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Improving biodiversity conservation in northern Australia

kakadu NATIONAL PARK

A strategy for the conservation of threatened species and threatened ecological communities in Kakadu National Park | 2014-2024

By J.C.Z. Woinarski and S. Winderlich - October 2014

Vision:

Kakadu National Park will be celebrated as a place in which management provides for the effective conservation of threatened species.

Acknowledgements

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The strategy will be progressively implemented by Kakadu National Park over 10 years. Some recommendations are already being implemented, while others require further planning and consultation.

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Kakadu landscapes by Professor Michael Douglas

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Yellow Snouted Gecko - *Lucasium occultum*

Photo: Anne O'Dea

Summary

This strategy underpins relevant components of the Kakadu National Park Management Plan 2014-2024, particularly the theme (5.2) of Looking after Country, with its objective to:

maintain the condition of the park's natural values, and support the recovery of threatened species.

This strategy aspires to the vision that:

Kakadu National Park will be celebrated as a place in which management provides for the effective conservation of threatened species

and the overall objective that:

Population trends for all threatened species in Kakadu are demonstrably stable or increasing.

This strategy has been developed in recognition that Kakadu holds important populations of very many species of threatened plants (15) and animals (60) – probably more than any other conservation reserve in Australia – and that this complement of threatened species is of international significance. Consequently the conservation of these threatened species represents a primary opportunity and responsibility for Park management.

This recognition has been long-standing and has been considered in previous Plans of Management and planning documents for threatened species in Kakadu. Notwithstanding such consideration, the status of many threatened species in Kakadu is declining, and trends for many other threatened species are unknown. This strategy works from the assumption that substantial changes are required in order to improve on this situation.

The challenge of this conservation management is profound. The range of threatened species is extremely varied, including, for example, highly localised fire-sensitive plants (and a threatened ecological community) in the Stone Country, endemic shrimps that may be susceptible to cane toads and that occur in only a few headwater pools, intercontinental migratory shorebirds, a set of rapidly declining woodland mammal species (including some species not recorded for Kakadu for many decades), an orchid known in Kakadu from only one rainforest patch, estuarine sharks and sawfish, and marine turtles. The range of threats is also extremely varied, including inappropriate fire regimes, predation by feral cats, invasive grassy weeds, predation and habitat degradation due to feral pigs, climate change and poisoning by cane toads. To add to the management challenge, many of these factors operate interactively in a synergistic or compound manner.

There are many options for responsive management to the diverse set of threats, but inevitably the choices are constrained by resources, and some threats may have no practical or effective solutions, at least in the short-term. Many threatened species – and their threats and their responses to management – are very poorly known, and this lack of knowledge may severely impair managers' capability to make optimal choices about management input, and may constrain the effectiveness of any applied management actions.

This strategy identifies those threatened species that should be priorities for management attention, due to a range of ecological, taxonomic, cultural and other values, including the extent to which conservation actions in Kakadu can contribute to the conservation outlook for the species across its entire range. This strategy also prioritises species for management attention and intervention based upon an analysis of experts' opinion on the likelihood of their persistence over a 20-year period in Kakadu with and without management actions.

This strategy identifies those management actions that are most likely to produce the best overall benefit for threatened species, and the optimal sets of management actions to collectively achieve most benefit within a range of budget options. The management actions that can achieve most substantial benefit, and/or most cost-effectiveness for the conservation of threatened species in Kakadu comprise:

(i) enhanced fire management in the lowlands, particularly to achieve a finer-scale mosaic of burning, and an increase in the extent of longer-unburnt woodlands;

(ii) maintenance or enhancement of the current fire management strategy in the Stone Country, with particular intensive management of areas known to contain highly localised threatened species;

(iii) maintenance of gamba grass control;

(iv) targeted management of feral cats, most realistically through maintenance or increase in the extent of predator-proof fenced areas, but potentially (contingent on results from specific research) through intensive baiting programs;

(v) staged reintroductions of several mammal species that have probably disappeared from Kakadu;

(vi) collection and maintenance of ex situ populations of threatened plant species and, where appropriate, their staged reintroduction;

(vii) at least localised intensive control of pigs, at sites of conservation significance (e.g. rainforest patches that may have the orchid *Dienia montana,* and turtle nesting areas); and

(viii) maintenance or enhancement of constraints on fishing activities that may be detrimental to sawfish and river sharks.

The management response for threatened species in Kakadu should not be seen as an isolated set of actions, but rather as a key component of an adaptive management process that also includes:

- the identification and enactment of research priorities, designed particularly to enhance management effectiveness;
- an integrated and systematic monitoring program that includes sufficiently powerful and sensitive measurement of management performance and the response of threatened species;
- reporting, and structured and ongoing review.

Furthermore, the management of threatened species in Kakadu should be an integral part of a broader management fabric, through the Plan of Management and other processes, such that the conservation of threatened species is an explicit and key component of, and is hard-wired into, complementary strategies for fire, feral animals, weeds, tourism and other issues – because a fundamental and explicit purpose of such management should be for the conservation of threatened species.

Additionally, although there is an unusually high number of threatened species that are endemic (or largely endemic) to Kakadu, most threatened species also occur beyond Kakadu, and the conservation outlook for these species will be enhanced if actions taken in Kakadu are complemented by actions taken elsewhere in the species' range. To this end, Kakadu conservation managers should seek effective collaborations with other landholders and agencies for recovery programs including landscape-wide management of threats, research and monitoring.

Consonant with the Plan of Management and other practice, there are also a series of principles that underpin this strategy. These include that:

- Bininj are appropriately involved in and instrumental to the operation of this strategy;
- actions taken are realistic and appropriately prioritised;
- the management and resourcing systems are as appropriately tailored for the task as possible;
- the greatest possible conservation gain is sought and achieved within the available resources;
- if in situ management is likely to fail, then adequate ex situ back-up is considered and/or provided;
- collaborative networks (notably with neighbours, relevant Northern Territory government agencies, and research institutions) are developed and employed;
- although the overall process is as collaborative as possible, there is also a clear line of responsibility and accountability; and
- the process invites external advice and is transparent, with outcomes regularly publicly reported.

Increased accountability is a fundamental requirement for this strategy. One mechanism to enhance this accountability is for the establishment of an external or independent review or advisory group of relevant experts and stakeholders (a 'Recovery Team' or equivalent) responsible for regular review of progress of this strategy. Such a group could be newly constituted or operate within the already established Kakadu Research Advisory Committee (KRAC), and would report directly or through KRAC to the Kakadu Board of Management.

This strategy proposes the establishment of explicit targets for conservation for every threatened species and for the conservation of threatened species generally, with the establishment of robust monitoring programs that measure performance relative to those targets. It proposes a system of reporting on those monitoring results, with annual review amongst managers and other stakeholders of performance relative to targets.

Accountability for this strategy and for delivering threatened species outcomes will also be made more explicit and effective through review of the Park's current staffing and budgetary structures. Currently, there is no dedicated staff position with sole responsibility for the conservation of threatened species, nor is there a dedicated budget for threatened species, nor an annual public process for reporting on overall performance in the conservation of the Park's threatened species.

Additionally, more effective conservation management of threatened species in Kakadu requires a substantial enhancement of data base systems and GIS and IT capability. It also requires that information about threatened species is more strategically and routinely provided to and by field staff and others; and that information about threatened species is made far more widely available and regularly used by managers as a basis for their work.

Where the information is available, the current trends for threatened species in Kakadu are more of decline than of increase. This strategy proposes some different and more efficient ways of management to attempt to improve that performance. However, to make a substantial difference, there is a need for more resources dedicated to the conservation management of threatened species in Kakadu. Recognising that budgets have many constraints, this strategy is informed by a cost-benefit analysis designed to prioritise management actions, across a range of financial investments.

The recovery of threatened species that have declined or the ongoing stabilisation of threatened species that are at risk is a long-term commitment. Many of the factors that cause endangerment are now deeply rooted and pervasive, and their control is not amenable to short-term responses. This strategy represents a foundation for long-term management. It aims to operate over a 10-year timeframe, with regular review and recalibration of operational priorities at annual and 3-year periods.

Summary table of principal conservation management actions

This strategy includes detailed consideration of research priorities, monitoring priorities, organisational structure, external advice, species' prioritisation and other matters, reflecting that conservation management is multi-dimensional. However, a major interest lies in what managers should be doing in relation to major threats, because most of the resources that Kakadu can devote to threatened species' conservation lie with the on-ground management work of rangers.

This strategy recognises that the most efficient and effective approach to conservation of Kakadu's threatened species lies with a landscape-scale perspective, and accordingly the Summary Management Table here is ordered by broad landscape type.

LOWLAND WOODLANDS

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Across the extent of lowland woodlands, (i) increase extent of 'longer-unburnt' (>10 years since last fire) habitat to at least 5%; (ii) increase extent of >3 years unburnt to at least 25%; (iii) reduce average patch size of fires to <1 km^2.	Develop and implement a lowland woodland fire strategy; maintain and enhance carefully planned strategic control burning (in wet season and early dry season); establish fire-breaks; suppress high risk fires; use fire history mapping tactically to set annual and ongoing fire management goals.	*Cycas armstrongii*, Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Crested Shrike-tit, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Bare-rumped Sheath-tailed Bat, Gouldian Finch
FERAL ANIMALS	In at least localised test areas (and/or areas of particular significance for high priority threatened species), reduce feral cat abundance by >90%	(i) Maintain or extend cat exclosure fencing; (ii) implement control program using suitable bait	Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat
WEEDS	Stabilise (or where possible, reduce) the incidence, extent and abundance of invasive pasture grasses (and prevent encroachment of gamba grass), across the extent of lowland woodlands	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Cycas armstrongii*, Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Crested Shrike-tit, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Bare-rumped Sheath-tailed Bat, Gouldian Finch
WEEDS	Substantially reduce the incidence, extent and abundance of invasive pasture grasses, in areas of particular significance for high priority threatened species	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	Yellow-snouted Gecko, Northern Brush-tailed Phascogale, Brush-tailed Rabbit-rat

FLOODPLAINS

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Maintain or enhance a fine-scale patchy fire regime in floodplain areas	Maintain and enhance strategic control burning; establish fire-breaks; suppress high risk fires.	Yellow Chat
FERAL ANIMALS	At floodplain wetlands important for threatened species, stabilise or reduce habitat degradation due to feral pigs and buffalo	Implement control program using traps and/ or shooting	*Monochoria hastata*
WEEDS	At floodplain wetlands important for threatened species, stabilise or reduce habitat degradation due to aquatic weeds	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Monochoria hastata*, Yellow Chat, Water Mouse

MARINE, RIVERS AND ISLANDS

Management issue	Objectives	Actions	Threatened species expected to benefit
FERAL ANIMALS	Increase breeding success for marine turtles	(i) Ensure no feral pigs establish on Field Island; (ii) reduce abundance of feral pigs and wild dogs on (current and historic) mainland nesting beaches, through trapping or shooting	Flatback Turtle
HUMAN INTERACTIONS	Ensure no significant detrimental impact from fishing activities	(i) Maintain or enhance existing constraints; (ii) enhance communication to fishers; (iii) if appropriate and necessary, regulate to reduce risks in important areas at appropriate times	Northern River Shark, Speartooth Shark, Dwarf Sawfish, Largetooth Sawfish

STONE COUNTRY

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Intensively manage fire regimes at important populations of highly localised threatened species; Across the extent of the Stone Country, (i) increase extent of 'longer-unburnt' (>10 years since last fire) habitat to at least 10%; (ii) increase extent of >3 years unburnt to at least 40%; (iii) reduce average patch size of fires to <1 km^2.	Maintain implementation of the Stone Country Fire plan (with some refinements to increase conservation outcomes for threatened species)	*Acacia equisetifolia, Hibbertia brennanii, Hibbertia pancerea, Hibbertia* sp. South Magela*, Hibbertia tricornis, Hibiscus brennanii, Jacksonia divisa, Lithomyrtus linariifolia*, Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat, Arnhem Rock-rat, Arnhem Plateau Sandstone Shrubland Complex
FERAL ANIMALS	In at least localised test areas (and/or areas of particular significance for high priority threatened species), reduce feral cat abundance by >90%	Implement control program using suitable bait	Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Rock-rat
WEEDS	Prevent spread and incursions of invasive pasture grasses; and stabilise incidence, extent and abundance of existing invasive pasture grasses, across the extent of the Stone Country	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Acacia sp. Graveside Gorge, Hibbertia brennanii, Hibbertia pancerea, Hibbertia* sp. South Magela*, Hibbertia tricornis, Hibiscus brennanii, Jacksonia divisa, Lithomyrtus linariifolia*, Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Rock-rat, Arnhem Plateau Sandstone Shrubland Complex

RAINFORESTS

Management issue	Objectives	Actions	Threatened species expected to benefit
FERAL ANIMALS	Exclude or intensively control feral pigs from rainforest patches supporting threatened plant species	(i) Establish pig exclosure fencing; (ii) implement control program using traps and/or shooting	*Dienia montana, Freycinetia excelsa*

Hibbertia tricornis

Photo: Kym Brennan

1. The purpose and approach of this strategy

This strategy provides operational detail, context and justification for the relevant section (**5.2 Looking after country**) of the forthcoming (2014-2024) Kakadu National Park Management Plan. For this section, the objective is to: *maintain the condition of the park's natural values, and support the recovery of threatened species*.

Within the framework and policy settings of that plan, this strategy seeks to prioritise and describe actions that will enable the achievement of that plan's objectives.

This strategy will provide explicit linkages to, and be consistent with, other strategies subordinate to the Plan of Management, including for the management of fire, feral animals and weeds. Such linkage is especially important because a key reason for the management of these factors is to provide benefit to threatened species.

The approach used here is essentially that now widely used for conservation planning and performance evaluation for conservation reserves (Hockings *et al.* 2006). It involves a series of logical steps: (i) crystallising the values, and prioritising them; (ii) proposing longer-term targets for those values that can be used to focus management; (iii) identifying sites in the landscape that are most significant for those values; (iv) identifying the factors that are having detrimental impact now (and in the future) on those values; (v) identifying and implementing cost-efficient and effective management responses to those threatening factors, particularly at sites significant for those values; (vi) monitoring of the response of the values and of the effectiveness of management; (vii) reporting on that response; (viii) filling key knowledge gaps that currently impede good management; and (ix) refining and re-applying management in light of that research and monitoring.

Within this cycle, there are also modes of operation or principles, including that:

- Bininj are appropriately involved in and instrumental to the operation of this strategy;
- actions taken are realistic and appropriately prioritised;
- the management and resourcing systems are as appropriately tailored for the task as possible;
- the greatest possible conservation gain is sought and achieved within the available resources;
- if in situ management is likely to fail, then adequate ex situ back-up is considered and/or provided;
- collaborative networks (notably with neighbours, relevant Northern Territory government agencies, and research institutions) are developed and employed;
- although the overall process is as collaborative as possible, there is also a clear line of responsibility and accountability; and
- the process invites external advice and is transparent, with outcomes regularly publicly reported.

The recovery of threatened species that have declined or the ongoing stabilisation of threatened species that are at risk is a long-term commitment. Many of the factors that cause endangerment are now deeply rooted and pervasive, and their control is not amenable to short-term responses. This strategy represents a foundation for long-term management. It aims to operate over a 10-year timeframe, with regular review and recalibration of operational priorities at annual and 3-year periods. This concluding section seeks to organise and integrate the numerous actions into a coherent framework. The subsidiary objectives described in section 5 of this document form the basis of that framework, and relevant actions that contribute to meeting those objectives are there collated, and matched with deliverables at one and 3 year periods. There is inevitably some degree of repetition in this packaging, as some actions contribute to multiple objectives, and because functionally similar actions were developed independently within different sections of this strategy.

Golden Bandicoot - *Isoodon auratus*

Nabarlek - *Petrogale concinna*

Photos: Ian Morris

2. The opportunity and obligation

Kakadu National Park is a place of outstanding value for biodiversity conservation. That value is recognised internationally, through World Heritage listing, including under Criterion x:

> *"to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation."*

In reporting to the Bureau of the World Heritage Committee on risks to Kakadu's world heritage values, Environment Australia (2000) noted:

> *'The Australian government is committed to the identification, protection, conservation, presentation and transmission to future generations of the World Heritage values … Australia takes its obligations and commitments under the World Heritage Convention seriously' and 'Australia undertakes to submit … a detailed program for monitoring the state of conservation of Kakadu National Park … and is continuing to develop a world's best practice regime for monitoring the state of conservation of Kakadu National Park.'*

Furthermore, the Australian government has committed to the United Nation's Millennium Development Goals, under which the conservation goals ('Aichi targets') include the commitment (Target 12) that

> *'by 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained'.*

Kakadu is listed as a wetland of international significance (a Ramsar site), including under Criterion 2:

> *'A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.'*[1]

The entire Kakadu area encompasses all or most of three contiguous internationally recognised Important Bird Areas (Arnhem Plateau, Kakadu savanna and Alligator Rivers floodplain) (Dutson ***et al.*** 2009; BirdLife International 2013b, 2013c, 2013a), with each listing based substantially on it containing threshold numbers of globally threatened bird species.

At Northern Territory level, most of Kakadu is included within two Sites of Conservation Significance, the Western Arnhem Plateau and the Alligator Rivers coastal floodplain, with the eligibility and definition of these sites relating in large part to the occurrence within them of threatened species.

Australia's national environmental legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), provides explicit obligations for the management of threatened species, particularly on Commonwealth lands and waters and for threatened species with Recovery Plans. For example, s 269(1) states that *'the Commonwealth must implement a recovery plan or threat abatement plan to the extent to which it applies in Commonwealth areas'*.

1 see http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=2, which notes that Kakadu National Park supports numerous nationally threatened species, notably the yellow chat, pig-nosed turtle, speartooth shark, northern river shark and flatback turtle

Largetooth Sawfish - ***Pristis pristis***

Photo: Michael Lawrence-Taylor

3. The values: threatened species considered

There is no single fixed, encompassing and definitive list of threatened species. However, the qualifying criteria for listing is now relatively consistent, with most threatened species lists using International Union for Conservation of Nature (IUCN) criteria (or minor variations on these) relating mostly to population size and trends and extent of range (IUCN 2001).

The Australian list under the EPBC Act includes species and ecological communities considered to be threatened, and many of its legal and regulatory provisions concerning threatened species and ecological communities apply particularly to Commonwealth lands, such as Kakadu. The EPBC Act listing is not subject to periodic comprehensive review and species are added to (or, rarely, deleted from) the list in a manner that is not necessarily systematic. Note that the EPBC Act explicitly treats subspecies as 'species', such that the term threatened species is taken to also include threatened subspecies.

All Australian states and territories also maintain their own lists of threatened species, and these provide another statutory and geographic context for Kakadu's conservation obligations and interests. The Northern Territory, in which Kakadu occurs, maintains a listing under the *Territory Parks and Wildlife Conservation Act 2000* (TPWC Act) of the conservation status of all species, but not of ecological communities. In contrast to the Australian list, the Northern Territory listing is comprehensively reviewed at c. 5 year intervals. Unlike the EPBC Act list, the Northern Territory listing also includes the categories of Near Threatened and Data Deficient.

Internationally, the IUCN maintains a global list of threatened species (the 'Red List': http://www.iucnredlist.org/). However, not all species-groups have been evaluated by the IUCN, the IUCN list has no legislative power in Australia and, for some species (such as the Dugong *Dugong dugon*), IUCN listing as threatened may more reflect conservation concern and priorities beyond the Australian range.

It is almost certain that the current lists of threatened species occurring in Kakadu will change over the course of this threatened species strategy; and this strategy should be flexible enough to accommodate such changes and to provide some immediate attention to the management requirements of species newly added to relevant threatened species listings. To some extent, this has been done here through some consideration of species listed under the TPWC Act as Near Threatened, on the grounds that such species may be most likely to qualify as threatened in the near future.

