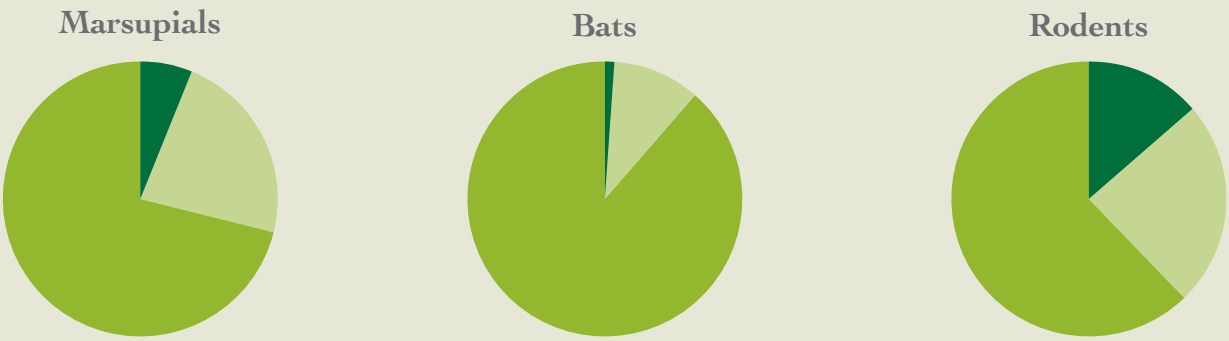


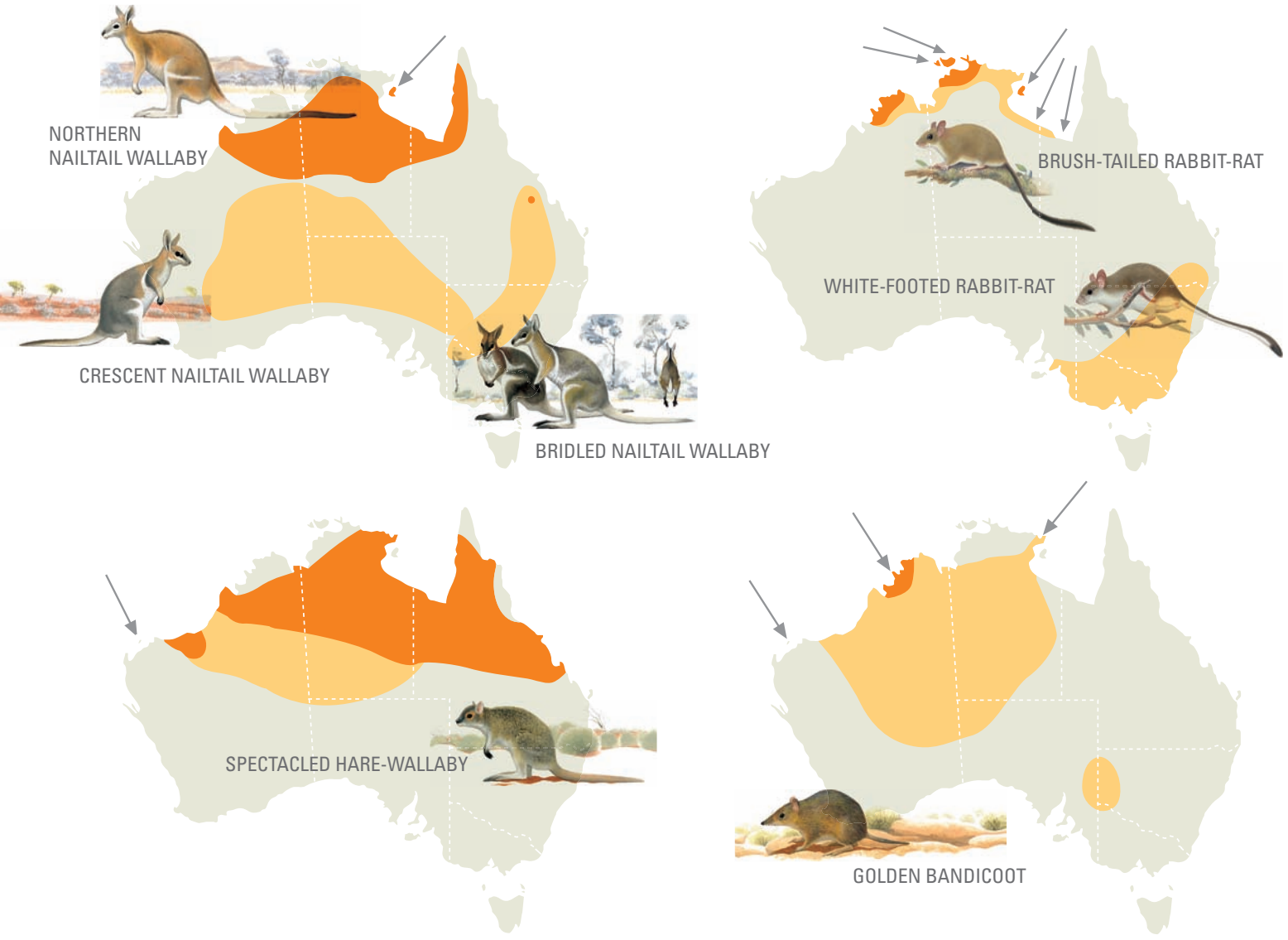
Fig. 2. Comparison of the conservation status of the main Australian terrestrial mammal groups.



The north Australian mammal fauna – recent evidence of change

Until recently, northern Australia has provided an important level of conservation security for Australian mammals (Fig. 3), and for other elements of biodiversity more generally. Some species, such as the Golden Bandicoot, with formerly extensive distributions across much of Australia, have disappeared from all of that range other than in parts of northern Australia. In other cases, such as the two rabbit-rats, the species formerly occurring in southern Australia has become extinct, whereas its northern Australian counterpart has persisted[7]. To some extent, this persistence in the north gives us a second chance to maintain some unique elements of the Australian biota.

Fig. 3. Examples of species or species-groups for which northern Australia has provided relative conservation security. [Illustrations from and maps adapted from Menkhorst, P. & Knight, F. (2010) *A Field Guide to the Mammals of Australia,* 3rd edition. Oxford University Press, Melbourne; Spectacled Hare-wallaby map adapted from Van Dyck, S. & Strahan, R. (eds.) (2008) *The Mammals of Australia,* 3rd edition, New Holland/Queensland Museum, Brisbane.].



However, it is now increasingly apparent that the conservation security assumed for or offered by northern Australia is rapidly eroding. Evidence of decline comes from a range of sources, including broad-scale inventory and comparison with historical records, large-scale formal monitoring programs, extensive documentation of Indigenous knowledge, and targeted studies of individual species.

Broad-scale inventory and comparison with historical records

There is a limited but critical historical baseline against which the present-day status of some mammals in northern Australia can be compared. The most important source is the work of the Norwegian zoologist Knut Dahl, who explored and collected in the Top End of the Northern Territory and the south-west Kimberley in the 1890s[8]. Some of his observations are summarised in Table 1 on page 8, against assessments of the present-day situation. (continued page 8)

Introducing some of the mammals of northern Australia

For most people, the inventory list of native mammals in northern Australia (Table 3 on pages 18-19) will simply be a collection of unfamiliar and odd names. This reaction is understandable, given that few people have had the unique pleasure of holding a tiny planigale in the palm of their hand, of observing the secretive but herculean-bodied Black Wallaroo quietly come to drink at dusk at a waterhole on the cliff tops of Arnhem Land, or feeling somewhat intimidated but impressed at the growling display of that most beautiful and feisty of rodents, the Black-footed Tree-rat.

To help make these names more meaningful, we offer descriptions of some of the distinctive mammal species of northern Australia.

LONG-TAILED PLANIGALE

The Long-tailed Planigale has the dubious honour of being the world's smallest marsupial, a tiny bundle of furred fury, weighing about one-third that of a House Mouse. This species is widespread across northern Australia and is still locally very abundant, particularly on cracking clay grasslands. It is a fierce hunter of insects, and shelters during the day mostly in cracks in the soil. As a group, planigales remain poorly known, and there are probably at least five currently undescribed species in northern Australia.

NORTHERN QUOLL

The Northern Quoll is an inquisitive carnivorous marsupial, the size of a small cat, and the smallest of Australia's four quoll species. All Australian quolls have fared badly since European settlement for a range of reasons. The Northern Quoll has been declining across northern Australia for many decades, but the decline has been precipitous in areas recently invaded by cane toads. The Northern Quoll is an attractive animal, with a coat marked by white spots on darker fur. It uses hollow logs, tree hollows or rock crevices for day-time shelter. Males typically live for only one year, with a more or less synchronous die-off after a hectic mating season. Following this die-off, almost the entire population comprises pregnant females.

NORTHERN BRUSH-TAILED PHASCOGALE

The Northern Brush-tailed Phascogale is an exquisite squirrel-sized animal, with beautiful soft grey fur. Unusually, the hairs on its long tail can be erected, forming a distinctive bottle-brush shape. This species forages mostly for insects in trees and on the ground, and dens during the day in tree hollows. This northern species is restricted to taller forests of the Top End of the Northern Territory. It was only recently recognised as distinct from the more widespread Brush-tailed Phascogale of eastern, south-western and north-western Australia. It is uncommonly recorded, but appears to have declined sharply in the last 10 to 20 years.

NINBING FALSE ANTECHINUS

The Ninbing False Antechinus is another small carnivorous marsupial, restricted to rocky ranges in the Kimberley and adjacent areas of the Northern Territory. The unfortunately-named "false antechinuses" form a group of several species across central and northern Australia, all of which are nocturnal hunters of insects and small vertebrates. Currently, this species may be stable, although there is little monitoring or other information available to reliably assess its status.

GOLDEN BANDICOOT

The Golden Bandicoot is a small bandicoot now found only on a few islands and a small area of rugged sandstone in the north-west Kimberley, the vestiges of a distribution that was formerly almost continental. It shelters during the day mostly in grass tussocks, and its decline probably owes much to predation by foxes and cats.

BILBY

The Bilby is one of Australia's most distinctive animals. Its core distribution is across central Australia, but its range extends to the south-west Kimberley. It constructs long, deep burrow systems, and eats invertebrates, fungi and roots. The Bilby has declined very substantially across much of its range; a similar but smaller species, the Lesser Bilby, is now extinct.

[Photos: Jiri Lochman/Lochman Tansparencies (Long-tailed Planigale, Northern Quoll, Ningbing False Antechinus, Golden Bandicoot, Bilby, Scaly-tailed Possum, Monjon), Hans & Judy Beste/Lochman Transparencies (Northern Bettong, Water Mouse), Frank Woerle/AUSCAPE (Northern Brush-tailed Phascogale, Black Wallaroo, Carpentarian Rock-rat), Alaric Fisher (Black-footed Tree-rat).]

SCALY-TAILED POSSUM

The Scaly-tailed Possum is a rock-dwelling possum restricted to the Kimberley, and is so unusual that it is the only representative of its genus. Its most notable physical feature is its tail, which is thickly-furred at the base and then unfurred and rasp-like for most of its length. It feeds on leaves, flowers and fruit, and shelters during the day in rock crevices. Currently, this species may be stable, although there is little monitoring or other information available to reliably assess its status.

NORTHERN BETTONG

The Northern Bettong is a macropod the size of a small cat, and has one of the most restricted ranges of all Australian mammals, occurring in eucalypt forests in only a few localities of northern Queensland. It feeds mainly by digging up fungi ("truffles"), and it shelters during the day usually in a grass nest placed in tussocks. This species is considered to be endangered.

BLACK WALLAROO

The Black Wallaroo is a highly restricted macropod, occurring only in the gorges and escarpment of western Arnhem Land. It is a moderately large and thickset kangaroo. Males and females contrast in size and colour, with the larger males having fur the colour of dark chocolate and females fawn-grey. They are solitary and shy. Currently, this species may be stable, although there is little monitoring or other information available to reliably assess its status.

MONJON

The Monjon is another highly range-restricted macropod, occurring only in the north-west Kimberley. The size of a small cat, it is the smallest of a series of rock-wallabies that occur discontinuously across the rugged ranges of northern Australia, and that are remarkable for their agility in moving around cliffs, boulders and rock faces. Currently, this species may be stable, although there is little monitoring or other information available to reliably assess its status. Another small northern Australian rock-wallaby, the Nabarlek (see front cover), appears to be undergoing a current decline.

BLACK-FOOTED TREE-RAT

The Black-footed Tree-rat is the giant of Australia's diverse native rodent fauna, a seemingly puzzling mix of squirrel and terrier, far more fierce in appearance than reality. Its notable features include large dark eyes and ears, long silky grey fur, and a remarkably long tail tipped with a brush of white fur. It has particularly large and strong teeth, sufficient to bite through some of the toughest fruits and seeds. It dens during the day in tree hollows, and forages in trees and on the ground. It is restricted to taller forests in northern Australia, and is declining, most likely because of the current regime of too frequent fire. Its only other close relative, the Golden-backed Tree-rat may have become extinct in the Northern Territory, but still occurs in the Kimberley.

WATER MOUSE

The Water Mouse occurs intermittently in coastal areas from near Brisbane to near Darwin. It paddles and puddles around mangroves and swamps, eating mostly small crabs and other marine and freshwater invertebrates. In some areas, it builds complex hardened mud nesting mounds. It has declined in some more settled areas due to development and habitat change.

CARPENTARIAN ROCK-RAT

The Carpentarian Rock-rat is one of Australia's most restricted vertebrates, recorded only from a few gorge systems on one pastoral property in the Northern Territory, adjacent to the Queensland border. Like the tree-rats, it is one of Australia's "old endemic" rodents, the legacy of ancient radiations of rodents on this continent. It is one of five Australian rock-rat species, all restricted to rocky ranges. Four of these species occur only in northern Australia. All eat seeds, fruits and other vegetable matter. Their appearance is characterised by extraordinarily long facial whiskers, large eyes, "Roman" noses, and a tail that can be thickened to carrot-shaped when food is plentiful. The rock-rats are unusual in having extremely delicate fur and tails, and these may be readily sloughed off if mis-handled, presumably a sacrificial defence against predators. This species is recognised nationally as endangered, largely because of its very restricted range and the threat posed to its habitat quality by frequent fire.

Table 1. Comparison of status of some mammal species in northern Australia as reported in the 1890s and now.

SPECIES: GOLDEN BANDICOOT

DAHL'S 1890s OBSERVATION:
"very numerous in the coast country around Roebuck Bay [around Broome]…great numbers being brought to me"

CURRENT SITUATION: now regionally extinct around Broome, and restricted to a few islands and a small number of locations in rugged high rainfall areas of the north Kimberley.

SPECIES: GOLDEN-BACKED TREE-RAT

DAHL'S 1890s OBSERVATION:
[around Broome] "the houses of settlers… are always tenanted by (this species)"

CURRENT SITUATION: now regionally extinct around Broome, but still present in rugged higher rainfall areas of the north Kimberley. Possibly extinct in the Northern Territory.

SPECIES: BURROWING BETTONG

DAHL'S 1890s OBSERVATION:
[around Broome] "the ground was nearly everywhere and in all directions excavated by the burrows of this little Macropod…all the scrubs, and especially the slopes…are inhabited by countless numbers"

CURRENT SITUATION: formerly a mostly inland species, now extinct on the Australian mainland, other than in several small managed re-introduced populations.

SPECIES: BRUSH-TAILED RABBIT-RAT

DAHL'S 1890s OBSERVATION:
"in Arnhem Land is everywhere common in the vicinity of water" and "numerous all over Arnhem Land, and in great numbers on the rivers on the lowlands"

CURRENT SITUATION: now extremely localised and rare on the mainland of northern Australia – only two populations known on the Northern Territory mainland, and scarce and restricted in the Kimberley.

SPECIES: BRUSH-TAILED PHASCOGALE

DAHL'S 1890s OBSERVATION:
"on the rivers Mary and Katherine it was frequently observed. In fact, nearly everywhere inland it was very constant, and on a moonlight walk one would generally expect to see this little marsupial"

CURRENT SITUATION: now extremely rare and highly localised in northern Australia.

(continued from page 5)

The extent and timing of these declines is difficult to pinpoint, for there were few assessments in the decades following Dahl. But we now have a reasonable idea of the distribution and abundance of most mammal species in northern Australia due to a fairly comprehensive collection of inventory surveys, particularly in the Top End and the Kimberley, over the last 30 or so years (Fig. 4). Based on such modern sampling we can reconstruct the shrinking distribution of some species since European settlement (for example, Fig. 5). Disturbingly, this information suggests that the rate of retreat is probably increasing.

Of particular concern is that the species which appear to be declining in northern Australia are from the same groups of species as those that proved most likely to become extinct elsewhere in Australia: the bandicoots, possums, smaller wallabies, quolls, and larger rodents.

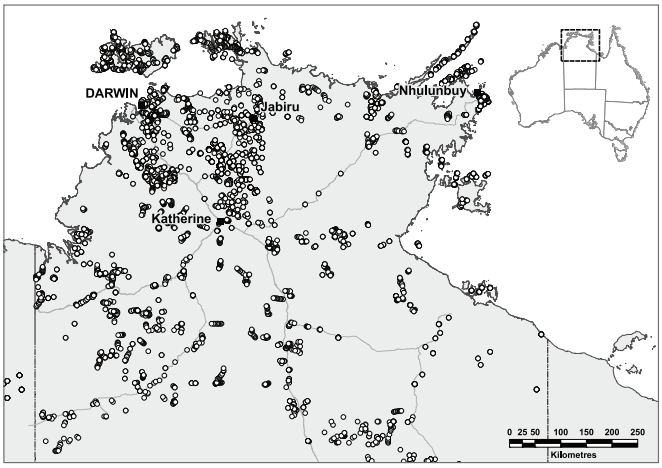


Fig. 4. Sites intensively sampled for mammals in the Top End of the Northern Territory.