Table 1 presents a list of all species (and ecological communities) with records from Kakadu that are currently considered threatened under the EPBC Act or TPWC Act. It also includes species recognised as threatened on the IUCN's Red List. This tabulation includes 30 species and one ecological community listed as threatened under the EPBC Act, an additional 32 species listed as threatened under the TPWC Act (but not the EPBC Act), and at least an additional 13 species listed by the IUCN but not under the EPBC Act or TPWC Act, for a total of 75 threatened species and one threatened ecological community. This strategy focuses particularly on species listed under the EPBC Act and the TPWC Act, a total of 62 species and one ecological community.

Information on the 75 threatened species listed under the EPBC Act or TPWC Act or by the IUCN is summarised in Appendix 1.

It is likely that there is no other conservation reserve in Australia that has management responsibilities for, and opportunities to make significant contributions to the conservation of, so many threatened species. The size of this list of threatened species is due in part to Kakadu's large area (c. 20,000 km^2), its very extensive range of habitats, its location in and adjacent to a site with unusually high species' richness and endemism (Ingwersen 1995; Woinarski *et al*. 2006; Woinarski *et al*. 2009), the individual and cumulative impacts of some severe landscape-scale threats operating in Kakadu and elsewhere, and the refuge offered by Kakadu from some threats (e.g. commercial fishing) for some species that are recognised as threatened because of broad scale declines other than in Kakadu.

Table 1. Threatened species and ecological communities recorded from Kakadu.

Conservation status codes: CR=Critically Endangered; EN=endangered; VU=vulnerable.

Common name	Scientific name	Status		
		EPBC Act	TPWC Act	IUCN
Plants				
(a shrub)	*Acacia equisetifolia*[1]	CR	CR	
(a mangrove)	*Avicennia integra*			VU
(a fern)	*Bolbitis quoyana*		VU	
(a cycad)	*Cycas armstrongii*[2]		VU	VU
(an orchid)	*Dienia montana*[3]		VU	
(a vine)	*Freycinetia excelsa*		VU	
(a shrub)	*Hibbertia brennanii*		VU	
(a shrub)	*Hibbertia pancerea*		VU	
(a shrub)	*Hibbertia* sp. South Magela		VU	
(a shrub)	*Hibbertia tricornis*		VU	
(a shrub)	*Hibiscus brennanii*	VU	VU	
(a shrub)	*Jacksonia divisa*		VU	
(a shrub)	*Lithomyrtus linariifolia*		VU	
(an aquatic herb)	*Monochoria hastata*		VU	
(a bladderwort)	*Utricularia dunstaniae*		VU	
Invertebrates				
(a decapod crustacean)	*Leptopalaemon gibbosus*			VU
(a decapod crustacean)	*Leptopalaemon glabrus*			CR
(a decapod crustacean)	*Leptopalaemon magelensis*			VU
Top End Dragon (a dragonfly)	*Antipodogomphus dentosus*			VU
Kakadu Vicetail (a dragonfly)	*Hemigomphus magela*			VU
Rock Narrow-wing (a dragonfly)	*Lithosticta macra*			VU
Fish				
Northern River Shark	*Glyphis garricki*[4]	EN	EN	CR
Speartooth Shark	*Glyphis glyphis*[5]	CR	VU	EN
Dwarf Sawfish	*Pristis clavata*	VU	VU	EN
Largetooth Sawfish	*Pristis pristis*[6]	VU	VU	CR
Narrow Sawfish	*Anoxypristis cuspidata*			EN

Common name	Scientific name	Status		
		EPBC Act	TPWC Act	IUCN
Reptiles				
Flatback Turtle	*Natator depressus*	VU		
Green Turtle	*Chelonia mydas*	VU		EN
Olive Ridley	*Lepidochelys olivacea*	EN		VU
Hawksbill Turtle	*Eretmochelys imbricata*	VU	VU	CR
Loggerhead Turtle	*Caretta caretta*	EN	VU	EN
Pig-nosed Turtle	*Carettochelys insculpta*			VU
Yellow-snouted Gecko	*Lucasium occultum*[7]	EN	VU	
Arnhem Land Skink	*Bellatorias obiri*[8]	EN	VU	
Merten's Water Monitor	*Varanus mertensi*		VU	
Mitchell's Water Monitor	*Varanus mitchelli*		VU	
Yellow-spotted Monitor	*Varanus panoptes*		VU	
Plains Death Adder	*Acanthophis hawkei*	EN	VU	
Oenpelli Python	*Morelia oenpelliensis*		VU	
Birds				
Partridge Pigeon	*Geophaps smithii*	VU[9]	VU	VU
Red Goshawk	*Erythrotriorchis radiatus*	VU	VU	
Grey Falcon	*Falco hypoleucos*		VU	VU
Greater Sand Plover (Mongolian)	*Charadrius leschenaultii leschenaultii*		VU	
Lesser Sand Plover	*Charadrius mongolus*		VU	
Australian Painted Snipe	*Rostratula australis*	EN	VU	EN
Bar-tailed Godwit	*Limosa lapponica baueri*		VU	
Eastern Curlew	*Numenius madagascariensis*		VU	VU
Asian Dowitcher	*Limnodromus semipalmatus*[2]		VU	
Red Knot	*Calidris canutus*		VU	
Great Knot	*Calidris tenuirostris*		VU	VU
Curlew Sandpiper	*Calidris ferruginea*		VU	
Masked Owl (northern)	*Tyto novaehollandiae kimberli*	VU	VU	
White-throated Grass-wren	*Amytornis woodwardi*		VU	VU
Yellow Chat (Alligator R.)	*Epthianura crocea tunneyi*	EN	EN	
Crested Shrike-tit (northern)	*Falcunculus frontatus whitei*	VU		
Gouldian Finch	*Erythrura gouldiae*	EN	VU	
Mammals				
Northern Quoll	*Dasyurus hallucatus*	EN	CR	EN
Northern Brush-tailed Phascogale	*Phascogale pirata*	VU	EN	VU
Fawn Antechinus	*Antechinus bellus*		EN	
Golden Bandicoot	*Isoodon auratus*[10]	VU	EN	VU
Nabarlek	*Petrogale concinna*		VU	
Ghost Bat	*Macroderma gigas*			VU
Arnhem Leaf-nosed Bat	*Hipposideros inornatus*		VU	VU
Northern Leaf-nosed Bat	*Hipposideros stenotis*		VU	

Common name	Scientific name	Status		
		EPBC Act	TPWC Act	IUCN
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus nudicluniatus*	CR		
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	VU	EN	
Black-footed Tree-rat	*Mesembriomys gouldii*		VU	
Golden-backed Tree-rat	*Mesembriomys macrurus*[10]	VU	CR	
Northern Hopping-mouse	*Notomys aquilo*[10]	VU	VU	EN
Kakadu Pebble-Mouse	*Pseudomys calabyi*			VU
Arnhem Rock-rat	*Zyzomys maini*	VU	VU	
Water Mouse	*Xeromys myoides*[10]	VU		VU
Pale Field-rat	*Rattus tunneyi*		VU	
Dugong	*Dugong dugon*			VU
Dingo	*Canis lupus dingo*			VU
Ecological communities				
Arnhem Plateau Sandstone Shrubland Complex		EN		

Notes: [1] Formerly known as *Acacia* sp. Graveside Gorge; [2] Occurrence in Kakadu may require further confirmation; [3] Formerly known as *Malaxis latifolia*, and recent taxonomic revision suggests that it may be re-named again as *Dienia ophrydis* (Margonska and Kowalkowska 2008); [4] Formerly known as *Glyphis* sp. C; [5] Formerly known as *Glyphis* sp. A; [6] Formerly known as *Pristis microdon*; [7] Formerly known as *Diplodactylus occultus*; [8] Formerly known as *Egernia obiri*; [9] As eastern subspecies *G. s. smithii*; [10] No confirmed records from Kakadu for at least 30 years

There have been two previous management planning documents for Kakadu's threatened species, in 1995 (Roeger and Russell-Smith 1995) and 2004 (Woinarski 2004a). The number of listed threatened species occurring in Kakadu has increased substantially (Table 2; Figure 1) over these successive plans. This increase is not so much due to new records of threatened species not previously known from Kakadu but rather mostly because of increased knowledge, particularly the demonstration of declining population trends of some species, causing additional species to be added to threatened species' lists. The increase also results from addition of some recently discovered and described species (e.g. *Hibbertia pancerea, H. tricornis*). The continuing increase in the number of threatened species occurring in Kakadu makes it increasingly important to develop and implement a coherent, integrated and strategic approach to their management.

Table 2. Changes in the number of listed (under EPBC Act or TPWC Act) threatened species reported from Kakadu here and in the two previous Kakadu threatened species documents.

Strategy	Listing	No. of listed species			
		plants	animals	communities	total
Roeger & Russell-Smith (1995)	EPBC Act[1]	0	8	0	8
	TPWCA[2]	0	0	0	0
	total	0	8	0	8
Woinarski (2004)	EPBC Act	6	16	0	22
	TPWCA	11	21	0	32
	total	16	30	0	46
this strategy	EPBC Act	2	28	1	32
	TPWCA	14	42	0	56
	total	14	48	1	63

Notes: [1] Listing was then under the Endangered Species Protection Act; [2] At the time there was no Northern Territory list of threatened species.

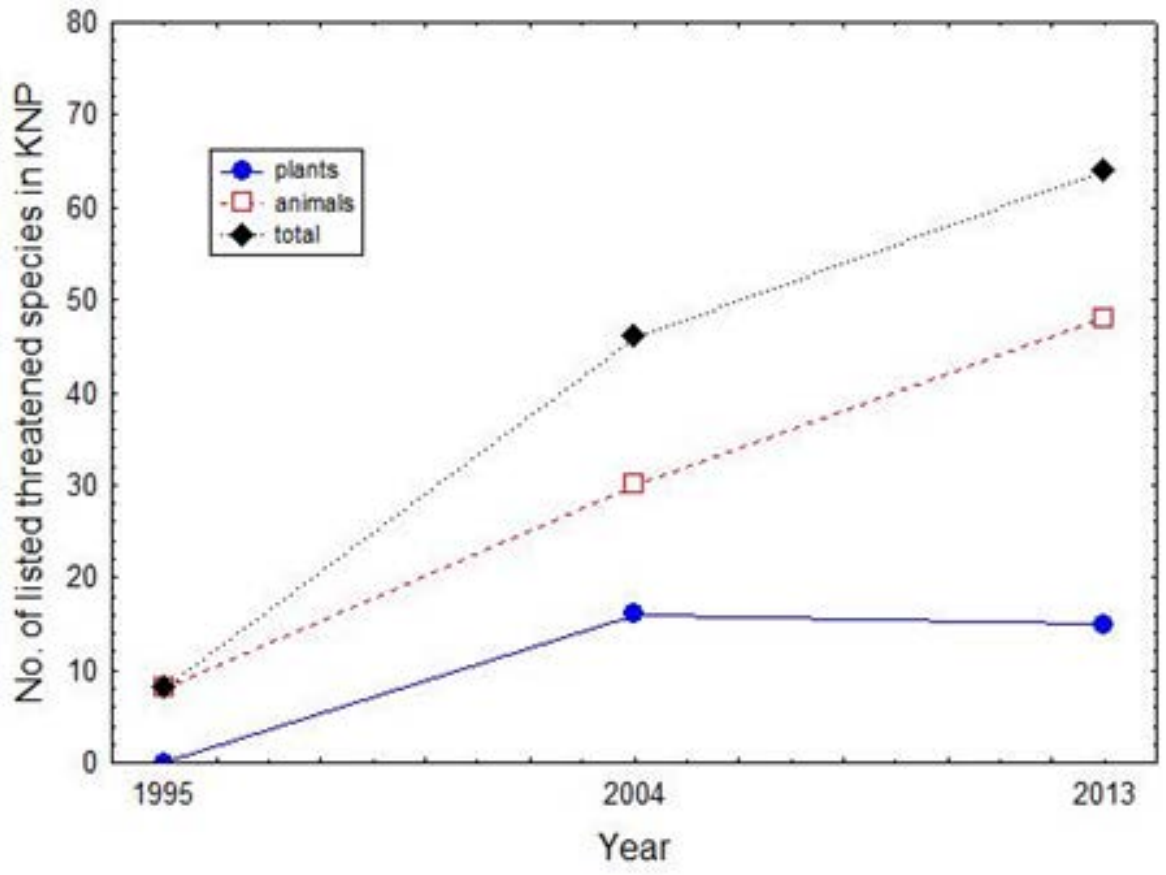

Figure 1. Change in the number of listed threatened species reported in this strategy in relation to the two previous Kakadu threatened species strategies.

Note that, against the trend for increase, some species occurring in Kakadu were formerly considered as threatened species (Roeger and Russell-Smith 1995; Woinarski 2004a), but are no longer listed as threatened (Table 3). In most cases, these species were removed from lists of threatened species not because of management-related increase in their abundance but rather because of increased knowledge of their distribution, population size and/or population trends, indicating that the previous listing was inappropriate.

Table 3. Species occurring in Kakadu that were formerly considered threatened (and listed as such in previous strategies) but are no longer considered to be threatened under the EPBC Act or TPWC Act.

Common name	Scientific name	Roeger & Russell-Smith (1995)	Woinarski (2004)
	Boronia laxa		√
	Boronia rupicola		√
	Boronia suberosa		√
	Boronia verecunda		√
	Boronia xanthastrum		√
	Calytrix inopinata		√
	Dubouzetia australiensis		√
	Gleichenia dicarpa		√
	Helicteres D21039 linifolia		√
	Sauropus filicinus		√
	Utricularia subulata		√
Northern Grassdart Butterfly	*Taractrocera ilia ilia*		√
Freshwater Tongue Sole	*Cynoglossus heterolepis*		√
Emu	*Dromaius novaehollandiae*		√
Australian Bustard	*Ardeotis australis*		√
Ghost Bat	*Macroderma gigas*	√	

Many additional species occurring in Kakadu are listed under the TPWC Act or by the IUCN as Near Threatened or Data Deficient (Appendix 2). However, notwithstanding that some of these are of conservation concern and some are likely to be listed as threatened over the course of this strategy, these are not the primary focus of this strategy, although the Near Threatened species are included in some prioritisation considerations.

Furthermore, some listed threatened species are known from areas lying just outside Kakadu (mostly on the western Arnhem Land plateau), but have not yet been recorded within Kakadu. Kakadu may have some role to play in the conservation management of such species because some management actions taken in the Park may provide some benefit to these species (e.g. fire management), because Kakadu could contribute to broader regional collaborative management programs, or because such species may reasonably be expected to be discovered to also occur in Kakadu. Such species are listed in Appendix 3.

Many more species are not listed as threatened, but are of some more local conservation concern and may have high cultural or other value. Again, these species are not the primary focus of this strategy, although some culturally significant species are included in some prioritisation considerations. Examples of such species include the Emu *Dromaius novaehollandiae*, Northern Cypress-pine *Callitris intratropica* and the rainforest tree Anbinik *Allosyncarpia ternata*.

4. The challenge

Kakadu National Park was established serially from 1979, and has been managed with biodiversity conservation as a goal since then. Notwithstanding this relatively long period of conservation management, and the direction offered by the two preceding threatened species' strategies, threatened species in Kakadu are generally not faring well. Some threatened species are declining in Kakadu (e.g. Table 4), in some cases, possibly being lost from the park completely; for most other threatened species, trends are unknown. More detailed information on the status of, and trends for, threatened species in Kakadu was reported recently in Winderlich and Woinarski (2014).

Table 4. Examples of population decline in Kakadu for some threatened species.

Note that in most cases, the population decline represents change in an abundance index at monitored sites rather than total population size.

Species	Period of monitoring	% popn change	Source	Location (part of Kakadu)
Dienia montana (an orchid)	1993-2003	-100%	Cowie and Liddle (2014)	single known Kakadu subpopulation no longer found at subsequent searches
Arnhemland Skink	1977-2002	-95%	Woinarski *et al*. (2007)	Nawurlandja only
Partridge Pigeon	2001-2009	-79%	Woinarski *et al*. (2012)	fire-plots
White-throated Grass-wren	2001-2009	-100%	Woinarski *et al*. (2012)	fire-plots (small sample size)
Northern Quoll	1986-1999	-98%	Woinarski *et al*. (2001)	Kapalga
	1991-1999	-57%	Woinarski *et al*. (2001)	Kapalga
	1977-2002	-95%	Watson and Woinarski (2003)	Nawurlandja only
	2001-2009	-96%	Woinarski *et al*. (2010)	fire-plots
Fawn Antechinus	1986-1999	-100%	Woinarski *et al*. (2001)	Kapalga
	1991-1999	-100%	Woinarski *et al*. (2001)	Kapalga
	2001-2009	-90%	Woinarski *et al*. (2010)	fire-plots
Black-footed Tree-rat	1986-1999	-100%	Woinarski *et al*. (2001)	Kapalga
	1991-1999	-100%	Woinarski *et al*. (2001)	Kapalga
Pale Field-rat	1986-1999	-100%	Woinarski *et al*. (2001)	Kapalga
	1991-1999	-100%	Woinarski *et al*. (2001)	Kapalga
	2001-2009	-94%	Woinarski *et al*. (2010)	fire-plots
Arnhem Rock-rat	1977-2002	-100%	Watson and Woinarski (2003)	Nawurlandja only
	1988-2001	-84%	Woinarski *et al*. (2003)	'Stage III'
	2001-2009	-53%	Woinarski *et al*. (2010)	fire-plots

Such trends are likely to be broadly representative of the region rather than indicative of any particular shortcoming of management in Kakadu. Nonetheless, the conservation of threatened species is clearly a key objective and obligation of Kakadu, so at least some past and current management may be considered to be failing.

This strategy is based on the premise that in order to achieve relevant objectives for the conservation of threatened species, there must be a substantial change in the way Kakadu is managed and/or in the resources directed towards management of its threatened species and those factors affecting them.

Note that this conclusion should not be read to imply that there have been no useful activities to date, or that there has been no commitment to the conservation of threatened species in Kakadu. Nor should the actions and objectives described in this strategy be seen to be all novel. Rather, much in this strategy builds on or includes current actions. A brief description of such current actions and approaches is provided in Appendix 4.

The challenge to improve on current trends is formidable. There are very many threatened species, occurring in many different environments, and each one may merit some significant and different management attention. The number is likely to continue to rise.

There is little information about many of the threatened species, so there is a need to manage with imperfect knowledge, and to monitor the efficacy of such management, and to refine it in response to monitoring results; and there is a need to seek to fill those information gaps that most impede good management. There are existing Recovery Plans for only a small proportion of Kakadu's threatened species, such that existing considered packages of management actions are not already established for most species.

Kakadu is a very extensive area (c. 20,000 km^2), and much of it has major access constraints, such that management actions may be expensive, difficult to apply and difficult to implement comprehensively across the park.

Many of the factors that are driving declines in threatened species are now deeply rooted, pervasive and difficult or impossible to control. For other threatened species (such as some migratory shorebirds), management actions taken in Kakadu may be almost irrelevant, because factors occurring outside the Park are primarily responsible for current population decline.

Conservation management is not necessarily straightforward. In many cases, threatened species are affected by a complex cocktail of factors, many of which are interactive, and some of which may operate indirectly and unexpectedly. So, management attention directed at a single priority threat may be insufficient, or even produce perverse results. As an example, Figure 2 provides a schematic 'wiring diagram' of the factors that may affect the conservation of the threatened Partridge Pigeon, directly or indirectly.

For some of Kakadu's threatened species, the ecological context (and hence management focus) may be much simpler; for others, it may be even more tangled. And in most cases, there is little evidence about the relative importance of these factors. This interconnectivity may often render it unhelpfully simplistic to try to evaluate the cost-effectiveness of investing in one management action *vis-à-vis* another management action. However, the interconnectivity may also mean that there may be substantial flow-on benefits of management investment for one species to many other species.