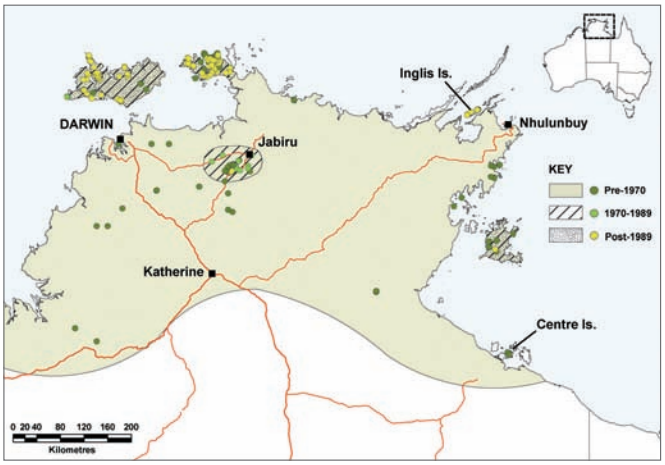


Fig. 5. Example of ongoing decline in distribution – Brush-tailed Rabbit-rat in the Northern Territory. Note that this species is also recorded from one island in Queensland, from few records in the Kimberley, and from very few records in New Guinea.

Left:
Brush-tailed Rabbit-rat.
[Photo: Kym Brennan]

Right:
Butler's Dunnart, a poorly known and declining species restricted to the Tiwi Islands and a small area in the north Kimberley. [Photo: Simon Ward]

Formal monitoring programs

Australia's human population is regularly censused. It is an expensive and logistically complex task. But charting trends in the population of most Australian animals is far more difficult, and there is much less public commitment to the challenge. The most comprehensive monitoring for Australian mammals is through aerial surveys of kangaroos in the eastern and southern Australian rangelands, but this is exceptional. Most native mammals are far less detectable, and estimates of abundance are based instead on numbers caught in a small number of intensive trapping studies.

For northern Australia, the most extensive and systematic monitoring programs for native mammals have been conducted in the Top End of the Northern Territory. For these monitoring programs, the same permanent sites are re-sampled in exactly the same way (typically through the use of live trapping and timed spotlight searches, with each sample over a three-night period) at regular intervals. The longer the duration of the monitoring, and the greater the number of sampling episodes, the more straightforward it is to distinguish between long-term trends and short-term fluctuations in population size.

The first major study quantifying changes in mammal populations in northern Australia was at Kapalga within Kakadu National Park. This study demonstrated a decline of 30-50% in the total mammal population (as measured by trap success) from 1986 to 1993, but this was initially thought to simply reflect changes due to a run of poor (low rainfall) years[9]. However, the same sites were re-sampled using the same protocol six years later (in 1999) following a run of good seasons, and the declining trends had persisted, or worsened[10].

Following from this study, a robust and more comprehensive long-term monitoring program was designed for a set of large conservation reserves (Kakadu, Litchfield, Nitmiluk and Garig Gunak Barlu National Parks) in the Top End. At each of these reserves, a large set of permanent monitoring sites has been established, with the objective of repeat sampling at five-year intervals[11].

For the Kakadu program, the results demonstrate an alarming decline over the last 10 to 15 years (Fig. 6)[12]. The abundance of 10 native mammal species has declined significantly, whereas no species increased significantly. The number of "empty" sites increased from 13% in 1996 to 55% in 2009. For 136 plots sampled between 2001 and 2004 and again between 2007 and 2009, site-level species richness declined by 65% and the total number of individuals declined by 75%. The most marked declines were for the Northern Quoll, Fawn Antechinus, Northern Brown Bandicoot, Common Brushtail Possum and Pale Field-rat. Declines are also evident in the monitoring programs for Litchfield and Garig Gunak Barlu National Parks, and too few mammals were caught in the initial sampling at Nitmiluk to allow any assessment of subsequent change.

Disturbingly, this current and clearly demonstrated decline is evident across all land tenures, even in the largest and best resourced conservation reserves in the Top End.

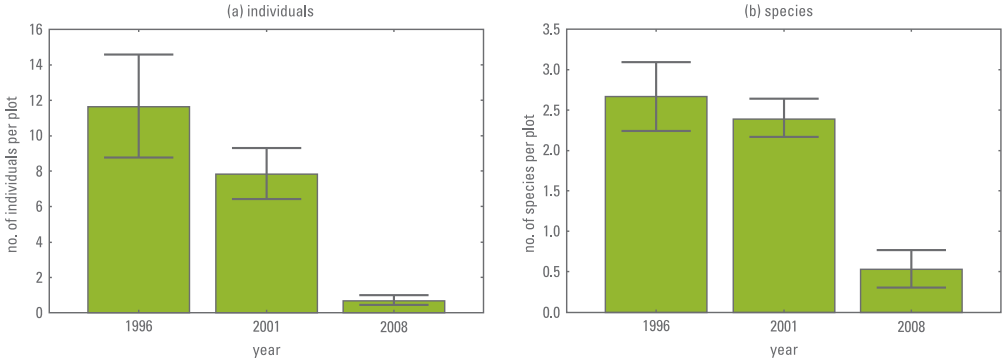


Fig. 6. Long-term monitoring results from Kakadu National Park. Results show the mean number of (a) mammal individuals and (b) mammal species per fixed monitoring plot, with 'whiskers' denoting standard errors. Data are based on 15 plots sampled three times; trends are comparable for 136 plots sampled twice over this period.

Chronicling of Indigenous knowledge

In extensive areas of northern Australia, Aboriginal people still live on or near their traditional clan estates and maintain an abiding interest in the condition of their country. Such residents can provide a perspective of the changing status of wildlife that may be longer in time and more extensive than "scientific" monitoring at a discrete number of small permanent sites, although it may be less numerically precise and may come with some interpretative constraints.

Over the last five years, Dr Mark Ziembicki has visited more than 30 remote Aboriginal outstations with a trailer load of stuffed mammal specimens, used as prompts to engage in discussions with long-term Aboriginal residents about the status of mammals. In many areas, the knowledge was detailed and incisive. In other communities, much of the once intricate knowledge of the natural environment and its plants and animals has eroded. Collating knowledge across communities, Dr Ziembicki has documented broad patterns of decline for many species within the last 20 or so years (Fig. 7). These patterns are strikingly consistent with the patterns of decline reported from the scientific monitoring programs, and given the entirely independent and contrasting protocols of these approaches, the conclusion of extensive rapid and current decline is very robust.

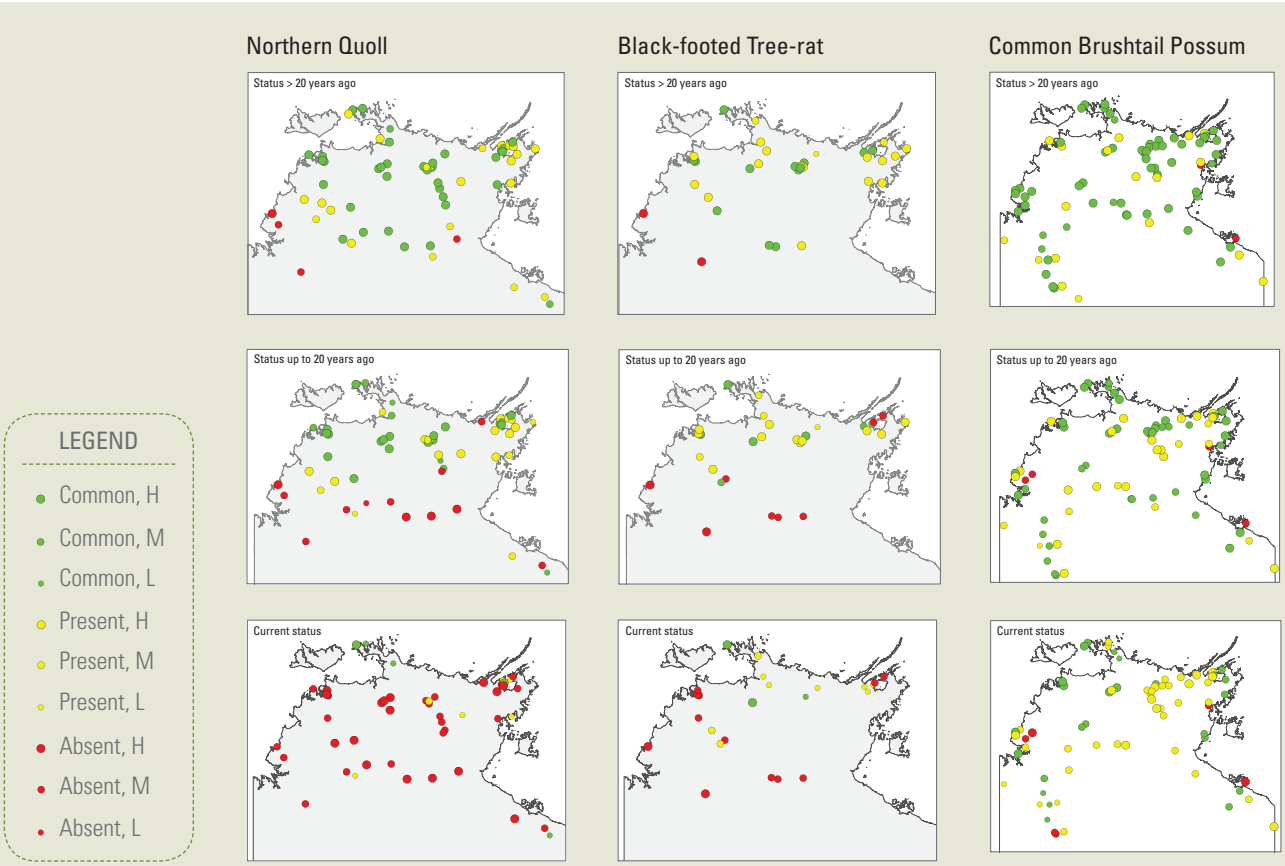


Fig. 7. Change in status of Northern Quoll, Black-footed Tree-rat and Common Brushtail Possum in northern Australia, derived from Indigenous knowledge, for three time periods (more than 20 years ago, 5-20 years ago, and present-day). Note that each record is based on interviews with one or more Aboriginal informants, who scored individual mammal species as common, present or absent, and each record was given a reliability code of high – H, medium – M, or low – L. Source: M. Ziembicki (unpubl.).

What is causing the decline?

Below:
Three species shown to have declined in northern Australia as derived from Indigenous knowledge: Northern Quoll, [Photo: Frank Woerle/AUSCAPE], Black-footed Tree-rat [Photo: Alaric Fisher] and Common Brushtail Possum [Photo: Wayne Lawler/AWC].

Opposite left:
Using stuffed mammals as prompts to engage in discussions with Aboriginal communities about the status of mammals. [Photos: Ian Morris]

The fundamentals of Australian ecology almost predispose its plants and animals to conservation risk. Australia, and hence its wildlife, has been isolated for a remarkably long time. Evolutionary pressure over this period has forced the "old endemic" fauna to live within the bounds of a typically low-fertility landscape. As with numerous Australian bird species, many Australian mammals have low reproductive output, but may live relatively long lives. For example, the "old endemic" tree-rats typically have one or two young per year, whereas non-native invasive Black Rats may have litters of 10 to 12, several times a year[13]. This disparity in reproduction rates provides introduced species with an advantage, at least in the short to medium term, over native mammals, rendering them particularly prone to new and intense pressures.

As with island populations anywhere, Australia's isolation has also rendered its endemic fauna particularly susceptible, through lack of immunity to novel diseases. Furthermore, for many native mammals, the history prior to European settlement was marked by comparatively benign predation regimes – relatively low-density Dingo, human and raptor populations, and goannas and snakes with relatively small demands for prey. The introduced foxes and cats have proven to be more effective, populous and greedy hunters. Most Australian mammals forage, shelter and breed on the ground, and are in the ideal prey size range for these exotic predators.

Elsewhere in the world, extinction is often linked with habitat destruction and fragmentation. For Australian mammals, this is not so much the case, and it is a more subtle transformation of the ecology that has driven decline – particularly ecological change following the spread of livestock, and of many other foreign plants and animals. The potentially devastating influence of these factors was predicted in colonial times by perceptive observers including John Gould and Charles Darwin. But it is still hard for most of us to reconcile the apparent vastness and naturalness of our continent with the inability of so many native animals to persist. This apparent paradox was expressed eloquently by the South Australian zoologist, H.H. Finlayson, the most compelling witness to the loss of the mammal fauna of central Australia:

"… incredulity is often expressed that such occupation as obtains in many parts of the interior could have caused appreciable changes to the original conditions. It is not so much, however, that species are exterminated by the introduction of stock, though this has happened often enough, but the complex equilibrium which governs long established floras and faunas is drastically disturbed or even demolished altogether. … The old Australia is passing. The environment which moulded the most remarkable fauna in the world is beset on all sides by influences which are reducing it to a medley of semi-artificial environments, in which the original plan is lost and the final outcome of which no man can predict … The man in the street has heard and read so much of a vast, empty centre that the conception of an untrodden wilderness enduring for all time has taken root. But it must always be remembered that even in those tracts where no stock have been depastured, those enterprising pests, the rabbits, foxes and feral cats, have in many cases gone on before and worked untold change and damage."[14]

The course of Finlayson's extensive studies, from the 1930s to the 1950s, largely book-ended the extinction event for central Australian mammals. In his final surveys in the late 1950s, many of the species that he'd found abundant 20 years previously had disappeared[15]. Finlayson recognised the combined effects of several coincident factors, particularly the impacts of feral predators, superimposed on an environment over-used by livestock and rabbits. In this section, we consider separately the possible impacts on the mammal fauna of northern Australia of individual threatening factors while acknowledging that combinations of independent and interacting factors are probably also involved in the current decline.

Right:
The nationally endangered Northern Hopping-mouse. [Photo: Frank Woerle/AUSCAPE]

Changed fire regimes

Fire is an inescapable part of the north Australian landscape, driven by an annual long rainless ("dry") season, during which a large biomass of grassy understorey becomes tinder dry. But the regime of fire has changed over the last century causing shifts in vegetation patterning and warping the ecological interactions of many animal species. Prior to European settlement, fire was a carefully honed tool, the major implement of Indigenous land management. Aboriginal people used fire for hunting, for opening up country to allow for easier movement, and for ceremony. Generally, fires were lit with care and close appreciation of environmental conditions, and consequently were typically of low intensity and small in scale, and produced an intricate landscape tapestry, a fine-scaled mosaic of burnt and unburnt areas[16].

The scale of that mosaic has now changed. Across much of the land, fires are now more extensive and burn with greater intensity and frequency. For example, many national parks and Aboriginal lands now have at least 50% of their extent burnt every year[17]. In contrast, in some areas devoted to pastoral production, fire is less frequent, as cattle consume much of the grassy fuel load, and managers may seek to exclude any fire. But some pastoralists have also introduced and spread super grasses, mostly from Africa, that grow far larger than the already impressive native grasses of northern Australia. These "pasture grasses", such as Gamba Grass and Mission Grass, may be highly invasive, and – because of their greater bulk and often later seasonal drying – fuel fires that may be at least five to ten times more intense, and hence destructive, than fires fuelled by native grasses[18].

In response to the change in fire regimes, "fire-sensitive" plants such as the Northern Cypress-pine, and many heathland species, are in broad-scale decline[19], as are many seed-eating birds[20]. The cypress-pines provide a particularly good marker of changed fire regimes, as trees killed by fire may remain standing in the landscape for decades, marking the location of former patches of this species. The evidence of fire's impacts on mammals in northern Australia is far less conspicuous. A basic knowledge of the ecology of mammal species is sufficient to suggest that fire may have an impact. Many species den during the day in thick grass tussocks, hollow logs or tree hollows, and these shelters may be particularly susceptible to intense or frequent fires. The diet of some species, such as possums and tree-rats, comprises a large component of native fruits, mostly from understorey plants. The size and fruit production of these plants is much affected by fire, being highest in long-unburnt areas and lowest in frequently-burnt areas.

Other mammals eat seeds from a range of native grass species. The diversity of grass species, and the seasonal pattern and amount of seeds, may vary substantially with different fire regimes. Notably, perennial grass species (that may be more likely than annual grasses to provide seeds at critical times of year) may be replaced by annual grasses under regimes of frequent fire. Fire will clear the undergrowth, allowing some individual mammal species to hunt and find food more easily but also making them, in turn, more obvious and vulnerable to predators.

Several studies now provide direct evidence of fire impacts on populations of mammals in northern Australia. One study, at Solar Village near Darwin, compared mammals in a forest site that had been protected from fire for 26 years with an adjacent forest site that was exposed to annual burning[21]. As a consequence of the resulting difference in vegetation structure and composition, these neighbouring sites now support very different mammal assemblages, with far more Black-footed Tree-rats and Common Brushtail Possums in the long-unburnt site and far more Northern Brown Bandicoots, Northern Quolls and Pale Field-rats in the frequently burnt site (Fig. 8). One of these sets is not necessarily more desirable than the other: the issue is that different fire regimes will lead to different mammal assemblages, and in the case of northern Australia, fire regimes are becoming increasingly homogenous.

At Kapalga in Kakadu, CSIRO applied a landscape-scale experiment, imposing four different fire regimes (unburnt, annual early dry season fire, annual late dry season fire, and annual progressive fires throughout the year) to large blocks of native forest, over a five-year period[22]. The most detailed analysis for this study considered the Northern Brown Bandicoot, which declined during the study in all four treatments, but especially markedly under the regime of annual late dry season fire. These results suggested that bandicoots prefer a fine-scale mixed fire regime, with small patches of burnt and unburnt vegetation within their territory[23].