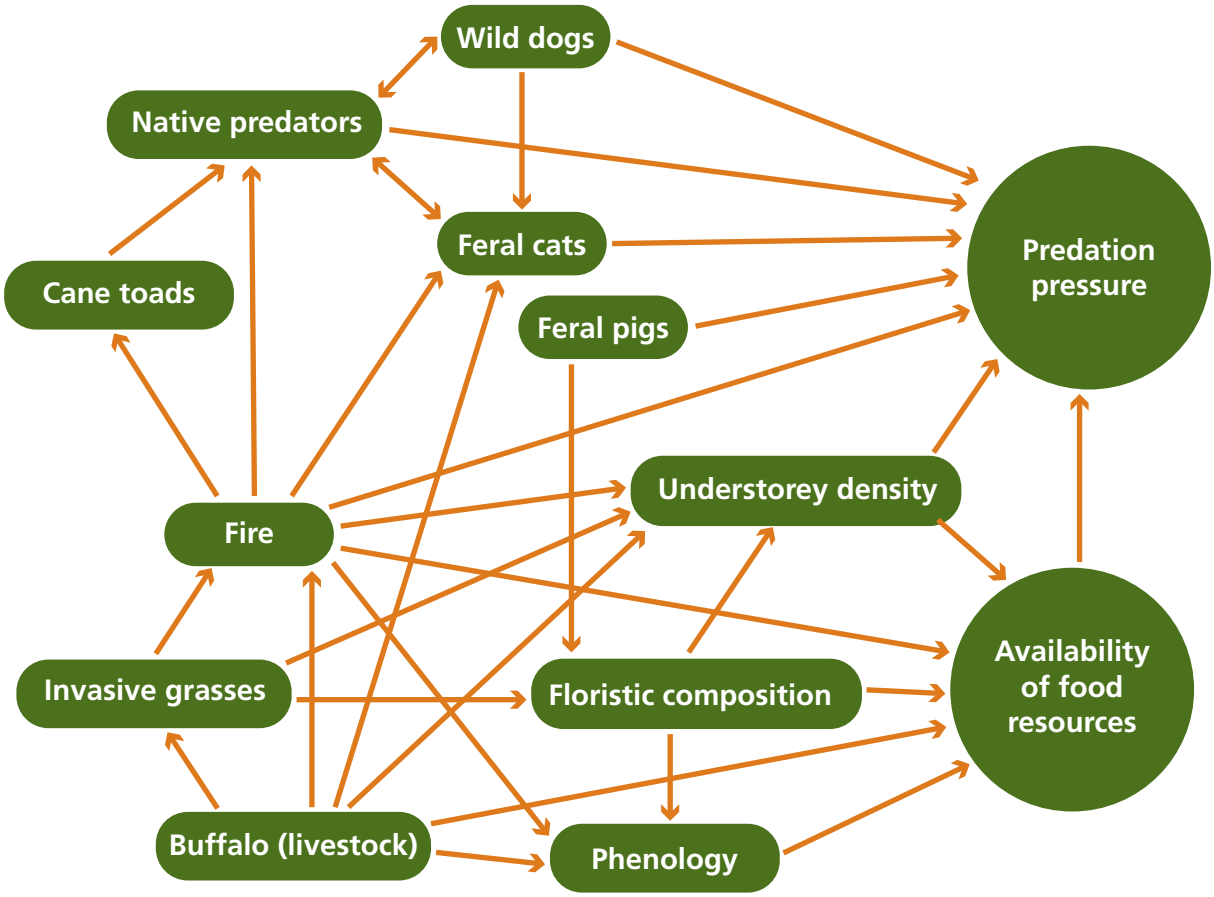

Figure 2. A schematic network diagram of the factors that may affect the conservation status of Partridge Pigeon in Kakadu, operating principally through impacts on food availability and predation.

Management considerations are also much dependent upon available resources, and the financial and personnel budget is finite. Furthermore, many factors additional to biodiversity conservation claim management attention and are, or have been, the primary determinant of the type, intensity and extent of at least some management activity.

The following sections describe a strategic and orderly approach to this formidable challenge.

Partridge Pigeon - *Geophaps smithii*

Photo: Cassie McMaster

Oenpelli Python - *Morelia oenpelliensis*

Photo: Anne O'Dea

5. Objectives

1.1 Overall objective

Population trends for all threatened species[2] in Kakadu are demonstrably stable or increasing.

This objective is ambitious and will be challenging to achieve, but it is an appropriate objective for one of Australia's premier conservation reserves with explicit obligations under World Heritage listing. A series of principles and subsidiary operational objectives are defined here that form the operational framework for working towards the overall objective.

1.2. Principles and subsidiary operational objectives

How we will work to achieve the overall objective [people]

1.2.1. Kakadu's environmental management is a shared responsibility, and Kakadu's traditional landowners are actively involved in threatened species management.

1.2.2. The management of threatened species (and their threats) involves an effective collaboration with neighbours and other relevant groups.

1.2.3. Visitors to Kakadu are increasingly aware of threatened species and their conservation management.

How we will work to achieve the overall objective [research]

1.2.4. A prioritised research program addresses key knowledge gaps that currently impede effective management of threatened species.

1.2.5. For poorly-known endemic species for which information is currently inadequate to list as threatened a strategic program is established to assess the conservation status and management requirements (and to then implement those requirements).

1.2.6. Options for management using ex situ measures and the reintroduction of threatened species now extirpated from Kakadu are considered.

1.2.7. Relevant knowledge about the distribution, abundance and habitat requirements of threatened species, and of their management requirements, is readily accessible to and used by all park managers.

how we will work to achieve the overall objective [management]

1.2.8. The management of threatened species in Kakadu is orderly, enduring, evidence-based, cost-effective and appropriately prioritised.

1.2.9. The outcome for threatened species is a key and explicit rationale for management strategies for fire, feral animals, weeds and other relevant factors.

2 Throughout where appropriate 'threatened species' is taken to mean 'threatened species and ecological communities', except that relevant measures of progress for threatened species relate mostly to abundance or population size, whereas those for ecological communities relate to condition and population trends for key constituent species

1.2.10. The Park's managers meet obligations to undertake conservation management actions within approved Recovery Plans and Threat Abatement Plans.

1.2.11. The outstanding and internationally recognised value of Kakadu for the conservation of threatened species is accepted as a pivotal factor in Park management, with explicit and appropriate staff and budget allocations.

how we will work to achieve the overall objective [monitoring and reporting]

1.2.12. The status of threatened species (and the effectiveness of management programs for them) is effectively monitored, and results from that monitoring are highlighted in public reporting.

1.2.13. The extent of progress towards the vision and all objectives is a key performance indicator for Park management.

how we will work to achieve the overall objective [review]

1.2.14. Actions described under this strategy are reviewed at one and three year intervals, based on monitoring and other assessment of the effectiveness of management actions.

1.2.15. Where additional species occurring in Kakadu are added to threatened species lists, their management requirements in Kakadu are considered in a timely fashion, and incorporated into this strategy.

1.2.16. A Recovery Team, or other advisory group, including external experts and other key stakeholders is established and operates as an effective advisory and oversight body to the management of Kakadu's threatened species.

6. Pathways to a solution

There is no single action that will lead to a marked and lasting improvement in the status of the set of threatened species in Kakadu. Instead, an integrated program of research, management and monitoring actions is required. The components of such a program are outlined below, and then described in more detail in the following sections.

- prioritisation of threatened species for conservation management response;
- grouping of species into those with similar management requirements;
- recognition and implementation of obligatory actions in existing recovery plans;
- development and implementation of a strategic research program (including identification of important areas, better knowledge of threats and preferred management regimes) on threatened species to garner sufficient information to enhance the likelihood of management success;
- development and implementation of a strategic research program on priority threats to identify effective and cost-efficient management options;
- prioritisation of actions to manage current and projected threats (to those actions that can most make a difference, particularly directed towards those species that are declining because of suboptimal management in Kakadu);
- enhanced dissemination and use of information to managers and others stakeholders;
- establishment of shorter- and longer-term targets for conservation outcomes;
- design and implementation of an integrated monitoring and reporting program;
- enhancement of collaborations (within and beyond Kakadu);
- (for some species) recognition of limitations of in situ options, and design and implementation of appropriate ex situ management and reintroduction;
- establishment of an effective oversight and advisory group;
- resourcing and management structure appropriate to meet the objectives.

In most of the following elaboration of these points, one or more actions are proposed that are fundamental steps on the pathway towards the conservation of Kakadu's threatened species. These actions are aggregated in section 7.

6.1. Prioritisation of threatened species

With many threatened species competing for management attention, there is some merit in attempting an objective prioritisation amongst species. But this is not straightforward. There are many options for assessing the 'value' of any species and its priority for management attention, and no option is necessarily ideal.

There is an egalitarian argument, that all species are equal and deserve equivalent attention. Alternatively, species can be ranked across many different criteria. Some species are more phylogenetically distinct than others: for example a Platypus has far fewer close relatives than does a Delicate Mouse, and hence the extinction of the Platypus would be far more substantial loss of genetic material than that of the Delicate Mouse. Some species are of more ecological importance than others: for example the Stone Country rainforest tree *Allosyncarpia ternata* dominates sandstone rainforests and provides much of the shade and shelter. The Dingo may control herbivore numbers and hence vegetation patterning, whereas it may be that no other species would be affected if the rare shrub *Hibbertia tricornis* disappeared. In Kakadu, some species are of profound cultural significance to Indigenous landowners, for spiritual reasons or as food resource; whereas other species are relatively unimportant. There is no single correct way of scoring each of these variables, nor of weighting the different dimensions of value, nor of aggregating scores across those dimensions, so any prioritisation scoring system should be seen as indicative rather than absolute.

In Appendix 5, a compound score is calculated for the 'value' of individual species (comprising all threatened species, along with all Near Threatened species and some additional culturally significant species), based on the sum of individual scores for conservation status, taxonomic distinctiveness, cultural value, ecological importance and the significance of Kakadu (as a proportion of the species' total population or range).

Threatened species with high scores on this composite value include the Northern River Shark, Dwarf Sawfish, Speartooth Shark, Partridge Pigeon, Oenpelli Python, Arnhem Land Skink, Flatback Turtle, Pig-nosed Turtle, Loggerhead Turtle, Olive Ridley, Hawksbill Turtle, Brush-tailed Rabbit-rat and Northern Brush-tailed Phascogale.

In general, where necessary, management investment should prioritise those threatened species with highest value, for which Kakadu comprises the only or most important conservation opportunity, and for which current population trends suggest that management response is most needed and may be most effective. However, the scores across species are very gradational (rather than well segmented); and the higher scoring species should not necessarily be considered to be priorities for management if, for example, they are unlikely to be declining or need management.

6.2. Management groupings of threatened species

There are very many threatened species in Kakadu, and management will be inefficient and probably suboptimal if each species is viewed as an entirely independent management unit. In this section, species with broadly similar management considerations are grouped, particularly by broad landscape type: Stone Country, lowland woodlands, rainforest, floodplain, aquatic environments and marine areas. Note that further information and recommended actions for individual species is presented in Appendix 1.

GROUP 1: Species listed by the IUCN but not under any Australian or Northern Territory legislation.

11 species: Leptopalaemon gibbosus, Leptopalaemon glabrus, Leptopalaemon magelensis, Antipodogomphus dentosus, Hemigomphus magela, Lithosticta macra Narrow Sawfish, Ghost Bat, Kakadu Pebble-Mouse, Dugong, Dingo

This is a heterogeneous group of dissimilar species occurring in different habitats. However, they are rated here as of relatively low management significance because there is no substantial legal obligation to prioritise their management, and because they have been assessed recently as not threatened (at Northern Territory level) or have not been the subject of recent rigorous evaluation of conservation status (at national level).

Nonetheless, these species may be close to eligible for listing as threatened at either national or Northern Territory level, so at least a watching brief should be maintained on their status in Kakadu. This may be particularly the case for the Ghost Bat, for which a recent national assessment (Woinarski *et al*. 2014b) concluded that its status should be Vulnerable. For the Narrow Sawfish, further information on local status and management requirements may be obtained through current ecological and monitoring studies on other elasmobranch species.

Research actions required:

- collate distributional records

Management actions required:

- nil

Monitoring actions required:

- develop a monitoring program for the three IUCN listed freshwater shrimps and three dragonflies and damselflies.

Priority action:

6.2.1. Survey for known roost sites (particularly maternity roosts) for Ghost Bats, and develop and implement a monitoring program based at these.

GROUP 2: Intercontinental migratory shorebirds whose major conservation concern lies beyond Australia.

8 species: Greater Sand Plover (Mongolian), Lesser Sand Plover, Bar-tailed Godwit, Eastern Curlew, Asian Dowitcher, Red Knot, Great Knot, Curlew Sandpiper

Kakadu is a moderately important staging or non-breeding site for most of these species (although the occurrence of Asian Dowitcher in Kakadu requires confirmation), but there is relatively little management action that can be taken in Kakadu that will contribute significantly to the conservation outlook for these species.

Research actions required:

- nil

Management actions required:

- maintain habitat suitability of floodplain wetlands and coastal areas
- where feasible, engage collaboratively in the global management of these species

Monitoring actions required:

- participate in collaborative national monitoring programs

Priority action:

6.2.2. Participate in national monitoring programs for shorebirds.

GROUP 3: Wide ranging (intracontinental) bird species, for which Kakadu is a relatively unimportant site.

2 species: Grey Falcon, Australian Painted Snipe

There are very few records of these two bird species in Kakadu, and Kakadu is a marginal and occasional part of the distribution, rather than a core. Both have low total population size but are widely distributed and may have irregular movement patterns. The main conservation concern (habitat degradation due to changed hydrology and impacts of livestock) for the Australian Painted Snipe lies elsewhere in its range. Little is known of the population trends and threats to the Grey Falcon.

Research actions required:

- collate distributional records in Kakadu

Management actions required:

- nil

Monitoring actions required:

- nil

GROUP 4: Marine turtle species for which Kakadu is a relatively unimportant site

4 species: Green Turtle, Olive Ridley, Hawksbill Turtle, Loggerhead Turtle

There are no reports of Loggerhead Turtle breeding in Kakadu (or elsewhere in the Northern Territory) and only few reports for Green Turtle, Olive Ridley and Hawksbill Turtle breeding in Kakadu (Woinarski 2004a); and Kakadu coastal waters do not support significant areas of foraging habitat or populations of these four species.

Research actions required:

- nil

Management actions required:

- maintain constraints on commercial fisheries;
- collaborate in the control of ghost nets and other significant marine debris;
- if feasible and cost-effective, control predators at any nesting beaches;
- where feasible, engage collaboratively in the global management of these species

Monitoring actions required:

- monitor beaches with previous nesting records for any ongoing use

Note that a current Recovery Plan (Environment Australia 2003) provides a set of research and management actions, and this Plan should guide actions taken in Kakadu.

GROUP 5: Mammal species whose only Kakadu records are historic

3 species: Golden Bandicoot, Golden-backed Tree-rat, Northern Hopping-mouse

These three mammal species are probably now extirpated (locally extinct) from Kakadu, with no records for at least 30 years, notwithstanding significant general survey effort. The Water Mouse may also be considered within this group, with the only confirmed Kakadu record in 1903. However, there has been relatively little survey effort in its habitat, so it is more likely to be extant.

The main conservation issue with these species relevant to Kakadu is consideration of their possible reintroduction, most likely at least initially in intensively managed predator-proof exclosures. Given that, across their entire range, all three species have generally declining trends and their current range is relatively small, there may be some overall conservation benefit in the establishment of such an insurance population.

Research actions required:

- evaluate the options, costs, benefits, risks and requirements of reintroduction

Management actions required:

- liaise with relevant management agencies in areas still occupied by these species to establish interest in any reintroduction program

Monitoring actions required:

- nil (unless and until any reintroduction undertaken)

Note that there is an existing Recovery Plan (Palmer *et al.* 2003) for two of these species (Golden Bandicoot and Golden-backed Tree-rat), but this plan does not explicitly foreshadow any such reintroduction to Kakadu.

Priority action:

6.2.3. Evaluate the options, costs, benefits, risks and requirements of reintroduction of mammal species for which there are no recent Kakadu records.

GROUP 6: Species whose Kakadu population has declined precipitously recently because of Cane Toads

5 species: Merten's Water Monitor, Mitchell's Water Monitor, Yellow-spotted Monitor, Plains Death Adder, Northern Quoll

These species represent a difficult conservation challenge. There is a wide divergence of opinion on options for the local-scale control of Cane Toads, and of the likelihood of some natural population recovery of toad-affected species.

For these five species, there is little scope for marooning individuals on any natural (Cane Toad free) island in Kakadu, because there are now no such sites and because any introduced population would most likely be detrimental to existing natural values of those islands. Populations of Yellow-spotted Monitor were present on Field and Barron Islands until at least 2007, but since at least 2010 Cane Toads have colonised, and the monitor populations are unlikely to persist.

However, in 2003 some Northern Quolls from Kakadu were included in a successful translocation to two toad-free islands off north-eastern Arnhem Land (Rankmore *et al.* 2008).

A current research project is examining the feasibility of enhancing recovery of Northern Quolls through toad aversion training and re-introduction of trained quolls (O'Donnell *et al.* 2010; Webb *et al.* 2012).

Research actions required:

- assess the persistence and population viability of monitor (goanna) species on Field Island;
- assess the feasibility of eradication of toads from Field Island, and of factors that could reduce subsequent recolonisation;

Management actions required:

- maintain current program of experimental release of aversion-trained quolls;
- where appropriate and cost-effective, implement recommended management actions arising from current experimental releases of toad-trained quolls

Monitoring actions required:

- assess the extent of natural recovery of all toad-susceptible species following toad-induced declines

Priority action:

6.2.4. Develop and implement monitoring programs for all toad-affected vertebrate species to assess the extent of natural or assisted recovery.

GROUP 7: Sharks and sawfish of rivers, estuarine and coastal areas

4 species: Northern River Shark, Speartooth Shark, Dwarf Sawfish, Largetooth Sawfish

Until recent research work, relatively little was known of the ecology or distribution of these species, but all have declined severely across their range, and Kakadu now represents an important stronghold (Kyne 2014). Most are relatively well protected in Kakadu waters, but face formidable threats when, as part of their life cycle, individuals engage in dispersal beyond Kakadu.

Research actions required:

- define critical habitat for all four species
- assess the extent of take and other interactions with fishers

Management actions required:

- if any significant fishery impact is demonstrated in Kakadu, improve regulation, management and enforcement
- where feasible, engage collaboratively in the global management of these species

Monitoring actions required:

- design and implement an integrated monitoring program for sawfishes and river shark species

Priority action:

6.2.5. Develop and implement an integrated monitoring program for sawfish and river shark species.

GROUP 8: Marine turtle species with a significant breeding site in Kakadu

1 species: Flatback Turtle

This is the only marine turtle that nests regularly on beaches in Kakadu (particularly on Field Island, although that habitat is limited), and there has been a long-standing monitoring program. This species may have benefitted from the decline of monitors (that formerly predated on eggs) on mainland areas due to cane toads, but feral pigs are major nest predators.

Research actions required:

- undertake satellite tracking to identify dispersal away from breeding sites and hence likely threats in those areas;
- assess extent of breeding, breeding success and causes of failure, on mainland areas.

Management actions required:

- maintain pig-free status on Field Island;
- if cost-effective, protect mainland breeding sites from predators;
- where feasible, engage collaboratively in the global management of these species

Monitoring actions required:

- maintain and review (analyse results and refine) existing monitoring program

Priority action:

6.2.6. Maintain and review (analyse results and refine) existing monitoring program for Flatback Turtle.

GROUP 9: Floodplain plant and animal species

3 species: Monochoria hastata, Yellow Chat (Alligator Rivers), Water Mouse

[Note also Yellow-spotted (Floodplain) Monitor within group 6]

This is a disparate set of three poorly-known species. None has been the subject of specific management and there are no current monitoring programs. There is no recent information on the occurrence (let alone population trends) of the Water Mouse (which may also occur in mangrove areas) in Kakadu, or of any factors that may threaten it. There has been one brief baseline study of the occurrence of the Yellow Chat in Kakadu (Armstrong 2004), occasional sampling and survey for the plant *Monocharia hastata* (Cowie and Liddle 2014), and some localised targeted sampling (albeit unsuccessful) for the Water Mouse.

Research actions required:

- undertake a targeted survey program for all three species in order to define distribution (and important populations), assess abundance, and examine habitat requirements;
- assess current and future (including consequences of climate change) threats and management requirements

Management actions required:

- control pigs and buffalo where their impact is having significant detrimental impacts at sites known to support *Monocharia hastata*;
- based on future research examining status and threats, implement management to control principal threats at sites containing important populations, where cost-effective to do so

Monitoring actions required:

- design and implement monitoring programs for these three floodplain species, incorporating previous sampling for Yellow Chat and *Monocharia hastata*

Note that there is an existing Recovery Plan for the Water Mouse (Department of the Environment and Resource Management 2010).

Priority actions:

6.2.7. Undertake a targeted survey program for three floodplain threatened species in order to define distribution (and important populations), assess abundance, and examine habitat requirements.

6.2.8. Design and implement monitoring programs for three floodplain threatened species.

GROUP 10: Rainforest plant species

2 species: Dienia montana, Freycinetia excelsa

In Kakadu, these rainforest plant species are each known from only one rainforest site, but both are also known from beyond Kakadu. For the orchid *Dienia montana*, limited recent searches have failed to relocate its known subpopulation. Both species may be threatened primarily by feral pigs (Cowie and Liddle 2014).

Research actions required:

- undertake targeted searches for further subpopulations in Kakadu, and more intensive survey at the sole known site for *Dienia montana*;
- assess conservation requirements and management options for the protection of the known subpopulations

Management actions required:

- ensure the significant locations for these important subpopulations are appropriately considered in management planning and action
- control or reduce the abundance of feral pigs at the sole subpopulation of *Dienia montana*

Monitoring actions required:

- design and implement monitoring programs for both rainforest plant species, for the abundance of pigs (and pig impacts) at both sites, and of the responses to management intervention

Priority actions:

6.2.9. Undertake targeted searches for further subpopulations in Kakadu, and more intensive survey at the sole known site for Dienia montana.

6.2.10. Control feral pigs at the sole subpopulation of Dienia montana.

6.2.11. Design and implement monitoring programs for both rainforest plant species, for the abundance of pigs (and pig impacts) at both sites, and of the responses to management intervention.

GROUP 11: (a) Lowland woodland plant and animal species; (b) Stony hills woodland species; (c) wetland species within lowland woodlands

12 species: Cycas armstrongii, Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl (northern), Crested Shrike-tit (northern), Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Bare-rumped Sheath-tailed Bat

1 species: Gouldian Finch

1 species: Utricularia dunstaniae

This and the following group represent the most formidable challenges for the management of Kakadu's threatened species.

Most of the species in this set are known to be, or may plausibly be, detrimentally affected by the current fire regime pervasive across Kakadu lowlands. For at least Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat and Pale Field-rat, longer-unburnt woodlands provide more suitable habitat than frequently burnt habitat (Friend and Taylor 1985; Friend 1987), and this is probably also the case for most other species in this group. For at least Partridge Pigeon and Gouldian Finch, suitable habitat is more about a fine-scale mix of burnt and unburnt areas. A clear management requirement for this group of threatened species is to change the current fire regime, to one that (i) increases the total area and proportion of longer-unburnt (>5 years without fire) lowland woodland area, and (ii) decreases the average size of burnt areas and increases the fire-imposed heterogeneity. Additional to committed change in fire management, such management objectives also require the control of those invasive grasses that exacerbate fire intensity.

Many of the species in this group (particularly the mammal species) are also known or likely to be detrimentally affected by predation by feral cats; and indeed such predation may be the most significant threat for at least some of these threatened species.

The Gouldian Finch is somewhat different to the other species in this lowland group in that it occurs mostly in stony woodlands. However, it is also threatened mostly by inappropriate fire regimes, and likely to benefit most from management that decreases the average size of burnt areas and increases the fire-imposed heterogeneity.

The small plant *Utricularia dunstaniae* has a restricted and patchy distribution in seasonally inundated lowland areas (but not floodplains per se), and may be affected mostly by habitat degradation by feral pigs and buffalo.

For some plant and animal species in this group, the distribution, ecology and management requirements are reasonably well known, and existing monitoring programs provide some measure of population trends. However, the distribution and ecology of some species are relatively poorly known: this is so most notably for Yellow-snouted Gecko, Northern Brush-tailed Phascogale, Bare-rumped Sheath-tailed Bat and *Utricularia dunstaniae*.

Research actions required:

- undertake targeted surveys and studies that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened lowland species (Yellow-snouted Gecko, Northern Brush-tailed Phascogale, Bare-rumped Sheath-tailed Bat and *Utricularia dunstaniae*);
- undertake targeted surveys that identify significant sites (i.e. holding important populations) for lowland threatened species;
- refine knowledge of the preferred fire regime and thresholds of concern for all lowland threatened species;
- assess the relative impacts of cat predation *vis-à-vis* other threats for threatened lowland animal species, and options for controlling cats to densities at which their impact is inconsequential;
- assess the impact of predation by wild dogs/dingoes upon threatened lowland mammal species, and of the extent to which dogs may constrain impacts upon threatened mammals of predation by feral cats.

Management actions required:

- change lowland fire management in a manner more analogous to the Stone Country Fire Management Plan (Petty *et al.* 2007), in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity;
- where cost-effective and/or at significant sites (holding important populations of threatened species), control (or exclude) feral cats;
- where cost-effective and/or at significant sites (holding important populations of threatened species), control invasive grasses

Monitoring actions required:

- design and implement monitoring programs for currently unmonitored threatened lowland species, and maintain and enhance existing monitoring programs for those species currently subject to some monitoring;
- monitor fire regimes in relation to targets set for threatened lowland species;
- establish monitoring programs for feral cats in areas with and without management effort;
- monitor the incidence and extent of invasive grass species, particularly in relation to management effort.

Note that there are existing national Recovery Plans for Partridge Pigeon (Woinarski 2004c), Red Goshawk (Department of Environment and Resource Management 2012), Masked Owl (Woinarski 2004c), Crested Shrike-tit (Woinarski 2004c), Bare-rumped Sheath-tailed Bat (Schulz and Thomson 2007) and Gouldian Finch (O'Malley 2006) and a proposed Recovery Plan for Brush-tailed Rabbit-rat (Woinarski *et al.* 2014a).

Priority actions:

6.2.12. Undertake surveys that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened lowland species.

6.2.13. Refine knowledge of the preferred fire regime and thresholds of concern for all lowland threatened species.

6.2.14. Assess the relative impacts of cat predation vis-à-vis other threats for threatened lowland animal species, and options for controlling cats to densities at which their impact is inconsequential.

6.2.15. Change lowland fire management in a manner more analogous to the Stone Country Fire Management Plan, in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity.

6.2.16. Where cost-effective and/or at significant sites (holding important populations of threatened species), control (or exclude) feral cats.

6.2.17. Design and implement monitoring programs for currently unmonitored threatened lowland species, and maintain and enhance existing monitoring programs for those species currently subject to some monitoring.

6.2.18. Monitor fire regimes in relation to targets set for threatened lowland species.

GROUP 12: Stone Country species and ecological community

17 species & 1 community: Acacia equisetifolia, Bolbitis quoyana, Hibbertia brennanii, Hibbertia pancerea, Hibbertia sp. South Magela, Hibbertia tricornis, Hibiscus brennanii, Jacksonia divisa, Lithomyrtus linariifolia, Sauropus filicinus, Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Nabarlek, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat, Arnhem Rock-rat, Arnhem Plateau Sandstone Shrubland Complex

This and the previous group of species comprise the most substantial management challenge for Kakadu's threatened species. The Stone Country is the main centre of endemism in Kakadu, and is one of Australia's most important centres of endemism (Crisp *et al.* 2001; Woinarski *et al.* 2006; Woinarski *et al.* 2009). Many of those endemic species are in decline, and in many or most of these cases, the primary cause of decline is the current fire regime: fire is too frequent, extensive and/or intense. The primary management requirement is to reduce fire impacts, if not pervasively across the Stone Country, then at least in those areas that hold important populations for threatened species. Recent analysis (Murphy 2013) suggests that current management is achieving significant progress towards this objective, at least in part because of a clear fire management strategy for the Stone Country (Petty *et al.* 2007).

Some of the species in this group (e.g. Arnhem Land Skink, Oenpelli Python, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat) are very poorly known, with little information on population size and trends, the location of important populations, ecology or management requirements. For these species, a targeted research program is likely to lead to substantially improved management effectiveness.

Many of the threatened species in this group would provide relevant indicators for the overall status of the Arnhem Plateau Sandstone Shrubland Complex ecological community, but additional criteria may be required for more comprehensive assessment and monitoring of the condition of this threatened community.

The fern *Bolbitis quoyana* is idiosyncratic in this group, with only one known Kakadu population which is threatened primarily by catastrophic flood events.

Research actions required:

- undertake targeted surveys that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened Stone Country species (e.g. Arnhem Land Skink, Oenpelli Python, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat);
- undertake targeted surveys that identify significant sites (i.e. holding important populations) of Stone Country threatened species;
- refine knowledge of the preferred fire regime and thresholds of concern for all Stone Country threatened species

Management actions required:

- maintain and enhance Stone Country Fire Management Plan, in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity.

Monitoring actions required:

- design and implement monitoring programs for currently unmonitored threatened Stone Country species, or maintain and enhance existing monitoring programs for those species currently subject to some monitoring;
- develop additional appropriate monitoring parameters for the condition of the Arnhem Plateau Sandstone Shrubland Complex ecological community, and implement appropriate monitoring;
- maintain and enhance the existing monitoring program for fire regimes in relation to targets set for threatened Stone Country species.

Priority actions:

6.2.19. Undertake surveys that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened Stone Country species.

6.2.20. Identify significant sites (i.e. those holding important populations) for threatened Stone Country species.

6.2.21. Refine knowledge of the preferred fire regime and thresholds of concern for all Stone Country threatened species.

6.2.22. Maintain and enhance Stone Country Fire Management Plan, in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity.

6.2.23. Design and implement monitoring programs for currently unmonitored threatened Stone Country species (and threatened ecological community), and maintain and enhance existing monitoring programs for those species currently subject to some monitoring.

6.2.24. Monitor fire regimes in relation to targets set for threatened Stone Country species.

6.3. Existing Recovery Plans: obligatory actions

For some of Kakadu's threatened species, there is already a national integrated research, management and monitoring plan that aims to improve the conservation status of the species. The EPBC Act mandates the implementation of such existing recovery plans on Commonwealth lands and marine areas, including Kakadu; and consequently such actions should be hard-wired into any Kakadu threatened species strategy, and be an important and essential component of management activity in Kakadu. Furthermore, the extent and success of their implementation should be a key component of regular reporting.

However, at least some of these Recovery Plans are now dated, and some actions in existing plans are national in focus and such scale may be of limited relevance to local-scale implementation.

Table 5 lists the set of existing Recovery Plans for threatened species in Kakadu, and the actions defined within them. It is likely that additional Recovery Plans will be developed over the course of this Kakadu threatened species strategy, and actions within such plans should be incorporated promptly into operational planning within the strategy.

Table 5. Existing Recovery Plans for threatened species occurring in Kakadu, along with relevant actions included within them.

Note that in most cases, the Recovery Plans provide substantial elaboration on the brief description given here.

Species	Relevant actions
Northern Shrike-tit, Partridge Pigeon, Masked Owl (Woinarski 2004c)	2.1. assess population size etc. for masked owl
	2.2. assess population size, etc. for northern shrike-tit
	2.3. undertake studies … to evaluate relative significance of threats to partridge pigeon
	2.5. develop and implement monitoring programs
	3.1. maintain habitat suitability through appropriate fire management
Northern Hopping-mouse[1] (Woinarski 2004b)	2.1. develop better sampling protocols
	2.2. refine distributional assessments
Bare-rumped Sheathtail Bat (Schulz and Thomson 2007)	1.3. conduct targeted surveys
	3.1. determine roosting requirements
	3.2. identify diet
	4.1. develop and implement monitoring program
Golden Bandicoot[1] and Golden-backed Tree-rat[1] (Palmer *et al.* 2003)	4.4. sample historic locations of golden-backed tree-rat to establish whether populations persist
	5.1. identify factors driving mammal decline through landscape-scale experiments
Gouldian Finch (O'Malley 2006)	1.1. reduce frequency of late dry season fires at critical sites
	1.2. test patch burning effectiveness
	1.3. incorporate adaptive burning strategies into fire management plans
	2.4. develop and implement best-practice grazing and fire management strategies
	3.3. establish a series of integrated monitoring sites
	3.4. regularly review and report on monitoring data
	5.1. develop and disseminate information products to key stakeholder groups

Species	Relevant actions
Northern Quoll (Hill and Ward 2010)	1.2. monitor offshore islands supporting quoll populations
	2.1 determine factors affecting survival in areas with toads
	2.3. identify important refugial areas
	3.5. fire management
	4.1. continue research into susceptibility of quolls to toad poisoning
	4.2. test efficacy of toad control measures
	5.1. manage translocated island populations of quolls
	5.3. manage key quoll populations in national parks
	6.1. monitor disease in quoll populations
	7.1. assess impacts of feral predators
	7.2. manage feral predators
	8.2. support Indigenous ranger groups in quoll management
	8.3, 8.4. communicate
Water Mouse[1] (Department of the Environment and Resource Management 2010)	1.1. conduct surveys to define distribution
	1.4. conduct surveys of potential habitat
	2.3. investigate key populations to determine ecology
	3.1. conduct monitoring program
	3.2. assess impacts of known threats
	3.3. assess impacts of potential threats
	3.4. implement threat management plan
	5.1. communicate with indigenous landowners
	5.4. community communications
marine turtles (Environment Australia 2003)	A2.1. engage Indigenous communities relating to customary use
	A3.1. monitor impacts of marine debris
	B1.1. develop monitoring protocols
	B1.2. monitor key nest areas
	C4.1. manage predation at nest sites
	D2.1. identify and manage key sea grass and other habitats
	E2.1. encourage volunteer participation in monitoring
	E3.1. support Indigenous involvement in management of nest sites
Brush-tailed Rabbit-rat (Woinarski *et al.* 2014a)	7.1. engage Board of Management, Indigenous landholders, and Parks staff with respect to conservation needs of this species, and interest in re-introduction
	7.2. respond to any ad hoc records with targeted sampling
	7.3. maintain or enhance benign (presumed to be low intensity low frequency) fire management
	7.4. enhance control of exotic invasive grass species
	7.5. maintain existing monitoring program
	7.6. within experimental re-location trial, experimentally manipulate (or model) fire and cat predation
	7.7. if re-location occurs, annual review of progress and management implications, with key stakeholders

Species	Relevant actions
Nabarlek (Pearson 2012)	1.1 survey distribution, conservation status and genetic diversity
	6.1 monitor the effectiveness of introduced animal control programs
	7.3 minimise the impacts of fire
	8.2 refine existing and develop new predator control techniques
	8.3 develop new monitoring techniques for rock wallabies and predators
	8.5 undertake landscape-scale research projects to understand the impact of fires on habitat, predation risks and population parameters (concurrent)
	8.10 investigate the prevalence of toxoplasmosis and other diseases and parasites
	9.1 provide interpretative materials for the community and tourism operators
	9.2 involve the community, especially Aboriginal people, in survey and management
	9.3 provide updates on progress to community groups and the general public
	10.1 establish recovery teams or similar forums to plan and oversee actions
	10.2 ensure continued Aboriginal and other land-holder involvement in the recovery process
	10.3 organise a workshop every 3 years to bring together Aboriginal people, researchers and managers to review and plan ongoing actions
Red Goshawk (Department of Environment and Resource Management 2012)	1.1. Collate information on known nest sites
	1.2. Produce descriptive maps of important habitat
	1.3. Conduct searches to identify previously unknown pairs
	3.1. Monitor at least 20 nest sites each year to determine territory occupancy and productivity
	4.2. Ensure locational information about red goshawk nest sites is secure
	5.1. Produce and distribute information material on the conservation status
	5.2. Provide feedback to the public and agency personnel on progress of red goshawk recovery

Notes: 1 no recent records from Kakadu

For this strategy, the principal required actions are to:

6.3.1. Assess and report on the extent of current and ongoing compliance with these mandated Recovery Plan actions.

6.3.2. Develop and implement local-scale interpretations of some of the more generic actions in existing national Recovery Plans.

6.3.3. Collaborate with other agencies and individuals that are collectively involved in the implementation of these national Recovery Plans.

6.3.4. Contribute to the review of these current plans and development of subsequent iterations of them.

6.3.5. Incorporate into management planning and implementation any actions from relevant newly developed plans for additional species.

6.4. Strategic research program on threatened species

Notwithstanding the benefit derived from decades of relevant and useful environmental research in Kakadu and nearby areas, the amount of information on threatened species generally is limited, and is particularly inadequate for some species. This deficiency should not be seen as a reason or excuse to delay management inputs, or as an argument to undertake a comprehensive research program for all threatened species in Kakadu. This strategy works instead from the assumption that there is sufficient information available to indicate appropriate management actions for most, if not all, threatened species, but that such management should be continually refined on the basis of results from monitoring of responses to management inputs and some further priority research.

There are particular research actions that can contribute most to addressing key knowledge gaps that currently impede optimal management, and such research actions that improve the likelihood of management success should be prioritised. For Kakadu's threatened species, such priority research actions comprise:

6.4.1. Geographically delineate important subpopulations for all spatially restricted threatened species in Kakadu (particularly Stone Country plants and animals, the two rainforest plant species, and some lowland animal species (such as Gouldian Finch and Brush-tailed Rabbit-rat)). This research activity will involve GIS-based collation of all current records and additional targeted survey. The research results should be incorporated into mapping and GIS coverages, such that all management staff are aware of the locations of these important subpopulations and use this information as a core consideration in their management planning.

*6.4.2. Refine knowledge of the responses of many threatened species to fire regime*s, with particular focus on identifying preferred fire regimes, threshold limits (comparable to the 'Thresholds of Potential Concern' used in Kruger National Park: e.g. Biggs and Rogers (2003)) and assessment of impacts of all plausible fire regimes. Such research is particularly important for Stone Country plant (and some animal) species and for some lowland animal species. Such research should include refinement of knowledge of life history characteristics, to allow for population viability modelling under a range of fire regimes (such as has been done for Northern Brown Bandicoot by Pardon *et al.* (2003) and for Brush-tailed Rabbit-rat by Firth *et al.* (2010)), and for spatial modelling of population trajectories based on current and potential fire regimes.

6.4.3. Refine knowledge of the population-level responses of some threatened animal species (particularly mammals) to feral cats, in order to assess the relative impacts of such predation *vis-à-vis* other threats, and of the response of threatened species to a range of potential cat control mechanisms.

6.4.4. Clarify the status (particularly population size), ecology and management requirements in Kakadu of some poorly-known threatened species, such as Northern Brush-tailed Phascogale, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat, Bare-rumped Sheath-tailed Bat, Yellow Chat, Oenpelli Python, Arnhemland Skink, sawfish and sharks, some invertebrates and some plants (notably the ground orchid *Dienia montana*).

6.4.5. Clarify the conservation status of all Data Deficient species occurring in Kakadu, and of species in priority groups that have not yet been subject to conservation status assessment. This is a very large set of species (Appendix 2), so the task is formidable. Priority groups are those most likely to have narrowly endemic, phylogenetically distinctive and relictual species: i.e. those for which an unnoticed lost may retrospectively be seen as of most regret.

The Kakadu Research Advisory Committee (KRAC) currently provides strategic advice to Park managers and the Kakadu Board of Management on matters relating to research in Kakadu, including on prioritisation of projected research and filtering of unsolicited research proposals. Those research directions identified here to be priority actions that are likely to most enhance the conservation management of threatened species should be used by KRAC to help order and plan future research programs.