Kakadu's extensive monitoring program provides further insight into the impacts of fire. Across a large set of fixed plots monitored at about five-year intervals, the extent of decline in native mammals was significantly related to the number of fires that the plot had experienced in the period between monitoring events, with appreciably more decline in plots that had been burnt most frequently (Fig. 9)[24].

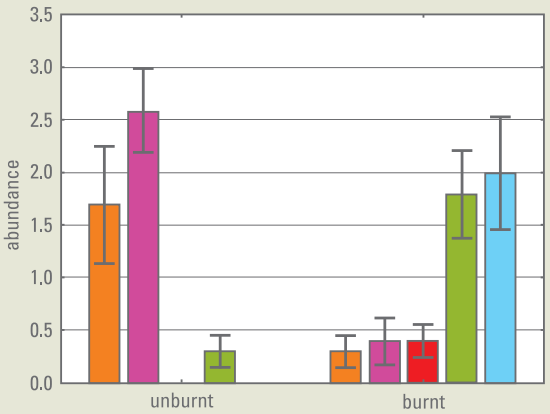


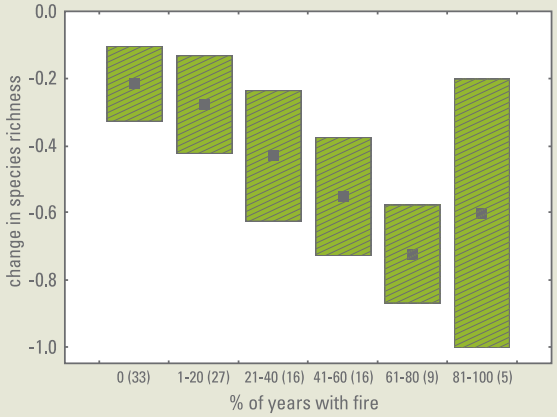
Fig. 8. "Cross-fence" comparison of mammal assemblages at a site from which fire has been excluded for 26 years (left photo) and an adjacent site subjected to annual early dry season fires (right photo) (Solar Village, near Darwin). (Photos: John Woinarski)

Above:
The Northern Brown Bandicoot (top), a species susceptible to annual late season fires. [Photo: Sarah Legge/AWC]

Numbers of Pale Field-rats (middle) have been found to decrease dramatically after extensive late season fires. [Photo: Jiri Lochman/Lochman Transparencies]

Spectacled Hare-wallabies (bottom) have undergone some decline in northern Australia, potentially linked to fire, grazing and predation. [Photo: Jiri Lochman/Lochman Transparencies]

Fig. 9. The relationship between fire incidence and the extent of change in mammal species richness, for 136 fixed monitoring plots sampled in the period 2001-04 and again in the period 2007-09. Small filled square denotes mean change, diagonally hatched box represents one standard error. The number of plots with different fire incidence is listed in brackets along the bottom axis. Note that the index of change can vary from +1 (maximum increase) to -1 (maximum decrease). Source: Woinarski *et al.* (2010).



Another study design has considered a broad-scale survey for individual species, and then related patterns of occurrence or abundance to a range of habitat features, including fire regimes. For many of these studies, such as for the declining Brush-tailed Rabbit-rat, the incidence of fire is a significant factor in explaining the observed pattern of distribution, with sites being exposed to more frequent fires being less likely to support this species[25]. Longer-term population studies of this species have shown negative impacts of individual fires, with resulting population modelling predicting extinction with frequent fires[26].

Table 2. The likelihood of local extinction for Brush-tailed Rabbit-rat at a stronghold site on the northern Australian mainland (Garig Gunak Barlu National Park), under different observed fire regimes (from population viability modelling based on data from intensive field studies[27]).

Fire regime	Likelihood of extinction
no fire	78% within 10 years
late dry season fire in 10% of years	89% within 10 years
late dry season fire in 30% of years	97% within 10 years
annual late dry season fires	100% within 10 years

The link between fire and mammal declines is not confined to research from the Northern Territory. A study at Mornington Sanctuary in the Kimberley sampled the species richness and abundance of mammals in burnt areas and the few remnant patches of unburnt vegetation after late dry season fire. Both richness and abundance were much lower at burnt sites within five weeks of the fire[28]. Indeed, populations of the two largest rodent species (Pale Field-rats and Western Chestnut Mice) were reduced by 90%. With this level of impact, fire regimes characterised by regular, extensive and intense fires would soon virtually remove small mammal populations over large landscapes.

Taken together, these studies demonstrate that the native mammals of northern Australia are much affected by fire, and that frequent, intense and large-scale fires will drive declines. The evidence suggests that managers should seek to reduce the scale and intensity of fires so that burnt patches are on a scale of hectares rather than hundreds of square kilometres.

Right:
Small, low-intensity and patchy fires in the early dry season such as this one, are likely to be more favourable for maintaining mammal populations than large, intense late season burns. [Photo: Wayne Lawler/AWC]

Cats

In many other parts of Australia, there is clear evidence that non-native predators (cats and foxes) have been the major cause of decline of native mammal species. However, most of the north (other than its lower rainfall fringe) is without foxes. Direct evidence of the role of feral predators in Australia's mammal decline comes mostly from fencing ("exclosure") studies, mammal responses to broad-scale predator baiting, and radio-tracking studies of native mammals[29]. Indirect evidence comes from the survival of many native mammal species on islands without non-native predators, contrasting to their extinction from their former mainland ranges[30].

Systematic, intensive studies of introduced predators in northern Australia have begun only recently. Nonetheless, there is substantial inferential support for the role of feral cats in the decline of mammals in northern Australia. The most compelling evidence is the relatively good survival on cat-free north Australian islands of some species that have declined catastrophically on the nearby mainland. Notable examples include the Golden Bandicoot and Brush-tailed Rabbit-rat[31]. Perhaps even more compelling is the high likelihood that some native mammal species have become regionally extinct from islands in the Sir Edward Pellew group (Gulf of Carpentaria area) in the last two to three decades, following the release of cats to these islands[32].

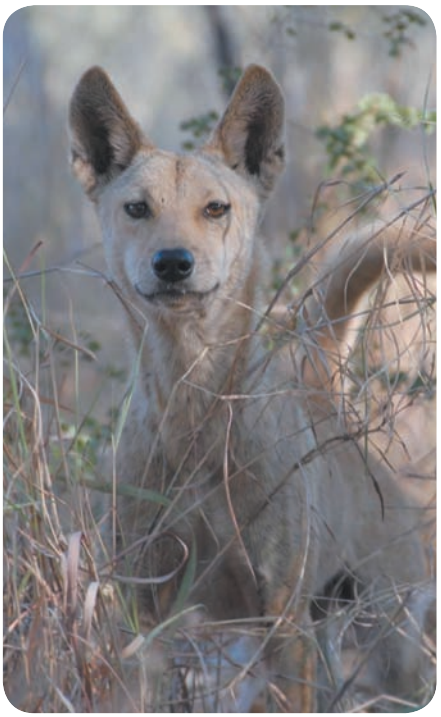
There have been some reservations in linking the predation by feral cats with the current decline of native mammals in northern Australia given the relatively long history of more than 100 years of cats in this region – the timing may seem wrong. Although there is little evidence for or against this argument, it may be countered by suggesting a recent increase in the abundance and distribution of feral cats or an increase in the efficiency of cat predation on native mammals (most likely through increased extent of open burnt areas). It is possible that a recent increase in feral cat numbers may be due to widespread baiting of Dingoes, the Aboriginal outstation movement of the 1960s (which resulted in some introductions of cats to very remote areas), or reductions in the native competitor, the Northern Quoll. It could also be that cats are simply accentuating the pressure of other recent threats on native mammals and killing off the last animals in dwindling populations.

Disease

Disease may be a factor contributing to the current mammal decline in northern Australia. Elsewhere, a particularly virulent, conspicuous and deforming disease is now driving one of southern Australia's most charismatic mammals, the Tasmanian Devil, towards extinction. The extinction of two endemic rodents on Christmas Island was caused by disease, introduced by non-native Black Rats[33]. However, the role and extent of disease in contributing to mammal decline in northern Australia is still being debated and losses of small, nocturnal native mammals because of disease may be very difficult to notice or prove.

There are two pieces of evidence supporting a role for disease. Firstly, as noted above, many native mammals have persisted better on islands than on the mainland. This may be because the islands are without feral cats, but it could also be because isolation may have prevented the spread of disease to those islands. Secondly, there is some evidence of an increase in the incidence of non-native Black Rats across northern Australia, including into conservation reserves and to some areas remote from infrastructure and other disturbance. Black Rats are well-known carriers of many diseases, including some diseases for which Australian mammals may have had little or no immunity.

A counter-argument may be that it is unlikely that any such novel disease would affect the wide taxonomic range exhibited by declining mammals in northern Australia. To attempt to provide more evidence on a possible role of disease, a current research project is examining the disease complement of Black Rats in Darwin and Kakadu, and comparing this with native mammal species.