6.5. Strategic research program on threats and their control

Broadly, the main factors affecting threatened species (and biodiversity generally) in Kakadu are well-established: fire, feral animals and weeds. There may also be more local detriment to some species associated with tourism, mining development (including residue impacts of now-abandoned mines within Kakadu, and impacts of current mines adjacent to Kakadu), other infrastructure (road construction and maintenance, powerline easements, etc.) and direct exploitation (hunting and fishing). The impacts of disease and pathogens are not well established, but some (e.g. myrtle rust) may become significant. Climate change is also expected to have some substantial impacts on Kakadu's environments and the status of some threatened species (Kutt *et al.* 2009; Winderlich 2010), and some factors (such as saltwater intrusion) linked to climate change are already affecting some Kakadu environments (and hence threatened species occurring within them). A brief account of those factors detrimentally affecting threatened species in Kakadu is provided in Appendix 6.

However, the ability to manage some of these threats effectively is currently constrained by some substantial information gaps. Furthermore, in a resource-limited environment, it is currently difficult to optimise the allocation of threat management actions, because the available information on costs of actions and benefits of some of those actions is limited and imprecise.

To enhance the effectiveness of management, research activity – linked within an adaptive management program – is required to:

6.5.1. Assess the current abundance of feral cats and the costs and effectiveness of a range of control and mitigation measures to reduce their abundance and impacts.

6.5.2. Assess the costs, effectiveness and feasibility of options to enhance fire management, particularly for options to increase the extent of longer-unburnt lowland woodlands (and Stone Country environments), increase fire patchiness, and enhance fire protection for identified important subpopulations of threatened species.

6.5.3. Assess the costs, effectiveness and feasibility of options to reduce the spread, incidence and cover of invasive grass species overall and at important sites for particular threatened species.

6.5.4. Assess the impacts of wild dogs on a set of threatened species, options for management, and interactions with feral cats.

6.6. Prioritisation of management responses

There are many threats affecting many different threatened species in Kakadu, in many different ways. Furthermore, many of these threats also affect values in Kakadu other than threatened species, and currently they may be managed principally to mitigate their impacts on these other values, or to attempt to mitigate impacts across diverse values. Hence, current management does not necessarily seek to optimise control for the benefit of threatened species, or does not necessarily achieve such an objective.

There are several resource prioritisation and allocation issues:

(i) The precision with which targets or objectives are defined will influence resource requirements. For example, if managers seek to be 50% sure that all threatened species will persist in Kakadu over a 20-year period then the budget required to meet that target will be less than if they seek to be 90% sure that all threatened species will persist, and different again if instead their concern focuses more narrowly on increasing the likelihood of persistence for high value species. If the management timeframe was instead 2-5 years rather than 20 years, the management prioritisation may be different again.

(ii) How should management investment be optimised amongst different (current and projected) threat factors? For example, if $X was available to manage factors affecting threatened species in Kakadu, what proportion of that available resource pool should be directed to the control of feral pigs, or to the control of gamba grass?

(iii) How should management action and investment be optimised for a given threat that differentially affects multiple values? For example, if a particular fire regime reduces by X% the risk of loss of tourism infrastructure but increases by Y% the likelihood of local loss of a subpopulation of a nearby threatened species, how should these projected impacts be balanced by managers?

These are issues that can appropriately be addressed through structured decision-making (e.g. (Gregory *et al.* 2012). In a supporting document for this strategy (see Background Paper), a management prioritisation analysis was undertaken, based on recent comparable management prioritisation plans for biodiversity in the Kimberley (Carwardine *et al.* 2011; Carwardine *et al.* 2012) and Pilbara (Carwardine *et al.* 2014). This process involved: (i) contributed assessments, by a series of experts familiar with Kakadu's threatened species, relating to the likelihood of persistence in Kakadu for all threatened, Near Threatened and some culturally significant species under current management, under no management, and under a series of candidate management actions; (ii) assessments of the feasibility and costs of those candidate management actions; (iii) an analysis of the relative benefit (measured by increase in the estimated likelihood of persistence) and cost:benefit across all threatened species for every candidate management action (with all species treated equally, and with various combinations of weightings according to the values described in Appendix 5); (iv) a series of analyses that determined the best set of management actions under a range of budget caps and persistence targets; and (v) an assessment of the best outcomes (in terms of persistence of threatened species) achievable under a range of resource investments.

The assessments and analyses developed in that Background Paper have substantially influenced the management priorities detailed in this strategy. However, they do not necessarily provide a single definitive answer on how to apportion optimally the available resources amongst possible management actions, or how much allocation is required to conserve Kakadu's threatened species. This is because: (i) the best set of actions will vary depending upon budget availability and the persistence targets set; (ii) the costs for some candidate management actions cannot yet be estimated robustly; (iii) there are very substantial interactions between many threats and hence between many of the candidate management actions; and (iv) there is still substantial uncertainty about what threats affect what species, and also about how effective some actions will be in controlling those threats.

Hence, this prioritisation process should be seen as a guide rather than as providing the prescriptive solution. Furthermore, the prioritisation assessment and analysis process should be repeated regularly over the course of this strategy, as additional information allows refinement from this initial assessment.

The management prioritisation assessment undertaken as background for this strategy focused specifically on threatened species in Kakadu, and the actions that can contribute most effectively to their conservation. However, some of the factors that affect those threatened species have also been considered in a broader context, through the development of national Threat Abatement Plans. The EPBC Act mandates (at s 269(1)) the implementation of Threat Abatement Plans for listed Key Threatening Processes on Commonwealth lands and marine areas. The listed Key Threatening Processes affecting threatened species in Kakadu are given in Appendix 7, with relevant actions included in their Threat Abatement Plans. The management advice given in this threatened species strategy is consistent with, but not identical to, these Threat Abatement Plans.

Of further immediate relevance for the management of threats to Kakadu's listed threatened species is the need to ensure that relevant actions described in this strategy are also appropriately nestled within any and all Kakadu threat management plans and strategies, such as for weeds, fire or feral animals. Such accommodation will ensure that plans for threats and for threatened species have consistent approaches and actions, and that threat management plans appropriately recognise that they function with a priority objective to enhance the conservation of threatened species.

To enhance the effectiveness of threat management for the conservation of Kakadu's threatened species, priority actions are:

6.6.1. Continue to refine and review management prioritisation at 2 to 3 year intervals

6.6.2. Assess and report on the extent of current and ongoing compliance with relevant national Threat Abatement Plan actions.

6.6.3. Collaborate with other agencies and individuals that are collectively involved in the implementation of these national Threat Abatement Plans.

6.6.4. Ensure that all relevant objectives and priority actions in this strategy are explicitly included in and provide direction to Kakadu threat management plans and strategies.

6.7. Access to, and use of, information

Information and its management is vital to the success of this strategy. Conservation management will be most effective when it is evidence-based, and when there is regular and reliable reporting of salient information on the benefits of such management to threatened species.

Currently, Kakadu managers (and the public generally) may find it difficult to know what threatened species occur in the Park, which of these are of highest management priority, where important populations occur, what their management requirements are, whether their populations are increasing or decreasing, and how current management actions are affecting these species.

The following actions will address such shortcomings:

6.7.1. Substantially enhance database management for biodiversity (specifically including threatened species, and data deficient and Near Threatened species) records in Kakadu. This should include compilation of all historic and current records, a more concerted effort to elicit new records, and an effective process to allow ready access by Park staff and visitors to input new records and to view existing records.

6.7.2. Substantially enhance GIS management in Kakadu, such that Park managers and others can readily access information on the locations of important populations of threatened species, and that such information is demonstrated to be used proactively by Park managers and other staff when they undertake relevant management actions (such as control burning).

6.7.3. Develop and maintain comprehensive and integrated data bases that store all relevant monitoring information about threatened species and threatening factors, and ensure that such information is interpreted and reported regularly to Park managers, traditional landowners, and others (see also section 6.9).

6.7.4. Develop and regularly update appropriate guides (handbooks, posters or web products) that allow Park managers, traditional landowners, tourists and others to readily identify threatened species and develop and widely disseminate appropriate management guidelines including management requirements and thresholds for threatened species. A notable recent contribution to this action has been the completion of a 'Ready Reckoner' guide, designed to familiarise or alert rangers and Traditional Owners to many threatened species in Kakadu (O'Dea 2014).

6.7.5. Consolidate compilation of traditional knowledge about threatened species, and ensure that such knowledge is appropriately considered in management guidelines. A notable recent contribution to this action has been the compilation of information on threatened species held by the some of the Park's traditional owners (Winderlich and O'Dea 2014).

6.7.6. Ensure researchers working on threatened species in Kakadu provide in timely manner explicit management advice arising from their work.

6.8. Targets

An overall objective, and a set of subsidiary objectives, for the conservation of threatened species in Kakadu is presented in Part 5 of this strategy. These objectives provide the broad direction and framework for this document.

Here, we also recognise the need for explicit quantitative targets that help to more specifically define management actions and allow for ongoing measurement of their effectiveness. There are well-established precedents in Kakadu for environmental management directed towards targets, most notably for the Stone Country fire management plan (Petty *et al.* 2007) which defined quantitatively-explicit thresholds of management concern for fire regimes in different vegetation types and sought to reduce and report on the proportion of 'overburnt' vegetation in fire-sensitive habitats and overall, and with progress towards such targets being measured (Murphy 2013). As described in section 6.2 of this strategy, comparable targets focusing a management program for fire in the lowland woodlands is also a high priority for the conservation of many Kakadu threatened species.

Targets help set management direction and allow measurement of management success. But their context is critical. Targets should be realistic; they should be accompanied by appropriate monitoring; they should have predefined trigger points or thresholds that prompt management review or the implementation of specific management response; and they should be set within a management framework that recognises accountability and consequences for when progress is substandard, or recognises and appreciates success when targets are achieved or progress towards them is satisfactory. Draft targets for every threatened species are given in Appendix 1.

Priority actions are to:

6.8.1. Establish realistic longer-term and shorter-term targets for every threatened species, that are consistent with the overall objective of this strategy, that are linked to monitoring programs, and for which measured progress or achievement is instrumental in management performance evaluation.

6.8.2. Where appropriate, describe thresholds that indicate that progress towards established targets is inadequate, and which trigger review of management.

6.8.3. Maintain and refine targets within the Stone Country Fire Management Plan, and set appropriate complementary thresholds of concern and targets for fire management in lowland woodlands. Targets recommended by Woinarski and Legge (2013) for bird conservation in north Australia generally provide reasonable initial settings for such targets: (i) at least 25% of the lowland woodlands is at least 3 years unburnt; (ii) at least 5% of the lowland woodlands is at least 10 years unburnt; (iii) fire-sensitive non-savanna vegetation types (such as rainforests) are increasing or stable in extent; (iv) the average size of burnt patches is <1 km^2; and (v) the average basal area of understorey shrubs is >1 m^2/ha.

6.8.4. Institute in annual reporting and performance review a clear accountability for progress towards these targets.

6.9. Integrated monitoring and reporting program

Monitoring is a key component of the conservation of threatened species and of assessment of the performance effectiveness of protected areas generally (Hockings *et al.* 2006). When appropriately designed and implemented, monitoring provides essential information relevant to the assessment of the conservation status of species (and ecological communities), of the need and urgency of action, of the success or failure of different management actions, and of the impacts of threats. Monitoring can include the direct counting of all individuals in a population of a species, a measure of the abundance (or other relevant life history or distributional parameter) of a species, the intensity or extent of a threatening factor, management investment, and progress towards specified targets. Features of any monitoring program for a threatened species include:

(i) *the extent to which the monitoring sites encompass or effectively represent the distribution of the target species.* A monitoring program that counts all individuals, or samples comprehensively across the environmental range of a species will be more reliable than one that makes many assumptions about general trends from data at few monitoring sites that are not necessarily representative;

(ii) *the interval between successive monitoring episodes.* A monitoring program should sample sufficiently frequently to provide managers with rapid feedback on trends and description of the target species' responses to their management interventions.

(iii) *the extent to which the monitoring program has been designed to assess the responses to one or more management actions.* Ambient monitoring in which sites are established without regard to management interventions, or without ancillary assessment of threat levels, will provide little information on management; whereas programs that are designed to measure responses to different management actions or intensities will provide vital information to assess management performance and refine that management.

(iv) *the amount of statistical power*. Monitoring programs with few sites and that measure parameters that are highly variable will not be able to reliably detect trends.

(v) *the duration of monitoring and commitment to ongoing sampling.* Many population trends are likely to be manifest only over decadal scales, but many monitoring programs are resourced for only a few years.

(vi) *the consistency and description of monitoring protocols*. By its nature, monitoring should continue over medium to long term timeframes; and the ability to reliably detect trends may depend upon ensuring that the same sites are sampled repeatedly in an identical manner (in order to minimise extraneous sampling 'noise' or bias). A clear Standard Operating Procedure for every monitoring program provides one mechanism for maintaining such consistency.

(vii) *the extent to which the monitoring program incorporates targets, thresholds and triggers for remedial actions*. In most cases for conservation reserves, managers will be seeking to stabilise or increase the population size of any threatened species, and monitoring programs should be designed to measure progress towards explicit targets. They should also have pre-set thresholds, beyond which specified remedial management actions should be triggered.

(viii) *the design specificity*. Monitoring programs should be tailored carefully to optimise the likelihood of detecting species at the sampled sites (e.g. by using the most appropriate species-specific search or trapping protocols) and/or to provide data on parameters of most relevance to population viability (e.g. there may be little point in counting adults of a long-lived tree whereas measurement of the number and age structure of recruits may be far more informative for population viability).

(ix) *the extent to which managers and other relevant stakeholders are involved in monitoring*. Wherever possible, it would be more desirable for rangers, traditional owners and other relevant managers to collaborate in monitoring activity because it gives them a direct feel for the consequences of their actions.

(x) *the extent to which data from the monitoring program is reliably and consistently entered and maintained, and readily accessible and interpretable*. As with the sampling protocols, a Standard Operating Procedure or similar should be developed and maintained for data entry, curation and access.

(xi) *the extent to which results from the monitoring program are regularly reported and considered consequential by managers*. For conservation reserves in which the maintenance or recovery of threatened species is a core objective, monitoring programs for such species should be a fundamental basis for assessing and regular reporting on management effectiveness.

(xii) *cost-effectiveness.* An ideal monitoring program may meet all of the above criteria but in doing so become impractically expensive. In almost all cases, monitoring programs may represent some compromise between expense and all other criteria.

There are some substantial, long-lasting and renowned monitoring programs in Kakadu, most notably that involving monitoring of responses of plants and, to some extent, vertebrate animals, to fire (Russell-Smith *et al.* 2009; Russell-Smith *et al.* 2014). A monitoring program for nesting Flatback Turtles in Kakadu (at Field Island) is also recognised in the national marine turtle recovery plan (Environment Australia 2003).

However, for most threatened species in Kakadu, there are no current monitoring programs (Appendix 8). For those species that are being monitored, almost all of the monitoring programs fail to adequately meet the criteria above (Appendix 8). Kakadu's headline fireplot monitoring program provides good information on trends for some threatened mammal and bird species, very limited information on trends for some other threatened mammal, bird and reptile species and no information for most threatened plant species (Edwards *et al.* 2003). This strategy will fail to meet its objectives if it cannot report on trends for threatened species, and management will continue to be suboptimal if it is not regularly and reliably informed by evidence concerning the responses of threatened species to management actions.

An integrated monitoring program is multi-faceted. Ideally, it should include (i) appropriately regular measures of trends in the population size (or abundance index) of every threatened species (and of the condition of the threatened ecological community); (ii) a composite index that appropriately collates trend data for all threatened species (see Appendix 9 for an example); (iii) measures of the incidence, extent or intensity of principal threatening factors (e.g. regular mapping of fire history); (iv) measures of the extent of management inputs and investments, and its success; and (v) measures of the progress towards targets, goals and objectives. Furthermore, it is important not only to design and implement such monitoring but also to report on its results in a manner that is publicly accessible and interpretable, that contributes readily to ongoing review of management performance, process and priority, and that is treated by managers as a measure of overall Park performance.

Requirements for monitoring of Kakadu threatened species are to:

6.9.1. Design (with regard to stipulated monitoring program criteria) and implement monitoring programs for every threatened species in Kakadu, including (i) re-sampling of those threatened plant species for which baseline monitoring has been established (mostly between 2003 and 2005), but have not subsequently been re-sampled; and for other plant species that have been re-sampled at least once; (ii) all other threatened plant species; (iii) threatened fish species, based on procedures being developed in current research programs; (iv) threatened invertebrate species; (v) threatened reptile species; (vi) threatened shorebird species, linked to existing national monitoring programs; (vii) threatened bird species not adequately sampled within the existing fireplot program; (viii) threatened mammal species not adequately sampled within the existing fireplot program; and (ix) the condition of the threatened Arnhem Plateau Sandstone Shrubland Complex community.

6.9.2. Enhance existing, or design and implement new, monitoring programs that report on the incidence, extent and impacts of current and projected threats, and of management actions designed to address such threats (for example, regular mapping that reports on the extent and proportion of long-unburnt lowland woodland patches in order to guide management to increase such extent).

6.9.3. Develop a comprehensive and integrated reporting process for all threatened species, a composite index for trends across all threatened species, and a report process for the measurement of progress towards objectives and targets; and develop a mechanism that appropriately relates such trends to management actions and investments.

6.9.4. Develop a comprehensive monitoring data, display and interpretation program, that ensures that all monitoring data are rapidly and reliably entered, and readily accessible and interpretable to all park managers and the public generally.

6.9.5. Develop a consistent series of Standard Operating Procedures (see a suggested template at Appendix 10) *for every monitoring program* that appropriately addresses the monitoring criteria described above, and ensure that such procedures are readily accessible and interpretable to all park managers and the public generally.

6.9.6. Commit to a regular review (at least annually) of all monitoring results (including for population trends for individual threatened species and progress towards targets and objectives) with all relevant Park managers and other stakeholders, to facilitate assessment of performance and refinement of ongoing management.

6.9.7. Report monitoring trends (and management investments) for threatened species in Kakadu to appropriate external bodies (e.g. World Heritage committee, Ramsar, etc.) to demonstrate trends in the condition of values on which listing is based.

6.9.8. Maintain the existing fire plot monitoring program.

This is a substantial set of obligations. It may be a formidable challenge to develop and implement such a comprehensive monitoring program, and priorities may need to be imposed according to species' values, the expected rate of change in status, and monitoring costs.

6.10. Collaboration

There are very many threatened species in Kakadu, and these face multiple threats. Given the scale of the challenge, conservation success will not be achieved by Kakadu managers acting alone.

There are two major opportunities to enhance collaboration: (i) cooperative involvement of researchers, rangers and traditional owners (and in some relevant cases, tourists) in threatened species research, monitoring and management actions undertaken in Kakadu (i.e. getting more people to work on and share the responsibilities in Kakadu), and (ii) coordination of research, monitoring and management actions undertaken in Kakadu with comparable work undertaken outside Kakadu (ranging in scale from neighbouring areas such as Nitmiluk National Park and Warddeken Indigenous Protected Area, to national scale to international scale) (i.e. getting the challenge shared across the broader landscape beyond Kakadu).

To a large extent these approaches are well-established in Kakadu. As described in the current Plan of Management, overseen by the Kakadu Research Advisory Committee, and implemented by relevant Parks staff, researchers operating in Kakadu, including on threatened species, have obligations to seek to involve and train Bininj in research activities, and to seek and incorporate Bininj considerations in research design. One notable existing example of cooperation beyond Kakadu is the Three Parks Fire Monitoring Program (Russell-Smith *et al.* 2009; Russell-Smith *et al.* 2014) implemented collaboratively across Kakadu, Nitmiluk and Litchfield National Parks. This strategy recognises that such collaboration is an essential foundation for implementing research and management actions, and achieving conservation outcomes; hence:

6.10.1. Maintain and enhance collaboration (and, where appropriate, training) amongst researchers, managers, Bininj, and, where appropriate, tourists and other volunteers, in research, management and monitoring activities for threatened species in Kakadu.

6.10.2. Maintain and enhance collaborative linkages between research, monitoring and management programs for threatened species in Kakadu and comparable programs elsewhere in the region (particularly in neighbouring and nearby conservation reserves), nationally and, where appropriate, internationally.

6.10.3. Where feasible and appropriate, seek to augment internally available resources with external funding and other resource support.

6.11. Captive breeding and staged reintroduction

It may seem counter-intuitive to consider a need for captive breeding in relation to one of the world's largest and most significant conservation reserves. However, some of Kakadu's threatened species have extremely restricted ranges and/or very small population sizes, many are affected by (and currently declining because of) factors that are pervasive across the Park and difficult to control, and the array of threats is likely to increase in the future, possibly in unexpected manner. Given these factors, there may be merit in seeking to secure insurance populations of some of the most 'at risk' species, with such insurance populations being maintained in perpetuity or simply as a short-term source of stock to restore wild populations that have suffered catastrophic loss.

Furthermore, there is a valid case for considering the staged reintroduction of some threatened species that may now no longer occur in Kakadu, or are reduced in Kakadu to remnant populations that may now be non-viable.

There is precedent for such programs at other Parks Australia reserves, including a substantial captive breeding program at Christmas Island for two threatened endemic reptile species, and reintroductions of the Mala *Lagorchestes hirsutus* to Uluru-Kata Tjuta National Park, although to date only within fenced enclosures from which feral predators are excluded.

There are three particular reintroduction scenarios for Kakadu that have been considered or implemented:

(i) Training and re-introduction of toad-smart Northern Quolls. There has been some recent success in aversion-training and the reintroduction to Kakadu of 'toad-smart' Northern Quolls (O'Donnell *et al.* 2010; Webb *et al.* 2012), and a continuation of this program is likely to help restore this species to Kakadu.

(ii) Establishment of a 'cat-proof' exclosure (or intensively-managed area) within which cat-susceptible threatened species (mostly mammals) are reintroduced. Predator-exclosure fencing has been demonstrated to work in many other locations in Australia (Short and Turner 2000; Moseby *et al.* 2009; Moseby *et al.* 2011; Anon 2013), although has a substantial establishment cost.

(iii) For some threatened plant species, establishment of a seed bank, ex situ population and staged reintroduction.

Both captive breeding and reintroduction programs provide some additional useful opportunity for research, particularly in relation to life history characteristics (for example factors relating to germination success or duration of seed viability) and experimentation on the relative impact of different threatening factors. In many cases, such research may be impossible or prohibitively expensive in wild populations.

Such captive breeding projects may provide direct benefit for the conservation of threatened species. But it is also possible that some projects may have substantial ancillary benefits for community awareness and participation, resourcing and tourism. Most of Kakadu's threatened species are unlikely to be seen by visitors (and indeed, many may not be likely to be seen in the wild by park managers and traditional owners), because they occur in remote and inaccessible areas, are nocturnal or inconspicuous, and/or are rare. An appropriately designed captive breeding facility, nursery or staged reintroduction site may allow visitors, managers and traditional landowners an opportunity to see such species, and hence develop a greater sense of affinity for, and understanding of, their conservation challenge, and enhanced opportunity for them to contribute to their conservation management.

However, captive breeding and reintroduction programs may be costly, they may unhelpfully divert attention and resources away from necessary in situ actions, and they may require very long-term commitments and specialist care. Currently, there is insufficient information available to assess the relative costs and benefits of most of the captive breeding and reintroduction possibilities, nor is there a clear policy or guidelines in place to assess the merit and operation of any proposed captive breeding program.

For this strategy, the following are priority actions:

6.11.1. Develop appropriate protocols for assessment and implementation of captive breeding programs, particularly with regard to possible detrimental impacts on wild populations, and guidelines for any reintroductions.

6.11.2. Assess likely options, costs and benefits for an integrated ex situ (and where appropriate, reintroduction) program for Kakadu threatened plant species. If such an assessment demonstrates the value of such a program, implement it.

6.11.3. Assess likely options, costs and benefits for the establishment of one or more cat-proof exclosures for the reintroduction of now extirpated mammal species, or to bolster those extant species with severely depleted existing populations. If such an assessment demonstrates the value of such a program, implement it.

6.12. Threatened Species Recovery Team

The management of many Australian threatened species is coordinated through a Recovery Team, and such teams are recognised to be particularly valuable for threatened species that occur across multiple jurisdictions (or with multiple responsible agencies), diverse stakeholder groups, or complex management requirements. Currently, there is no established Recovery Team for any threatened species occurring in Kakadu.

The establishment of one or more Recovery Teams would provide a set of benefits to the implementation of this strategy and the achievement of its objectives. It would help to provide access to assistance from relevant experts; to link with complementary management actions outside Kakadu; to disseminate results and information and provide access to new information; to help resolve complex management challenges; to act where relevant to highlight and encourage actions that contribute to threatened species' recovery; and to help implement, monitor and refine this strategy.

There are several possible models for the establishment of a Recovery Team, varying in their focus and geographic scope:

(1) A single Recovery Team that could advise on the coordination of research, management and monitoring within Kakadu for all Kakadu threatened species;

(2) Involvement in a set of Recovery Teams that each focuses on a coherent set of species across their relevant geographic range (e.g. threatened mammals in northern Australia, threatened sharks and sawfish in northern Australia, Stone Country plants);

(3) A single Recovery Team for the coordination of research, management and monitoring within Kakadu and nearby areas for all threatened species.

The first option provides the tightest and most comprehensive focus on Kakadu threatened species, and is the most appropriate to facilitate the implementation of this strategy, hence the following action is recommended:

6.12.1. Establish and maintain a Kakadu threatened species recovery and advisory group, with clear responsibilities relating to the provision of guidance on threatened species issues and on the implementation of this strategy, with well-defined operational procedures, and with substantial representation of appropriate experts, stakeholders and relevant agencies.

Such a Recovery Team should include at least representatives of experts in the conservation of all main taxonomic groupings of threatened species, of the Northern Territory Department of Land Resource Management, of Indigenous landholders, and of neighbouring groups that may also be involved in relevant conservation management programs. The existing Kakadu Research Advisory Committee may provide an appropriate model for its operation.

6.13. Resourcing and management structure appropriate to meet the objectives

The overall objective of this strategy is justifiable but unlikely to be achievable under current levels of resourcing (see Background Paper), and hence this strategy has sought to provide priorities for actions.

It is currently not feasible to provide a precise estimate of how much is being expended on threatened species conservation in Kakadu (in part because many management actions are undertaken for diverse objectives, including for the conservation of threatened species), or how much would need to be expended to meet the overall objective. Such an evaluation would be simplified if there is an explicit and dedicated account in the overall Kakadu budget for threatened species management.

Given the complex challenge articulated in this strategy, its likelihood of success may be enhanced if there is a dedicated position of a Threatened Species Conservation Officer within the current organisational setting of the Natural and Cultural Resource Management group, whose primary responsibility would be to implement this strategy, and report on its delivery.

Research, monitoring and conservation management for threatened species in Kakadu is already being bolstered by partnerships by research institutions (particularly Charles Darwin University and CSIRO) and other management agencies (particularly the Northern Territory Department of Land Resource Management), and Kakadu management has been proactive and successful in increasing the resource pool through accessing external funding sources such as the ARC Linkage grants and the National Environmental Research Program. Maintaining and increasing such (and other) external funding input will be necessary in order to adequately implement this strategy.

Actions considered here to be important for the strategy's implementation are:

6.13.1. Develop and maintain an account and itemisation in Kakadu's budget that relates explicitly to investments made for the conservation of threatened species.

6.13.2. Dedicate a staff position to a Kakadu Threatened Species Conservation Officer with primary responsibility for the delivery of this strategy, and with dedicated budget.

6.13.3. Seek to maintain and enhance resource contributions from external sources.

Northern Quoll - *Dasyurus hallucatus*

Photo: Jonathan Webb

7. Implementation

This strategy proposes an overall objective, 16 principles and subsidiary operational objectives and 70 actions (collated in Appendix 11). This may seem unnecessarily complex and exhaustive, however the challenge is formidable, the responsibility and opportunity substantial, and the current practice demonstrably at least partly unsuccessful. Much needs to be done, and done differently, if the international value of Kakadu as a refuge for threatened species is to be maintained.

These actions relate to research, monitoring, organisational structure, collaboration and other activities, but a key priority is to enhance on-ground management of threats. Based on management prioritisation analysis and the practicality of managing threats at a landscape scale, the highest priority management actions are summarised in Table 6. The collective implementation of these actions is likely to lead to substantial increase in the likelihood of securing most of Kakadu's threatened species. As reported in the Background Paper describing the management prioritisation, these actions are likely to benefit not only threatened species, but also Near Threatened species and culturally significant species.

Table 6. Key management actions, for main landscape types in Kakadu

LOWLAND WOODLANDS

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Across the extent of lowland woodlands, (i) increase extent of 'longer-unburnt' (>10 years since last fire) habitat to at least 5%; (ii) increase extent of >3 years unburnt to at least 25%; (iii) reduce average patch size of fires to <1 km^2.	Develop and implement a lowland woodland fire strategy; maintain and enhance carefully planned strategic control burning (in wet season and early dry season); establish fire-breaks; suppress high risk fires; use fire history mapping tactically to set annual and ongoing fire management goals.	*Cycas armstrongii,* Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Crested Shrike-tit, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Bare-rumped Sheath-tailed Bat, Gouldian Finch
FERAL ANIMALS	In at least localised test areas (and/or areas of particular significance for high priority threatened species), reduce feral cat abundance by >90%	(i) Maintain or extend cat exclosure fencing; (ii) implement control program using suitable bait	Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat
WEEDS	Stabilise (or where possible, reduce) the incidence, extent and abundance of invasive pasture grasses (and prevent encroachment of gamba grass), across the extent of lowland woodlands	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Cycas armstrongii,* Yellow-snouted Gecko, Partridge Pigeon, Red Goshawk, Masked Owl, Crested Shrike-tit, Northern Quoll, Northern Brush-tailed Phascogale, Fawn Antechinus, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Bare-rumped Sheath-tailed Bat, Gouldian Finch
WEEDS	Substantially reduce the incidence, extent and abundance of invasive pasture grasses, in areas of particular significance for high priority threatened species	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	Yellow-snouted Gecko, Northern Brush-tailed Phascogale, Brush-tailed Rabbit-rat

FLOODPLAINS

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Maintain or enhance a fine-scale patchy fire regime in floodplain areas	Maintain and enhance strategic control burning; establish fire-breaks; suppress high risk fires.	Yellow Chat
FERAL ANIMALS	At floodplain wetlands important for threatened species, stabilise or reduce habitat degradation due to feral pigs and buffalo	Implement control program using traps and/or shooting	*Monochoria hastata*
WEEDS	At floodplain wetlands important for threatened species, stabilise or reduce habitat degradation due to aquatic weeds	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Monochoria hastata,* Yellow Chat, Water Mouse

MARINE, RIVERS AND ISLANDS

Management issue	Objectives	Actions	Threatened species expected to benefit
FERAL ANIMALS	Increase breeding success for marine turtles	(i) Ensure no feral pigs establish on Field Island; (ii) reduce abundance of feral pigs and wild dogs on (current and historic) mainland nesting beaches, through trapping or shooting	Flatback Turtle
HUMAN INTERACTIONS	Ensure no significant detrimental impact from fishing activities	(i) Maintain or enhance existing constraints; (ii) enhance communication to fishers; (iii) if appropriate and necessary, regulate to reduce risks in important areas at appropriate times	Northern River Shark, Speartooth Shark, Dwarf Sawfish, Largetooth Sawfish

STONE COUNTRY

Management issue	Objectives	Actions	Threatened species expected to benefit
FIRE	Intensively manage fire regimes at important populations of highly localised threatened species; Across the extent of the Stone Country, (i) increase extent of 'longer-unburnt' (>10 years since last fire) habitat to at least 10%; (ii) increase extent of >3 years unburnt to at least 40%; (iii) reduce average patch size of fires to <1 km^2.	Maintain implementation of the Stone Country Fire plan (with some refinements to increase conservation outcomes for threatened species)	*Acacia equisetifolia, Hibbertia brennanii, Hibbertia pancerea, Hibbertia* sp. South Magela, *Hibbertia tricornis, Hibiscus brennanii, Jacksonia divisa, Lithomyrtus linariifolia,* Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat, Arnhem Rock-rat, Arnhem Plateau Sandstone Shrubland Complex
FERAL ANIMALS	In at least localised test areas (and/or areas of particular significance for high priority threatened species), reduce feral cat abundance by >90%	Implement control program using suitable bait	Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Rock-rat
WEEDS	Prevent spread and incursions of invasive pasture grasses; and stabilise incidence, extent and abundance of existing invasive pasture grasses, across the extent of the Stone Country	Develop and implement enhanced biosecurity protocols and practices; develop and implement relevant weed strategy; strategic control of existing outbreaks	*Acacia* sp. Graveside Gorge, *Hibbertia brennanii, Hibbertia pancerea, Hibbertia* sp. South Magela, H*ibbertia tricornis, Hibiscus brennanii, Jacksonia divisa, Lithomyrtus linariifolia,* Arnhem Land Skink, Oenpelli Python, White-throated Grass-wren, Northern Quoll, Nabarlek, Arnhem Rock-rat, Arnhem Plateau Sandstone Shrubland Complex

RAINFORESTS

Management issue	Objectives	Actions	Threatened species expected to benefit
FERAL ANIMALS	Exclude or intensively control feral pigs from rainforest patches supporting threatened plant species	(i) Establish pig exclosure fencing; (ii) implement control program using traps and/or shooting	*Dienia montana, Freycinetia excelsa*

Gouldian Finch - *Erythrura gouldiae*

Photo: Cassie McMaster

8. Assessment and review

This strategy includes numerous components that stipulate regular monitoring and performance review. Progress on its implementation should be reported annually to a Kakadu Threatened Species Recovery and Advisory Group or Kakadu Research Advisory Committee or equivalent, the Kakadu Board of Management, and publicly through Kakadu's website. Such progressive review should include not only the extent of progress towards targets described here, but also the opportunity and requirement to modify the strategy (particularly its priorities and actions) if these are demonstrated to be suboptimal.

A formal review and recalibration of the strategy should be conducted at years 3, 6 and 9, with such reviews forming the foundation for a new strategy developed in year 10. Such reviews should highlight not only the extent to which the strategy is being implemented and delivering on its objectives, but also the extent to which it functions effectively as a complementary basis for management with other Kakadu strategies (such as for fire, ferals and weeds), and to which it fulfils the objectives of the overall Kakadu Plan of Management.

Commitment to such ongoing review and refinement is important. Such review did not happen for either of the two preceding Kakadu threatened species strategies and plans (Roeger and Russell-Smith 1995; Woinarski 2004a), and the lack of implementation and such performance scrutiny may have been a factor contributing to the general trend for decrease in Kakadu threatened species over this period. Furthermore, the limited extent of systematic and integrated implementation of those previous strategies means that the management knowledge base underlying the current strategy is weak, and many actions prescribed, but not implemented, in those previous plans have to be restated here.

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Appendices

Flatback Turtle - *Natator depressus*

Photo: Miriam Sheridan

Appendix 1 - Kakadu threatened species: dossiers on individual threatened species

These dossiers are intended to provide a concise summary of existing information relevant to management for all species that occur or have been reported in Kakadu and that that are listed as threatened at Australian and/or at Northern Territory and/or at global levels. Each summary also includes one or more long-term targets and a set of monitoring actions that measure progress towards those targets.

Note that conservation status is subject to ongoing change: those listed are as at September 2014.

Common name	Scientific name	status		
		EPBC Act	TPWC Act	IUCN
Plants				
(a shrub)	*Acacia equisetifolia*	CR	CR	
(a mangrove)	*Avicennia integra*			VU
(a fern)	*Bolbitis quoyana*		VU	
(a cycad)	*Cycas armstrongii*		VU	VU
(an orchid)	*Dienia montana*		VU	
(a vine)	*Freycinetia excelsa*		VU	
(a shrub)	*Hibbertia brennanii*		VU	
(a shrub)	*Hibbertia pancerea*		VU	
(a shrub)	*Hibbertia* sp. South Magela		VU	
(a shrub)	*Hibbertia tricornis*		VU	
(a shrub)	*Hibiscus brennanii*	VU	VU	
(a shrub)	*Jacksonia divisa*		VU	
(a shrub)	*Lithomyrtus linariifolia*		VU	
(an aquatic herb)	*Monochoria hastata*		VU	
(a bladderwort)	*Utricularia dunstaniae*		VU	
Invertebrates				
Humped Kakadu-shrimp	*Leptopalaemon gibbosus*			VU
Smooth Kakadu-shrimp	*Leptopalaemon glabrus*			CR
Magela Shrimp	*Leptopalaemon magelensis*			VU
Top End Dragon	*Antipodogomphus dentosus*			VU
Kakadu Vicetail	*Hemigomphus magela*			VU
Rock Narrow-wing	*Lithosticta macra*			VU
Fish				
Northern River Shark	*Glyphis garricki*	EN	EN	CR
Speartooth Shark	*Glyphis glyphis*	CR	VU	EN
Dwarf Sawfish	*Pristis clavata*	VU	VU	EN
Largetooth Sawfish	*Pristis pristis*	VU	VU	CR
Narrow Sawfish	*Anoxypristis cuspidata*			EN
Reptiles				
Flatback Turtle	*Natator depressus*	VU		
Green Turtle	*Chelonia mydas*	VU		EN
Olive Ridley	*Lepidochelys olivacea*	EN		VU
Hawksbill Turtle	*Eretmochelys imbricata*	VU	VU	CR
Loggerhead Turtle	*Caretta caretta*	EN	VU	EN
Pig-nosed Turtle	*Carettochelys insculpta*			VU
Yellow-snouted Gecko	*Lucasium occultum*	EN	VU	

Common name	Scientific name	status		
		EPBC Act	TPWC Act	IUCN
Arnhem Land Skink	*Bellatorias obiri*	EN	VU	
Merten's Water Monitor	*Varanus mertensi*		VU	
Mitchell's Water Monitor	*Varanus mitchelli*		VU	
Yellow-spotted Monitor	*Varanus panoptes*		VU	
Plains Death Adder	*Acanthophis hawkei*	EN	VU	
Oenpelli Python	*Morelia oenpelliensis*		VU	
Birds				
Partridge Pigeon	*Geophaps smithii*	VU9	VU	VU
Red Goshawk	*Erythrotriorchis radiatus*	VU	VU	
Grey Falcon	*Falco hypoleucos*		VU	VU
Greater Sand Plover (Mongolian)	*Charadrius leschenaultii leschenaultii*		VU	
Lesser Sand Plover	*Charadrius mongolus*		VU	
Australian Painted Snipe	*Rostratula australis*	EN	VU	EN
Bar-tailed Godwit	*Limosa lapponica baueri*		VU	
Eastern Curlew	*Numenius madagascariensis*		VU	VU
Asian Dowitcher	*Limnodromus semipalmatus*		VU	
Red Knot	*Calidris canutus*		VU	
Great Knot	*Calidris tenuirostris*		VU	VU
Curlew Sandpiper	*Calidris ferruginea*		VU	
Masked Owl (northern)	*Tyto novaehollandiae kimberli*	VU	VU	
White-throated Grass-wren	*Amytornis woodwardi*		VU	VU
Yellow Chat (Alligator R.)	*Epthianura crocea tunneyi*	EN	EN	
Crested Shrike-tit (northern)	*Falcunculus frontatus whitei*	VU		
Gouldian Finch	*Erythrura gouldiae*	EN	VU	
Mammals				
Northern Quoll	*Dasyurus hallucatus*	EN	CR	EN
Northern Brush-tailed Phascogale	*Phascogale pirata*	VU	EN	VU
Fawn Antechinus	*Antechinus bellus*		EN	
Golden Bandicoot	*Isoodon auratus*	VU	EN	VU
Nabarlek	*Petrogale concinna*		VU	
Ghost Bat	*Macroderma gigas*			VU
Arnhem Leaf-nosed Bat	*Hipposideros inornatus*		VU	VU
Northern Leaf-nosed Bat	*Hipposideros stenotis*		VU	
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus nudicluniatus*	CR		
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	VU	EN	
Black-footed Tree-rat	*Mesembriomys gouldii*		VU	
Golden-backed Tree-rat	*Mesembriomys macrurus*	VU	CR	
Northern Hopping-mouse	*Notomys aquilo*	VU	VU	EN
Kakadu Pebble-Mouse	*Pseudomys calabyi*			VU
Arnhem Rock-rat	Zyzomys maini	VU	VU	
Water Mouse	*Xeromys myoides*	VU		VU
Pale Field-rat	*Rattus tunneyi*		VU	
Dugong	*Dugong dugon*			VU
Dingo	*Canis lupus dingo*			VU

Acacia equisetifolia (a shrub)

NOTE: Until recent formal description (Maslin and Cowie 2014), this species was known (and listed under the EPBC Act) by the phrase name *Acacia* sp. Graveside Gorge (V.J. Levitzke 806).