Grazing

Introduced large herbivores are found across northern Australia in all tenures, including conservation reserves, and usually at high densities[34]. Cattle, horses, donkeys and pigs are widespread; swamp buffalo, banteng and various deer species occur with more limited distributions.

Introduced herbivores could affect native mammals in several ways. Trampling and soil compaction makes life harder for animals that live under the surface (such as planigales) or that dig into the soil; grazing reduces the grass and seed that native mammals eat[35] and simplifies the structure of vegetation in a way that increases exposure to predators[36].

Research from African and North American savannas has shown that small mammal abundance and species richness is reduced in the presence of large herbivores[37]. In addition, studies of responses to livestock grazing in Australian arid zones have also demonstrated an impact on small mammals[38].

There has been relatively little research on this issue in northern Australia. Studies in blacksoil grasslands on the southern margin of the tropical savannas showed that the abundance of one mammal species declined with increasing grazing intensity (although all mammals were sparse)[39]. Reasonably limited sampling (single surveys at fewer than 30 sites) in two studies in Queensland tropical savannas showed that mammals were more abundant at ungrazed sites[40], and there was a significant negative relationship with increased grazing for abundance of two mammal species[41]. Two large-scale grazing trials also found a muted response of mammals to variation in stocking rate or cattle exclusion[42].

The strongest evidence for negative impacts from introduced herbivores comes from a landscape-scale destocking experiment carried out at Mornington Sanctuary, which showed that mammal abundance in a 40,000 hectare fenced area doubled in three years, following the removal of cattle, horses and donkeys (Fig. 10).

Left:
Cats are a known cause of mammal decline in many parts of Australia [Photo: Australian Wildlife Conservancy], and have potentially increased in numbers resulting from the baiting of Dingoes. [Photo: Peter Rothlisberg/AWC]

Opposite right:
Cane Toads (top) are known to have caused widespread declines of the Northern Quoll. [Photo: Sarah Legge/AWC]

The impact of the Cane Toad on other carnivorous marsupials, such as the Northern Brush-tailed Phascogale (middle), is not well known. [Photo: Frank Woerle/AUSCAPE]

Swamp Buffalos (bottom) and other feral herbivores have a range of negative impacts on small mammal habitat. [Photo: Sarah Legge/AWC]

Right:
Introduced herbivores concentrate at wetlands and can cause substantial damage, reducing the habitat quality for native species. [Photo: Wayne Lawler/AWC]

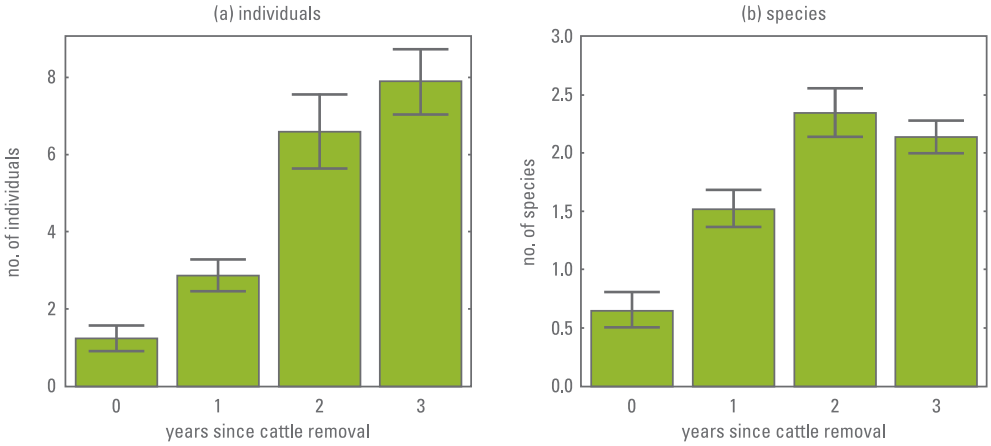


Fig. 10. Response of native mammals to removal of cattle at fixed sampling points within Mornington Sanctuary, in the Kimberley, Western Australia: (a) number of native mammal individuals per plot, and (b) number of native mammal species per plot. (S. Legge, unpublished data).

Cane Toads

Cane Toads were introduced to Australia in 1935 and have since spread rapidly across Queensland, and – over the last 20 years – across the Top End of the Northern Territory. They have now reached the east Kimberley, and are likely to colonise all of the Kimberley mainland by about 2015. They are now amongst the most abundant of all vertebrates in northern Australia, and occupy most habitats. Cane Toads are voracious predators, and consume many native species, but their major impact is through poisoning of animals that seek to eat them. Some species are particularly susceptible because their normal diet includes frogs, they have little or no resistance to the toad toxin, or they attack toads in a particular way (notably by biting at the neck, where the main poison glands lie). The Northern Quoll has proven to be the native mammal most at risk from toads, with most populations disappearing within a few years of toad arrivals[43]. Over the last 20 years, its population in the mainland Top End of the Northern Territory has declined from about 1 million to perhaps, at most, a few hundred. No other mammal species has been so obviously affected by Cane Toads, although in part this may be because there is little information available for some rarer native mammals that may attack Cane Toads (such as the Northern Brush-tailed Phascogale).

Notwithstanding its catastrophic recent collapse, there is some hope for the Northern Quoll. Some populations are known to have persisted with toads in Queensland, mostly in more rugged rocky areas. Also, quolls are known to inhabit about 20 islands off the north Australian coast, and these islands may prove harder for toads to reach.

However, toads are indomitable and inventive travellers and have even rafted on floodwaters to all the islands in the Sir Edward Pellew group in the Gulf of Carpentaria. Their arrival there probably caused the local extinction on Vanderlin Island of the only quoll population in that group of islands.

Interactions of the above factors

Combinations of independent and interacting factors are probably also involved in the current decline of many of the northern Australian mammal species. For example, cat predation is likely to be more substantial in frequently and extensively burnt areas, cat numbers may increase because of cane toads (reducing some native predators) or with Dingo-baiting associated with pastoralism, and cats may spread some novel diseases.

Likewise, fire regimes will be different in areas under intensive pastoral management compared to areas without such management. Invasive pasture grasses often associated with pastoralism will change fire regimes and may produce a fire-grass vortex. Cats may hunt most effectively in heavily stocked areas, may concentrate around artificial water sources, and may increase in abundance because of Dingo-baiting.

Elsewhere, Cane Toad numbers may increase in more heavily grazed areas and in more extensively burnt areas, while disease may be more serious if native mammals are already stressed by other factors. The role of these various interactions requires further research.

The importance of maintaining Australia's mammal species

Why should we care if there are no more Northern Quolls, Golden Bandicoots, Brush-tailed Rabbit-rats or Spectacled Hare-wallabies? There are several compelling answers to this question.

1. Our society has created national, state and territory legislation and signed international commitments that oblige us to conserve our biodiversity.
2. The nature-based tourism sector contributes $23 billion to the Australian economy each year. The ability to see or learn about Australian wildlife is an essential component of this sector. Losing mammal species comes at a significant risk to Australia's reputation as a 'clean, green' nation that conserves its unique wildlife.
3. The decline of native mammals in northern Australia may be a signal of looming environmental decay, the first and most obvious indicator of more pervasive ecological ill-health. The factors that affect these species are likely to be affecting, perhaps more gradually, other components of biodiversity. By addressing the causes of mammal decline, we may also prevent other impending – but currently far less evident – losses. In this context, it is notable that there is increasing evidence of declines in some birds, plants and other groups across much of northern Australia.
4. Our native mammal species, along with other biodiversity, play useful and integral roles in maintaining ecological processes that also collectively underpin human life.
5. Our native mammal species, along with other biodiversity, have intrinsic value and the right to exist.
6. These species have value to many people, aesthetically and out of interest in our surrounds. Their value may be especially existential and significant for Aboriginal people, for many of these mammals are important threads in the fabric of life's meaning, totemic, part of the immemorial story that connects people with their origins and their environment, and part of the responsibility to pass on the heritage for future generations. The loss of these species can tear the cultural connections, another impairment in the erosion of Indigenous culture.
7. We should mark our character as a nation by the way we value, cherish and enrich our heritage, the way we can develop responsibly and sustainably. Ongoing diminution and degradation of our natural environment sullies our stewardship and marks us as poor managers of our land.
8. On a world stage and in our national psyche, our remote wild lands are an extraordinary asset, one of the world's last great natural systems. Our appreciation of these lands becomes far more hollow if it is evident that the 'naturalness' is but a veneer masking ecological dysfunction and losses of key species.

We should accept responsibility. We now know that these species are declining. We cannot pretend that it is not happening, or that maybe they will hang on a little longer and disappear on someone else's watch. We have the capability to conserve them – they are not declining due to "natural" processes or lack of evolutionary vitality. Rather, they are disappearing because of what we have done to their environment, because of a small range of factors that should be within our understanding and budget to reverse, manipulate and manage.

How to respond to these looming extinctions?