Conservation status
AUSTRALIA: Critically Endangered
NORTHERN TERRITORY: Critically Endangered

Target for 2025:
1. Population trends stable or increasing over 3 consecutive monitoring episodes.
2. Establishment of a viable *ex situ* population.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area
2. Establish an ex situ population

Key research needed to enhance management effectiveness:
1. Delineate subpopulations and ensure that information is on management GIS.
2. Define key life history parameters (age to maturity, longevity, survival of seeds) and hence provide fire regime thresholds.
3. Survey for additional subpopulations

Recommended monitoring needed to chart management effectiveness:
Indirect monitoring parameter(s)
1. Map fire history across range at least annually, and record fire-free intervals at important subpopulations.

Direct monitoring parameter(s)
1. Annual monitoring of numbers and age class at marked plots for all known subpopulations.

Is there an existing management standard operating plan or protocol?
No; but broadly considered within the Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
Yes (maintained by NT DLRM)

Distribution
Total range This species is known only from two subpopulations (separated by c. 1 km) near Graveside Gorge. The total extent of occurrence is estimated at considerably less than 1 km^2 (Cowie and Liddle 2014)
Kakadu As above.
% Kakadu: 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Not known

Ecology
Very little is known about the ecology of this species, although evidence suggests it is an obligate seeder. Collection notes record it growing on W to SW facing rocky sandstone slopes and ledges at the tops of sheer cliff lines.

Impacts of fire
How fire affects the species Fire may kill adult plants and seedlings, and repeated fires at intervals less than the time to maturity may eliminate subpopulations, unless there is a long-lasting soil seedbank.
Preferred fire regime Not known precisely, but likely to be fire-free intervals of >3 years.

Impacts of feral animals
Not known and not likely

Impacts of weeds
Not known and not likely

Impacts of other threatening processes
Disease: Not known and not likely
Climate change: Not known and not likely
Exploitation: Nil

Estimate of population size in Kakadu
850-950 mature individuals (as at last sampling, in 2006)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☒ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☐ not known

When sampled in 2004, the then only known subpopulation comprised a single adult individual and c. 20 seedlings. At this site, some of the seedlings matured by the next monitoring period; and a further subpopulation was discovered (Woinarski *et al*. 2007; Cowie and Liddle 2014).

Current monitoring programs
An initial monitoring plot was established in 2004 (Kerrigan 2004), and re-sampled in 2005 and 2006 (Woinarski *et al*. 2007). There has been no subsequent monitoring (Cowie and Liddle 2014).

Extent of current targeted management in Kakadu
Some general consideration in Stone Country fire management planning.

Options/needs for ex situ breeding and/or assisted re-introduction
Given small population size and limited distribution, an ex situ insurance population is a desirable risk mitigation measure.

Feasibility of applying preferred management
Medium

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Woinarski, J., Pavey, C., Kerrigan, R., Cowie, I., and Ward, S. (2007). *Lost from our landscape: threatened species of the Northern Territory*. (NT Government Printer, Darwin.)

Avicennia integra (a mangrove)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Near Threatened
IUCN Red List: Vulnerable

Target for 2025:
1. Population trends stable or increasing over 3 consecutive monitoring episodes.

Key management prescriptions:
1. No known relevant management actions

Key research needed to enhance management effectiveness:
1. Assess distribution and abundance in Kakadu
2. Assess likely response to sea level rise

Recommended monitoring needed to chart management effectiveness:
Indirect monitoring parameter(s)
1. Nil.

Direct monitoring parameter(s)
1. 3-5 year interval monitoring of numbers and age class at marked plots for any known subpopulation.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range This species is known from only 15 locations in northern Australia (Duke 2010). The total extent of occurrence is estimated to be less than 20,000 km^2 (Duke 2010)
Kakadu Not well defined.
% Kakadu: c. 5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
Not known

Ecology
This species is found in the low intertidal zone and in the mid-upstream position of larger catchments or riverine-affected estuaries. It grows on soft-intertidal mud banks of convex meandering riverbanks (accreting zone). This species is a tree or shrub, 2-7 m tall. This species has a high tolerance to hypersaline conditions (Tomlinson 1986)

Impacts of fire
How fire affects the species Fire is unlikely to occur in its habitat.
Preferred fire regime n/a.

Impacts of feral animals
Not known and not likely

Impacts of weeds
Not known and not likely

Impacts of other threatening processes
Disease: Not known and not likely
Climate change: Not known
Exploitation: Nil

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
None

Extent of current targeted management in Kakadu
None

Options/needs for ex situ breeding and/or assisted re-introduction
No urgent need.

Feasibility of applying preferred management
No known management requirements

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Duke, N. (2010). *Avicennia integra*. In: IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed 27 April 2014.
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Bolbitis quoyana (a fern)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Population trends stable or increasing over 3 consecutive monitoring episodes.
2. Establishment of a viable *ex situ* population.

Key management prescriptions:
1. Establish an ex situ population
2. Assess options and cost-benefit of an introduction to an additional suitable site.

Key research needed to enhance management effectiveness:
1. Targeted survey for additional subpopulations.
2. Investigate propagation and cultivation techniques.
3. Assess potential for introduction to suitable habitats at other sites.
4. Assess ongoing risks from natural disturbance and possible mitigation responses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Nil

Direct monitoring parameter(s)
Annual monitoring of population size at sole known site.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No current monitoring.

Distribution
Total range This species (or species-complex) occurs in tropical Queensland, New Guinea and Malesia. In the Northern Territory, it is known from only one site.
Kakadu Known only from Dinner Creek gorge.
% Kakadu <5%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
The sole known Northern Territory subpopulation occurs on sandstone in a protected wet gorge (Dinner Creek).

Ecology
Not well known

Impacts of fire
How fire affects the species Probably fire-sensitive, but existing location probably provides adequate shelter from fire.
Preferred fire regime Probably absence of fire.

Impacts of feral animals
Not known and not likely

Impacts of weeds
Not known and not likely

Impacts of other threatening processes
Disease: Not known and not likely
Climate change: Not known and not likely
Exploitation: Not known and not likely

Major threat may be natural disturbance events (scouring of limited habitat by flood).

Estimate of population size in Kakadu
200 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, but anecdotal and incidental information (Cowie and Liddle 2014)

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Given small population size and limited distribution, an ex situ insurance population is a desirable risk mitigation measure.

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
No likely direct benefit

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Cycas armstrongii (a cycad)

Conservation status
AUSTRALIA: not Listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. Status resolved in Kakadu.
2. If occurrence confirmed, abundance stable or increasing.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.
4. Abundance and extent of invasive pasture grasses stable or decreasing.

Key management prescriptions:
1. Reduce incidence and extent of invasive pasture grasses in and near any important populations.
2. Reduce incidence of high intensity and extensive fires in and near any important populations.

Key research needed to enhance management effectiveness:
1. Undertake genetic or morphological assessment of putative *Cycas armstrongii* in Kakadu.
2. if confirmed, survey to assess abundance and distribution.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics for lowland woodlands.
2. Annual assessment of extent and abundance of invasive pasture grasses.

Direct monitoring parameter(s)
1. Assessment (at 2-3 year) intervals of abundance and age structure at known sites.

Is there an existing management standard operating plan or protocol?
No existing management protocol for Kakadu, however there is a general management program for all cycad species in the Northern Territory (Liddle 2009).

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol for Kakadu, but relevant monitoring protocols have been established for this and other cycads in other Northern Territory conservation reserves (Liddle 2009).

Distribution
Total range *Cycas armstrongii* is endemic to the Northern Territory, where its distribution is restricted to a relatively small area from Gunn Point to Hayes Creek, west to Bradshaw and east to the Mary River catchment, with a few records from the Wildman River catchment. It also occurs on the Tiwi Islands and Cobourg Peninsula.
Kakadu Reported in Kakadu only from the far northwest edge (Wildman River system); however the taxonomic status of Kakadu populations may need review.
% Kakadu <1%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements

Ecology
This cycad occurs mainly in open grassy woodland on yellow and red earths.

Impacts of fire
How fire affects the species High intensity fires cause substantial mortality and reduce seed viability (Liddle 2003); and population viability modelling predicts substantial decline under fire regimes fuelled by invasive grasses (Liddle 2003).
Preferred fire regime Relatively tolerant of fire regimes other than extensive and high intensity fires (e.g. Woinarski *et al*. 2004).

Impacts of feral animals
No significant impacts

Impacts of weeds
Invasive pasture grasses are a serious threat, because they exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Not a threat in Kakadu

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No existing monitoring

Extent of current targeted management in Kakadu
No targeted management in Kakadu

Options/needs for ex situ breeding and/or assisted re-introduction
No current need for ex situ cultivation

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Anon. (1997). *A Management Program for Cycads in the Northern Territory of Australia*. (Parks and Wildlife Commission of NT, Darwin.)

Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Dienia montana (an orchid)

NOTE: Formerly known as *Malaxis latifolia*, but recent taxonomic review has included that taxon within *Dienia montana*. Recent review (Margonska and Kowalkowska 2008) suggests that the name may be changed again to *D. ophrydis*. This taxonomic reconsideration does not affect the conservation status in the Northern Territory.

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Population rediscovered in Kakadu, and population trends stable or increasing.
2. Feral pigs excluded from rainforest patch with sole known Kakadu population.

Key management prescriptions:
1. Exclude feral pigs from site with known population (and any subsequently discovered populations).

Key research needed to enhance management effectiveness:
1. Repeated intensive surveys of site with previously-recorded population, at appropriate times to assess whether it has persisted; and, if so, its status.
2. Survey of comparable rainforest patches.
3. Assess cost-benefits of ex situ cultivation and reintroduction.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Abundance of feral pigs in rainforest patch that supports (or supported) the sole known Kakadu population.

Direct monitoring parameter(s)
1. (If population relocated) annual counts of all individuals.

Is there an existing management standard operating plan or protocol?
No existing management protocol.

Is there an existing monitoring standard operating protocol?
No; Kerrigan (2003) described a thorough search, but no individuals were reported.

Distribution
Total range This species is distributed extensively from mainland south-eastern Asia, Japan, Malesia, New Guinea to north-eastern Queensland.
Kakadu Despite broad-ranging surveys of more than 1000 rainforest patches in the Northern Territory (Russell-Smith 1991; Liddle *et al*. 1994), this species has been recorded from only one locality (Bellyungardy Springs: 27 plants) in the Northern Territory and was last recorded in 1993.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☒ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific requirements relative to management.

Ecology
Across its broader range, Jones (1988) noted that the species is widespread and common in rainforests, along protected stream banks in open forest and sometimes close to low-lying swampy areas.

Impacts of fire
How fire affects the species Currently restricted to wet rainforest; but feasibly high intensity fire (or regime of frequent fires) could diminish this patch.
Preferred fire regime No fire; or pre-emptive burning around rainforest edge.

Impacts of feral animals
Rooting up and consumption by feral pigs is likely to be the major threat.

Buffalo may degrade habitat quality.

Impacts of weeds
Invasive pasture grasses at rainforest margin may increase risk of fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
<100 individuals (perhaps 0)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
First (and only time) recorded from this site in 1993, re-sampled unsuccessfully in 2003; no subsequent sampling (Cowie and Liddle 2014).

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Consideration should be given to ex situ cultivation and re-establishment

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
Low

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Freycinetia excelsa (a vine)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates that the population is stable or increasing.
2. No feral pigs present at sole known site in Kakadu.

Key management prescriptions:
1. Maintain (or reinstate) pig-free status of the single rainforest patch supporting the known Kakadu population.
2. Implement enhanced Stone Country fire plan, with explicit protection from fire afforded to the rainforest patch supporting the sole known Kakadu population.

Key research needed to enhance management effectiveness:
1. Assess abundance at, and threats to, sole known Kakadu population.
2. Survey other comparable rainforest sites to seek additional populations.
3. Assess options for establishment of an ex situ population, and effective propagation protocols.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire impacts at known site.
2. Annual assessment of pig presence at known site.

Direct monitoring parameter(s)
1. Assess abundance and age/size structure at known site, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No existing management protocols, but broadly considered within Stone Country fire plan (Petty *et al*. 2007).

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol.

Distribution
Total range This species is known from Australia and New Guinea. In the Northern Territory, it has been recorded from seven localities from Bathurst Island to the Arafura Swamp (Stone 1982; Liddle *et al*. 1994).
Kakadu Only known in Kakadu from a single sandstone rainforest site at Dinner Creek (Cowie and Liddle 2014)
% Kakadu c. 5%

Habitat
☐ Stone Country
☐ lowland woodlands
☒ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No particular habitat requirements relevant to management.

Ecology
This small woody climber occurs in wet lowland rainforest and spring-fed rainforests in sandstone gullies (Woinarski *et al*. 2003).

Impacts of fire
How fire affects the species Severe fire could degrade its rainforest environment.
Preferred fire regime Absence of fire

Impacts of feral animals
Trampling or browsing by feral pigs could reduce population size and reproductive success.

Impacts of weeds
Invasive pasture grasses at rainforest margins could exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
<1000

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Plausible need to establish an ex situ population, but priority may be influenced by more evidence-based assessment of risks to sole known Kakadu population (and/or by any additional populations being located).

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
Medium

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Woinarski, J., Brennan, K., Cowie, I., Kerrigan, R., and Hempel, C. (2003). *Biodiversity conservation on the Tiwi islands, Northern Territory. Part 1. Plants and environments*. (Department of Infrastructure Planning and Environment, Darwin.)

Hibbertia brennanii (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol

Distribution
Total range Restricted to a small area (extent of occurrence c. 18 km^2: Cowie and Liddle 2014) of the sandstone plateau of western Arnhem Land (Toelken 2010), including Kakadu and adjacent areas of Warddeken IPA.
Kakadu Known from few locations near Hollow Rock (c. 10 km NNE of Jabiru) (Toelken 2010).
% Kakadu c. 50%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species grows in rock crevices in dissected sandstone in heathlands (Toelken 2010). It is likely to be a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
> 1000 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No existing monitoring

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Hibbertia pancerea (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
Included in fireplot monitoring program, described in Edwards *et al*. (2003).

Distribution
Total range Restricted to the Lightning Dreaming area of Kakadu (Toelken 2010), within an extent of occurrence of 2 ha (Cowie and Liddle 2014).
Kakadu as above
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species is reported from shallow soil on top of or among sandstone outcrops (Toelken 2010). It is probably a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
'? very small' (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
This species occurs in one quadrat in the fire-plot monitoring program (Cowie and Liddle 2014), monitored at 5 year intervals

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Toelken, H.R. (2010). Notes on *Hibbertia* (Dilleniacae) 5. *H. melhanioides* and *H. tomentosa* groups from tropical Australia. *Journal of the Adelaide Botanic Gardens* **23**, 1-117.

Hibbertia sp. South Magela (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
Included in fireplot monitoring program, described in Edwards *et al*. (2003).

Distribution
Total range Restricted to the Magela Creek Gorge, within an extent of occurrence of 1 km^2 (Cowie and Liddle 2014).
Kakadu as above
% Kakadu c. 90%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species grows on cliff faces. It is probably a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy. Its cliff face habitat provides some protection from most fires.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
<1000 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring, but some recent systematic survey provides a reasonable baseline (Cowie and Liddle 2014)

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

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Hibbertia tricornis (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol

Distribution
Total range Restricted to the Mt Brockman area (Toelken 2010).

Kakadu It is known only from the single location of the type specimen (Toelken 2010).
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species is reported from sand on scree of sandstone escarpment (Toelken 2010). It is a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
'? very small' (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No existing monitoring

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

Toelken, H.R. (2010). Notes on *Hibbertia* (Dilleniacae) 5. *H. melhanioides* and *H. tomentosa* groups from tropical Australia. *Journal of the Adelaide Botanic Gardens* **23**, 1-117.

Hibiscus brennanii (a shrub)

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates that the population is stable or increasing over at least three successive monitoring periods.

Key management prescriptions:
1. Ensure no repeat incidence of high intensity fires at intervals <5 years across its range.

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across known range.

Direct monitoring parameter(s)
1. Counts of total number of individuals and age structure, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No standard management plan, but the species is broadly included within the Stone Country fire plan (Petty *et al*. 2007).

Is there an existing monitoring standard operating protocol?
Kerrigan (2003, 2004) described a standard monitoring protocol.

Distribution
Total range *Hibiscus brennanii* is endemic to the Northern territory, where it is restricted to the Baroalba Creek, Mt Brockman area (Craven and Fryxall 1993).
Kakadu Only known from the Baroalba Creek area, where Kerrigan (2003, 2004) reported it from an extent of occurrence of 1.5 km^2.

% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements

Ecology
This species occurs on sandstone cliffs, in gullies and on broken sandstone pavements.

Impacts of fire
How fire affects the species Not well known. Recurrent fire at intervals of <5 years is likely to lead to local extirpation (Cowie and Liddle 2014); but long-term fire exclusion may also be detrimental.
Preferred fire regime Probably infrequent fine-scale low intensity fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
441 (Kerrigan 2003, 2004)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
Baseline for monitoring established by Kerrigan (2003, 2004), but not subsequently re-sampled.

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Craven, L.A., and Fryxell, P.A. (1993). Additions to the Australian *Hibiscus* (Malvaceae): a new species and a new record. *The Beagle* **10**, 1-6.

Kerrigan, R. (2003). *Kakadu Threatened Flora Report. Results of a threatened flora survey 2003*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Kerrigan, R. (2004). *Kakadu Threatened Flora Report. Volume 2. Results of a threatened flora survey 2004*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

Jacksonia divisa (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol

Distribution
Total range Restricted to the Bloomfield Springs area of south-western Kakadu, where it is known from two nearby sites with a total extent of occurrence of <2 km^2 (Cowie and Liddle 2014).
Kakadu as above.
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species is reported from shrublands on kaolinite clays on the Marrawal Plateau edge. It is a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
?<1000 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No existing monitoring

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

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Lithomyrtus linariifolia (a shrub)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Across range, fire return interval is at least 3-5 years.

Key management prescriptions:
1. Reduce fire frequency (inter-fire interval >3-5 years) and intensity across range area

Key research needed to enhance management effectiveness:
1. More intensive study to detail life history characteristics and responses to a range of fire management regimes; and thence modelling to predict viability under a range of regimes.
2. Assess options for establishment of an ex situ population, and effective propagation protocols.
3. Survey to better resolve status, abundance and distribution (including significant populations)

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across distribution

Direct monitoring parameter(s)
1. Counts of total number of individuals in set of permanent plots.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but included broadly in Stone Country fire plan (Petty *et al*. 2007)

Is there an existing monitoring standard operating protocol?
Standard monitoring protocol described in Kerrigan (2003, 2004)

Distribution
Total range Restricted to the western Arnhem Land plateau and escarpment, with a total extent of occurrence of 3411 km^2 (Cowie and Liddle 2014).
Kakadu as above.
% Kakadu c. 90%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relative to management.