If we accept that our society recognises a responsibility to conserve the Northern Quoll, Golden Bandicoot, Brush-tailed Rabbit-rat or Spectacled Hare-wallaby and the many other declining species in northern Australia, then what needs to be done? In this section, we outline the steps towards a solution.

Above from top:
The mostly nocturnal and semi-arboreal Brush-tailed Rabbit-rat. [Illustration: Frank Knight]

Rock Ringtail Possum depicted in rock art, west Arnhem Land. Many mammal species have particular significance for Indigenous people of northern Australia. [Photo: James Fitzsimons/TNC]

1. Manage now, based on best evidence, even if more research needs to be done. Targeted management based on the currently available evidence is urgently required. In this case, the available evidence suggests that native mammals are most likely to survive in northern Australia if:
   - The size and intensity of fire is reduced so that fires occur in fine-scale mosaics;
   - Feral cats are more effectively controlled, through intensive cat management (targeted baiting), exclosure fences and/or reduction in Dingo controls;
   - Numbers of feral herbivores are reduced and cattle are better managed;
   - These management actions do not necessarily need to be implemented across all of northern Australia, but will be most strategic and effective if directed to priority areas that still retain most native mammals.

Above from top:
Small mammal monitoring at Piccaninny Plains, Cape York Peninsula. [Photo: Zoe Davies/TNC]

Effective management across multiple tenures is required to ensure the survival of northern Australia's unique mammal species (middle and bottom). [Photos: Glenn Walker/TWS]

- Wherever possible, such management should be accountable, that is, tied to specific conservation objectives and accompanied by monitoring of the management performance.

2. Define exactly what is causing the problem. Broadly, the more certain we are about the causes of mammal (or any other) decline, the stronger and more effective the management response will be. Managers will also be more willing to invest in expensive actions if the justification for such action is strong.

   - Despite much good ecological research in northern Australia, there is an urgent need for additional targeted studies, particularly into the extent and impact of cat predation and the incidence of disease.

   - Cost-benefit analyses are also required to indicate and allow best choices amongst different options to manage these and other threats; that is, which threats have the most impact on which species, and which management responses are most cost-efficient and effective?

3. Integrated monitoring. Monitoring has been a largely neglected component of Australia's environmental management.

   - For the mammals of northern Australia, there is an urgent need for more comprehensive and long-term monitoring programs, coordinated across the Northern Territory, Western Australia and Queensland: (a) to gain a clearer picture of the conservation trends and status of many species, (b) to measure management performance, (c) to provide early warnings of new problems, and (d) to more closely relate changes in abundance to particular factors.

   - The results of monitoring and other research need to better inform and influence management practices.

Northern Australia offers a number of other features that need to be considered within the solution to this conservation problem.

- It has a series of large and rugged islands that may offer particular security to many mammals from factors that are causing their decline in mainland areas. Australian islands in general have served as "lifebuoys" to many mammal species that have otherwise disappeared from formerly extensive mainland ranges. The priority for mammals on these islands is to enhance their quarantine security, in order to prevent unwanted introductions of toads, cats or disease.

- Indigenous Australians own much of northern Australia. Through innovative policy, we are witnessing a revolution in land management across vast extents of this area, through the establishment of Indigenous protected areas (IPAs) and Indigenous ranger groups. This new approach to land management has seen the establishment of 38 IPAs, which now make up 23% of Australia's National Reserve System, and the reintroduction of traditional fire and other management practices. This development has been a successful mechanism to address social and economic disadvantage in Indigenous communities and potentially offers substantial gains for biodiversity with targeted and accountable management.

- Non-government conservation groups have recently become holders of large, ecologically-important tracts of former pastoral lands in northern Australia. In most cases, this has resulted in the removal of introduced herbivores, including feral cattle, and changes in fire management. The benefits to native mammals of these changes have been well-demonstrated through monitoring.

- Many pastoral enterprises in northern Australia are now either voluntarily, or through changes in government policy and legislation, accepting responsibility for environmental outcomes on their lands. In part, this is because there may be more options for income associated with environmental care, from conservation covenants, green-branding, or carbon markets.

- National parks have increased in number and size in northern Australia, and in some cases, are managed with more explicit conservation targets. The information collected in Northern Territory parks from monitoring studies on native mammals demonstrates that the establishment of parks and conservation reserves are important for biodiversity conservation. However, parks will lose their biodiversity just as much as non-reserved areas, unless they are managed effectively and with explicit conservation targets.

Northern Australia is a vast natural landscape, and management focused on only individual properties or parks within that landscape will largely fail. More than most other places in Australia, or the world, northern Australia remains an extensive interconnected system, making a collaborative approach to land management critical. For northern Australia's mammals, this collaboration must occur across neighbouring properties and regions, including national parks, Indigenous Protected Areas, covenants on pastoral lands, non-government reserves and other private landholdings and include effective management of native wildlife, fire, weeds, feral animals and other threats.

Table 3 – Conservation status of northern Australia's mammal species.

COMMON NAME	SCIENTIFIC NAME	TRENDS FOR NORTHERN AUSTRALIAN MAMMALS	CURRENT STATUS OF LISTED SPECIES					RANGE (IF NOT TRULY SAVANNA)
			2008 IUCN	NATIONAL	WA (KIMBERLEY)	NT (TOP END)	QLD (NORTH)	
Platypus	*Ornithorhynchus anatinus*		LC					East
Short-beaked Echidna	*Tachyglossus aculeatus*	Stable	LC			LC		
Kultarr	*Antechinomys laniger*		LC			NT (EX)		South
Rusty Antechinus	*Antechinus adustus*		LC					East/Rainforest
Fawn Antechinus	*Antechinus bellus*	Some decline	LC			DD		
Yellow-footed Antechinus	*Antechinus flavipes*		LC					East
Atherton Antechinus	*Antechinus godmani*		NT					East/Rainforest
Cinnamon Antechinus	*Antechinus leo*		LC					East/Rainforest
Northern Quoll	*Dasyurus hallucatus*	Marked decline	EN	EN	EN	CR		
Spot-tailed Quoll	*Dasyurus maculatus*		NT	EN			EN	East/Rainforest
Brush-tailed Phascogale	*Phascogale tapoatafa*	Some decline	NT					
Northern Brush-tailed Phascogale	*Phascogale pirata*	Marked decline	VU	VU		VU		
Long-tailed Planigale	*Planigale ingrami*	Stable	LC			LC		
Common Planigale	*Planigale maculata*	Stable	LC			LC		
Sandstone False Antechinus	*Pseudantechinus bilarni*	Some decline	NT			DD		
Carpentarian False Antechinus	*Pseudantechinus mimulus*	Some decline	EN	VU		EN		
Ningbing False Antechinus	*Pseudantechinus ningbing*	Uncertain	LC			NT		
Chestnut Dunnart	*Sminthopsis archeri*	Uncertain	DD					
Kakadu Dunnart	*Sminthopsis bindi*	Uncertain	LC			DD		
Butler's Dunnart	*Sminthopsis butleri*	Some decline	VU		VU	VU		
Fat-tailed Dunnart	*Sminthopsis crassicaudata*		LC					South-east
Julia Creek Dunnart	*Sminthopsis douglasi*		NT	EN			EN	South-east
White-footed Dunnart	*Sminthopsis leucopus*		VU					East/Rainforest
Stripe-faced Dunnart	*Sminthopsis macroura*	Stable	LC			LC		
Common Dunnart	*Sminthopsis murina*		LC					East
Red-cheeked Dunnart	*Sminthopsis virginiae*	Some decline	LC			DD		
Lesser Hairy-footed Dunnart	*Sminthopsis youngsoni*		LC					South-west
Rufous Spiny Bandicoot	*Echymipera rufescens*		LC					East/Rainforest
Golden Bandicoot	*Isoodon auratus*	Marked decline	VU	VU	VU	EN		
Northern Brown Bandicoot	*Isoodon macrourus*	Some decline	LC			LC		
Southern Brown Bandicoot	*Isoodon obesulus*		LC					East
Long-nosed Bandicoot	*Perameles nasuta*		LC					East
Bilby	*Macrotis lagotis*		VU		VU		EN	South
Northern Marsupial Mole	*Notoryctes caurinus*		DD	EN	VU			South
Northern Hairy-nosed Wombat	*Lasiorhinus krefftii*		CR	EN			EN	East
Koala	*Phascolarctos cinereus*		LC					
Southern Common Cuscus	*Phalanger intercastellanus*		LC					East/Rainforest
Common Spotted Cuscus	*Spilocuscus maculatus*		LC					East/Rainforest
Common Brushtail Possum	*Trichosurus vulpecula*	Marked decline	LC			LC		
Scaly-tailed Possum	*Wyulda squamicaudata*	Stable	DD					
Long-tailed Pygmy Possum	*Cercartetus caudatus*		LC					East
Common Striped Possum	*Dactylopsila trivirgata*		LC					East/Rainforest
Yellow-bellied Glider	*Petaurus australis*		LC	VU*			VU	East
Sugar Glider	*Petaurus breviceps*	Stable	LC			LC		
Mahogany Glider	*Petaurus gracilis*		EN	EN			EN	East
Squirrel Glider	*Petaurus norfolcensis*		LC					East
Lemuroid Ringtail Possum	*Hemibelideus lemuroides*		NT					East/Rainforest
Greater Glider	*Petaurus volans*		LC					East
Rock Ringtail Possum	*Petropseudes dahli*	Uncertain	LC			LC		
Common Ringtail Possum	*Pseudocheirus peregrinus*		LC					East
Green Ringtail Possum	*Pseudochirops archeri*		LC					East/Rainforest
Daintree River Ringtail Possum	*Pseudochirulus cinereus*		LC					East/Rainforest
Herbert River Ringtail Possum	*Pseudochirulus herbertensis*		LC					East/Rainforest
Feathertail Glider	*Acrobates pygmaeus*		LC					East
Musky Rat-kangaroo	*Hypsiprymnodon moschatus*		LC					East/Rainforest
Rufous Bettong	*Aepyprymnus rufescens*		LC					East
Burrowing Bettong	*Bettongia lesueur*	Extinct	NT	EX*	EX			
Northern Bettong	*Bettongia tropica*		EN	EN			EN	East
Bennett's Tree-kangaroo	*Dendrolagus bennettianus*		NT					East/Rainforest
Lumholtz's Tree-kangaroo	*Dendrolagus lumholtzi*		LC					East/Rainforest
Spectacled Hare-wallaby	*Lagorchestes conspicillatus*	Some decline	LC			NT		

The mammal species of northern Australia, their population trends and current listing under threatened species legislation is presented above. Listing the mammal fauna of northern Australia is not a clearcut issue. Northern Australia does not have a single clearly defined boundary. However, biologists have identified broad regionalisations for Australian biodiversity, including a "Torresian" zone that corresponds to northern Australia. As rainfall declines at its southern (inland) edge, this zone blurs into a more arid "Eyrean" zone, and some mammals that are characteristic of Australia's arid or semi-arid zone occur in the southern fringes of northern Australia – for example, the Bilby extends to the Dampier Peninsula (near Broome, in north-western Australia). In north-eastern Australia, there may be an even more complex mix of faunas from different evolutionary areas, with extensions northwards of many species whose stronghold is in south-eastern Australia, and pockets of more typically New Guinean species occurring in rainforests of Cape York Peninsula. For those species that can be considered core representatives of the mammal fauna of north Australian savanna habitat, we assess their trends as either uncertain, or probably stable, or probably showing some local or moderate decline, or showing marked and extensive decline. Bats and marine mammals have not been included in this listing.

(continued)

COMMON NAME	SCIENTIFIC NAME	TRENDS FOR NORTHERN AUSTRALIAN MAMMALS	CURRENT STATUS OF LISTED SPECIES					RANGE (IF NOT TRULY SAVANNA)
			2008 IUCN	NATIONAL	WA (KIMBERLEY)	NT (TOP END)	QLD (NORTH)	
Agile Wallaby	*Macropus agilis*	Stable	LC			LC		
Antilopine Wallaroo	*Macropus antilopinus*	Some decline	LC			LC		
Black Wallaroo	*Macropus bernardus*	Uncertain	NT			DD		
Black-striped Wallaby	*Macropus dorsalis*		LC					South-east
Eastern Grey Kangaroo	*Macropus giganteus*		LC					East
Whiptail Wallaby	*Macropus parryi*		LC					East
Euro	*Macropus robustus*	Stable	LC			LC		
Red Kangaroo	*Macropus rufus*		LC			LC		
Bridled Nailtail Wallaby	*Onychogalea fraenata*		EN	EN			EN	East
Northern Nailtail Wallaby	*Onychogalea unguifera*	Uncertain	LC			NT		
Allied Rock Wallaby	*Petrogale assimilis*		LC					East
Short-eared Rock-wallaby	*Petrogale brachyotis*	Stable	LC			LC		
Monjon	*Petrogale burbidgei*	Uncertain	NT					
Cape York Rock-wallaby	*Petrogale coenensis*		NT					East
Nabarlek	*Petrogale concinna*	Some decline	DD			NT		
Godman's Rock-wallaby	*Petrogale godmani*		LC					East
Herbert's Rock-wallaby	*Petrogale herberti*		LC					East
Unadorned Rock-wallaby	*Petrogale inornata*		LC					East
Black-footed Rock-wallaby	*Petrogale lateralis*		NT	VU*	VU			South-west
Purple-necked Rock-wallaby	*Petrogale purpureicollis*	Uncertain	LC				VU	
Mareeba Rock-wallaby	*Petrogale mareeba*		LC					East
Proserpine Rock-wallaby	*Petrogale persephone*		EN	EN			EN	East
Sharman's Rock-wallaby	*Petrogale sharmani*		LC				EN	East
Red-legged Pademelon	*Thylogale stigmatica*		LC					East
Black Wallaby	*Wallabia bicolor*		LC					East
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	Marked decline	NT	VU		VU		
Water Rat	*Hydromys chrysogaster*	Stable	LC			LC		
Desert Short-tailed Mouse	*Leggadina forresti*		LC			LC		South
Tropical Short-tailed Mouse	*Leggadina lakedownensis*	Uncertain	LC			LC		
Grassland Melomys	*Melomys burtoni*	Stable	LC			LC		
Cape York Melomys	*Melomys capensis*		LC					East
Fawn-footed Melomys	*Melomys cervinipes*		LC					East/Rainforest
Bramble Cay Melomys	*Melomys rubicola*		CR	EN			EN	East
Black-footed Tree-rat	*Mesembriomys gouldii*	Marked decline	NT			NT		
Golden-backed Tree-rat	*Mesembriomys macrurus*	Marked decline	LC	VU		CR		
Spinifex Hopping-mouse	*Notomys alexis*		LC			LC		South
Northern Hopping-mouse	*Notomys aquilo*	Uncertain	EN			VU	VU	
Prehensile-tailed Rat	*Pogonomys mollipilosus*							East/Rainforest
Kakadu Pebble-mound Mouse	*Pseudomys calabyi*	Stable	VU			NT		
Delicate Mouse	*Pseudomys delicatulus*	Stable	LC			LC		
Desert Mouse	*Pseudomys desertor*		LC			LC		South
Eastern Chestnut Mouse	*Pseudomys graciliicadatus*		LC					East
Sandy Inland Mouse	*Pseudomys hermannsburgensis*		LC			LC		South
Central Pebble-mound Mouse	*Pseudomys johnsoni*	Uncertain	LC			NT		
Western Chestnut Mouse	*Pseudomys nanus*	Some decline	LC			NT		
Eastern Pebble-mound Mouse	*Pseudomys patrius*		LC					East
Dusky Rat	*Rattus colletti*	Some decline	LC			LC		
Bush Rat	*Rattus fuscipes*		LC					East
Cape York Rat	*Rattus leucopus*		LC					East/Rainforest
Swamp Rat	*Rattus lutreolus*		LC					East
Canefield Rat	*Rattus sordidus*	Stable	LC			VU		
Pale Field-rat	*Rattus tunneyi*	Marked decline	LC			NT		
Long-haired Rat	*Rattus villosissimus*		LC			NT		South
Giant White-tailed Rat	*Uromys caudimaculatus*		LC					East/Rainforest
Masked White-tailed Rat	*Uromys hadrourus*		VU					East/Rainforest
Water Mouse (False Water-rat)	*Xeromys myoides*	Uncertain	VU	VU		DD	VU	
Common Rock-rat	*Zyzomys argurus*	Stable	LC			LC		
Arnhem Land Rock-rat	*Zyzomys maini*	Some decline	NT	VU		VU		
Carpentarian Rock-rat	*Zyzomys palatalis*	Marked decline	CR	EN		CR		
Kimberley Rock-rat	*Zyzomys woodwardi*	Uncertain	LC					

Trends for Northern Australian mammals column based on published sources, extensive monitoring data for some regions and expert opinion arising from the Northern Australian Mammal Decline Workshop, 10-11 February 2009 (see www.savanna.org.au/all/decline_workshop.html). Trends for species with marginal ranges in the northern Australian savannas were not assessed.

Current status of listed species:

- International status based on the International Union for Conservation of Nature (IUCN) 2008 Red List of Threatened Species
- National status as listed under the *Environment Protection and Biodiversity Conservation Act 1999;* * relates to particular subspecies listing
- Northern Territory status as listed under regulations of the *Territory Parks and Wildlife Conservation Act 2000*
- Queensland status as listed under the *Nature Conservation Act 1992*
- Western Australian status based on WA Department of Environment and Conservation assessments of species listed under the *Wildlife Conservation Act 1950*
- Threat status codes: EX = Extinct, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient, LC = Least Concern.

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Cover Photo: The Nabarlek, a small rock-wallaby of the Top End and Kimberley, has undergone recent declines in parts of its range. [Photo: Jiri Lochman/Lochman Transparencies]

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