Ecology
This species occurs in heaths or eucalypt woodlands on sandstone, in sandy or skeletal soils, often along the margins of *Allosyncarpia ternata* forest and almost always growing amongst *Triodia microstachya*. It is a fire-sensitive obligate seeder, probably requiring fire-free intervals of at least 3-5 years (Cowie and Liddle 2014).

Impacts of fire
How fire affects the species Not well known. Fires with return intervals of <5 years may extirpate local populations, unless there is a persistent soil seedbank, or unless fires are patchy.
Preferred fire regime Probably infrequent (>5 year interval) and low intensity (patchy) fire.

Impacts of feral animals
No known impact

Impacts of weeds
No current known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
?>200 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
A monitoring program was established by Kerrigan (2003, 2004), but has not subsequently been resampled.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited total population size and range, an ex situ population would provide an important insurance.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Kerrigan, R. (2003). *Kakadu Threatened Flora Report. Results of a threatened flora survey 2003*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Kerrigan, R. (2004). *Kakadu Threatened Flora Report. Volume 2. Results of a threatened flora survey 2004*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

Monochoria hastata (an aquatic herb)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.
2. Aquatic weeds show no increase at its single known Kakadu site.
3. The abundance of feral pigs and buffalo are sufficiently low that there is no habitat degradation at its single known Kakadu site.

Key management prescriptions:
1. Reduce abundance of feral pigs and buffalo at its single known Kakadu site.
2. Prevent any incursions of aquatic weeds at its single known site, and reduce abundance of any already present.

Key research needed to enhance management effectiveness:
1. Survey to better resolve status, abundance, habitat requirements and distribution (including important populations).
2. Study to assess relative impacts of threats and responses to management actions.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of abundance of feral pigs and buffalo (or of their habitat degradation) at known site.
2. Annual assessment of abundance of aquatic weeds at known site.

Direct monitoring parameter(s)
1. Annual assessment of population size.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
Kerrigan (2003) describes a standard monitoring protocol.

Distribution
Total range This species occurs from India, Sri Lanka and south-eastern Asia and extending to New Guinea and Australia. In Australia the only records are from the Northern Territory, on floodplains of the Finniss, Reynolds and Wildman Rivers (Cowie *et al*. 2000).
Kakadu Known from Ben Bunga floodplain, Wildman catchment.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
No known specific habitat requirements relevant to management.

Ecology
Recorded as a component of floating mats in both the Finniss and Reynolds Rivers but also occurs on back-swamps.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Habitat degradation by feral pigs and buffalo may be a major threat, with some evidence of local recovery following reduction in buffalo numbers (Kerrigan 2003).

Impacts of weeds
Aquatic weeds may be a substantial threat through competition and changes in hydrological processes.

Impacts of other threatening processes
Disease Not known or likely
Climate change Saltwater intrusion likely to be a serious threat.
Exploitation Population in Kakadu probably not exploited; used as a vegetable food in other locations.

Estimate of population size in Kakadu
5000 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
Kerrigan (2003) established a baseline for monitoring at the single Kakadu location, but it has not been re-sampled since.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given its limited range in Kakadu, an ex situ population may provide an important insurance.

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
Low

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Cowie, I.D., Short, P.S., and Osterkamp Madsen, M. (2000) *Floodplain Flora.* Flora of Australia Supplementary Series No. 10. (ABRS, Canberra and PWCNT, Darwin.)

Kerrigan, R. (2003). *Kakadu Threatened Flora Report. Results of a threatened flora survey 2003*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Utricularia dunstaniae (a bladderwort)

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.

Key management prescriptions:
1. Reduce abundance of feral pigs and buffalos at known site(s) to threshold levels below which they cause no habitat degradation.

Key research needed to enhance management effectiveness:
1. Survey to better resolve status, distribution (and important populations).
2. Study to assess relative impacts of different putative threats, and responses to management.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of abundance of feral pigs and buffalos (or of any habitat degradation by them) at known site(s).

Direct monitoring parameter(s)
1. Annual assessment of abundance at known site(s).

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol, but some monitoring programs have been established for other *Utricularia* species in the Darwin area (D. Liddle *unpubl*.)

Distribution
Total range Known from the Kimberley (Mitchell Plateau) and Top End, where known from scattered records from near Darwin to Cobourg Peninsula.

Kakadu Known only from a single collection 'near Jabiru at the foot of the Arnhem Land escarpment' prior to 1989 (Taylor 1989).
% Kakadu 5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Utricularia dunstaniae is known only from small patches of sandy wetlands.

Ecology
The species grows in wet sand, often in shallow water, mostly in *Melaleuca nervosa* woodland or *Verticordia* shrubland.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Not well known, but feral pigs and buffalo may be attracted to and degrade its localised preferred habitat.

Impacts of weeds
Not known

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
?<1000 (Cowie and Liddle 2014)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Cost-benefits and likelihood of success should be evaluated, given the poorly resolved status of the species in Kakadu (and its limited occurrence and threats elsewhere).

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Cowie, I. D., and Liddle, D. T. (2014). Threatened plants in Kakadu: past, present and future. In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 31-47. (Supervising Scientist, Darwin.)

Taylor, P. (1989). The genus *Utricularia*: a taxonomic monograph. Kew Bulletin Series XIV. (Her Majesty's Stationery Office, London.)

HUMPED KAKADU-SHRIMP *Leptopalaemon gibbosus*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes. If so, it is unlikely that the putative threat (competition with cane toad tadpoles) is of concern.
2. If monitoring indicates substantial decline, options for ex situ management should be considered, and if feasible, implemented.

Key management prescriptions:
It is unlikely that the putative threat (competition with cane toad tadpoles) can be managed in the wild.
1. Assess need for and cost-benefits of ex situ management.

Key research needed to enhance management effectiveness:
1. Test the impacts of cane toads.
2. If toads are found to have a severe impact, assess options for and cost-benefits of ex situ management.

Note that De Grave (2013) considered that survey effort had been adequate..

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Nil.

Direct monitoring parameter(s)
1. Initial assessment of abundance at the two known sites, with periodicity of ongoing monitoring determined by likelihood of population change.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This recently-described species (Short *et al*. 2013) is known from only two small headwater tributaries of Namarrgon Creek (with the two sites c. 8 km apart).
Kakadu As for total range.
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This species occurs only in small headwater creeks. All known sites do not have fish.

Ecology
Little is known of its ecology. It is gregarious and active during daylight and does not seek shelter when disturbed (Short *et al*. 2013).

Impacts of fire
How fire affects the species Probably no impact: the few known sites are in sheltered very rocky areas with little fuel load.
Preferred fire regime Not known

Impacts of feral animals
Competition with cane toad tadpoles is considered to be a plausible threat, especially in small dry season pools (De Grave 2013).

Impacts of weeds
Not likely

Impacts of other threatening processes
Disease Not known or likely
Climate change Considered 'highly vulnerable' to 'the long-term effects of climate change' (Short *et al*. 2013), with any more protracted or hotter dry seasons possibly causing loss of pools for part of year.
Exploitation Nil

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Cost-benefits and likelihood of success for ex situ management could be evaluated. Note that endemic shrimps are attractive to the aquarium trade.

Feasibility of applying preferred management
Other than ex situ conservation, there is unlikely to be any feasible management

Likelihood that such management may benefit other threatened species
Ex situ management could readily encompass other endemic threatened shrimps.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
De Grave, S. (2013). *Leptopalaemon gibbosus*. In IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed **29 April 2014.**

Short, J.W., Humphrey, C.L. and Page, T.J. (2013). Systematic revision and reappraisal of the Kakaducarididae Bruce (Crustacea: Decapoda: Caridea) with the description of three new species of *Leptopalaemon* Bruce & Short. *Invertebrate Systematics* **27**, 87-117.

SMOOTH KAKADU-SHRIMP *Leptopalaemon glabrus*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Critically Endangered

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes. If so, it is unlikely that the putative threat (competition with cane toad tadpoles) is of concern.
2. If monitoring indicates substantial decline, options for ex situ management should be considered, and if feasible, implemented.

Key management prescriptions:
It is unlikely that the putative threat (competition with cane toad tadpoles) can be managed in the wild.
1. Assess need for and cost-benefits of ex situ management.

Key research needed to enhance management effectiveness:
1. Test the impacts of cane toads.
2. If toads are found to have a severe impact, assess options for and cost-benefits of ex situ management.

Note that De Grave (2013) considered that survey effort had been adequate.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Nil.

Direct monitoring parameter(s)
1. Initial assessment of abundance at the two known sites, with periodicity of ongoing monitoring determined by likelihood of population change.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This recently-described species (Bruce 1993; Short *et al*. 2013) is known from only above and below the waterfall of Lightning Dreaming Creek.
Kakadu As for total range.
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This species occurs only in small headwater creeks. The type locality is a plunge pool.

Ecology
Little is known of its ecology. All known sites are in areas without fish. It is gregarious and active away from shelter during daylight (Short *et al*. 2013).

Impacts of fire
How fire affects the species Probably no impact: the few known sites are in sheltered very rocky areas with little fuel load.
Preferred fire regime Not known

Impacts of feral animals
Competition with cane toad tadpoles is considered to be a plausible threat, especially in small dry season pools (De Grave 2013). This may be more pronounced for this species than for the other threatened endemic shrimps because of the possibly greater access of toads to this species' locations.

Impacts of weeds
Not likely

Impacts of other threatening processes
Disease Not known or likely
Climate change Considered 'highly vulnerable' to 'the long-term effects of climate change' (Short *et al*. 2013).
Exploitation Nil

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Cost-benefits and likelihood of success for ex situ management could be evaluated. Note that endemic shrimps are attractive to the aquarium trade, and this species in particular may attract some interest because of its colouration.

Feasibility of applying preferred management
Other than ex situ conservation, there is no feasible management

Likelihood that such management may benefit other threatened species
Ex situ management could readily encompass other endemic threatened shrimps.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Bruce, A.J. (1993). *Kakaducaris glabra* gen. nov., sp. nov., a new freshwater shrimp from the Kakadu National Park, Northern Territory, Australia, Crustacea: Decapoda: Palaemonidae with the designation of a new subfamily Kakaducaridinae. *Hydrobiologia* **268**, 27-44.

De Grave, S. (2013). *Leptopalaemon glabrus*. In IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed **29 April 2014.**

Short, J.W., Humphrey, C.L. and Page, T.J. (2013). Systematic revision and reappraisal of the Kakaducarididae Bruce (Crustacea: Decapoda: Caridea) with the description of three new species of *Leptopalaemon* Bruce & Short. *Invertebrate Systematics* **27**, 87-117.

MAGELA SHRIMP
Leptopalaemon magelensis

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes. If so, it is unlikely that the putative threat (competition with cane toad tadpoles) is of concern.
2. If monitoring indicates substantial decline, options for ex situ management should be considered, and if feasible, implemented.

Key management prescriptions:
It is unlikely that the putative threat (competition with cane toad tadpoles) can be managed in the wild.
1. Assess need for and cost-benefits of ex situ management.

Key research needed to enhance management effectiveness:
1. Test the impacts of cane toads.
2. If toads are found to have a severe impact, assess options for and cost-benefits of ex situ management.

Note that De Grave (2013) considered that survey effort had been adequate.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Nil.

Direct monitoring parameter(s)
1. Initial assessment of abundance at the two known sites, with periodicity of ongoing monitoring determined by likelihood of population change.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This recently-described species (Short *et al*. 2013) is known from only two streams in the upper southern arm of Magela Creek (with the two sites c. 1 km apart).
Kakadu As for total range.
% Kakadu 100%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This species occurs only in small headwater creeks. All known sites are without predatory fish.

Ecology
Little is known of its ecology. It is known to form large midwater aggregations 'indicative of a sizeable population' (De Grave 2013).

Impacts of fire
How fire affects the species Probably no impact: the few known sites are in sheltered very rocky areas with little fuel load.
Preferred fire regime Not known

Impacts of feral animals
Competition with cane toad tadpoles is considered to be a plausible threat, especially in small dry season pools (De Grave 2013).

Impacts of weeds
Not likely

Impacts of other threatening processes
Disease Not known or likely
Climate change Considered 'highly vulnerable' to 'the long-term effects of climate change' (Short *et al*. 2013).
Exploitation Nil

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Cost-benefits and likelihood of success for ex situ management could be evaluated. Note that endemic shrimps are attractive to the aquarium trade.

Feasibility of applying preferred management
Other than ex situ conservation, there is no feasible management

Likelihood that such management may benefit other threatened species
Ex situ management could readily encompass other endemic threatened shrimps.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
De Grave, S. (2013). *Leptopalaemon magelensis*. In IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed **29 April 2014.**

Short, J.W., Humphrey, C.L. and Page, T.J. (2013). Systematic revision and reappraisal of the Kakaducarididae Bruce (Crustacea: Decapoda: Caridea) with the description of three new species of *Leptopalaemon* Bruce & Short. *Invertebrate Systematics* **27**, 87-117.

TOP END DRAGON
Antipodogomphus dentosus

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.

Key management prescriptions:
1. Maintain water quality at known sites, through management of contaminated mine sites, tourism activity and/or degradation due to stock (Hawking 2009).

Key research needed to enhance management effectiveness:
1. Assess distribution and abundance.
2. Assess impacts of putative threats.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Monitoring of water quality around abandoned mine sites.

Direct monitoring parameter(s)
1. Assessment of abundance at known sites, or number of sites occupied in more extensive sampling.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This species has been reported from seven locations in the Kakadu-Katherine area (Hawking 2009).
Kakadu Sites not reported in Hawking (2009).
% Kakadu c. 60%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This dragonfly species inhabits 'streams, rivers and riverine pools' (Hawking 2009).

Ecology
Little is known of its ecology.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Not reported as a threat (Hawking 2009)

Impacts of weeds
Not reported as a threat (Hawking 2009)

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil
Other Hawking (2009) lists pollution from mines and disturbance by tourists as threats.

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
Water quality protection may benefit other species.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Hawking, J. (2009). *Antipodogomphus dentosus*. In: IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed 29 April 2014.

KAKADU VICETAIL
Hemigomphus magela

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.

Key management prescriptions:
1. Maintain water quality at known sites, through management of contaminated mine sites, tourism activity and/or degradation due to stock (Hawking 2009).

Key research needed to enhance management effectiveness:
1. Assess distribution and abundance.
2. Assess impacts of putative threats.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Monitoring of water quality around abandoned mine sites.

Direct monitoring parameter(s)
1. Assessment of abundance at known sites.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This species has been reported only from Kakadu and Litchfield (Florence Falls) areas (Hawking 2009).
Kakadu Reported from Radon Springs, Baroalba Gorge, Magela Creek at Bowerbid Lagoon, Jim Jim Falls and Dinner Creek (Hawking 2009).
% Kakadu c. 70%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This dragonfly species inhabits 'streams, rivers and riverine pools' (Hawking 2009).

Ecology
Little is known of its ecology.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Not reported as a threat (Hawking 2009)

Impacts of weeds
Not reported as a threat (Hawking 2009)

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil
Other Hawking (2009) lists pollution from mines and disturbance by tourists as threats.

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
Water quality protection may benefit other species.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Hawking, J. (2009). *Hemigomphus magela*. In: IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed 29 April 2014.

ROCK NARROW-WING
Lithosticta macra

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population is stable or increasing across three successive monitoring episodes.

Key management prescriptions:
1. Maintain water qaulity at known sites, through management of contaminated mine sites, tourism activity and/or degradation due to stock (Hawking 2009).

Key research needed to enhance management effectiveness:
1. Assess distribution and abundance.
2. Assess impacts of putative threats.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Monitoring of water quality around abandoned mine sites.

Direct monitoring parameter(s)
1. Assessment of abundance at known sites.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range This species has been reported only from Oenpelli, Kakadu and Katherine areas (Hawking 2009).
Kakadu Reported from Mt Brockman massif, Rockhole mine area, Koongara and Nawurlandja (Hawking 2009).
% Kakadu c. 60%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This dragonfly species inhabits 'streams and rivers, and rocky regions away from them' (Hawking 2009).

Ecology
Little is known of its ecology.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Not reported as a threat (Hawking 2009)

Impacts of weeds
Not reported as a threat (Hawking 2009)

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil
Other Hawking (2009) lists pollution from mines and disturbance by tourists as threats.

Estimate of population size in Kakadu
not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring program

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
Water quality protection may benefit other species.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Hawking, J. (2009). *Lithosticta macra*. In: IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed 29 April 2014.

NORTHERN RIVER SHARK
Glyphis garricki

NOTE: Until recent taxonomic review, this species was called *Glyphis* sp. C.

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Endangered
IUCN Red List: Critically Endangered

Target for 2025:
1. Robust monitoring program indicates population is stable or increasing over three successive monitoring episodes.

Key management prescriptions:
Note that most major threats probably operate outside Kakadu, but affect Kakadu populations because of broad-scale dispersal patterns.

1. Maintain or enhance protocols and constraints on take (including bycatch) in recreational fishing.
2. Maintain integrity of estuarine-river-floodplain connectivity.
3. Engage with relevant fisheries and other agencies in surrounding areas to enhance conservation management actions at regional scale.

Key research needed to enhance management effectiveness:
1. Undertake study to define critical habitat (nursery sites, foraging and predator avoidance).
2. Assess relative impacts of putative threats within Kakadu, including level of take.
3. Examine possible consequences of changing climate.
4. Survey to better resolve status, habitat requirements and distribution (research currently underway: Kyne 2014).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. (In collaboration), extent of bycatch in commercial fisheries in region around Kakadu

Direct monitoring parameter(s)
1. Annual assessment of extent of take (including bycatch) in recreational and Indigenous fishing.
2. Assessment of abundance and population structure through targeted sampling across range, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but a national multi-species recovery plan is expected to be released in 2014.

Is there an existing monitoring standard operating protocol?
No current monitoring protocol, but current survey (Kyne 2014) may provide appropriate methodology.

Distribution
Total range The Northern River Shark is known only from the Kimberley, Top End and southern Papua New Guinea (Compagno *et al*. 2008; Pillans *et al*. 2010).
Kakadu Recent sampling has shown it to be relatively abundant in the South, East and West Alligator Rivers.
% Kakadu c. 80%. Kakadu is considered one of two known international hotspots for this species (Kyne 2014); 80% of all known records are from Kakadu (P. Kyne *pers. comm*.); recent sampling has indicated relatively high numbers in the Alligator Rivers system.

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
Nursery areas may be critical for population viability.

Ecology
The Northern River Shark occurs in tidal stretches of rivers, estuaries and marine environments (Kyne 2014). This species uses river systems as nursery areas.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact

Impacts of weeds
No impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Some Indigenous take, and some bycatch and illegal take (due to confusion with similar-looking Bull Shark) in recreational fishing, but level of harvest and hence impact has not been quantified (Kyne 2014).

Estimate of population size in Kakadu
Not known; however current research will provide robust information on population status (Kyne 2014).

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Limited targeted management (some constraints on recreational fishing, and prohibition of commercial fishing and netting).

Options/needs for ex situ breeding and/or assisted re-introduction
Not feasible

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Compagno, L.J.V., White, W.T., and Last, P.R. (2008). *Glyphis garricki* sp. nov., a new species of river shark (Carcharhiniformes: Carcharhinidae) from northern Australia and Papua New Guinea, with a redescription of *Glyphis glyphis* (Müller & Henle, 1839). In *Descriptions of New Australian Chondrichthyans*. (Eds P.R. Last. W.T. White and J.J. Pogonoski.) pp. 203-225. CSIRO Marine and Atmospheric Research Paper No. 022. (CSIRO Publishing, Melbourne.)

Kyne, P.M. (2014). Threatened fish and marine turtles of Kakadu National Park (with notes on marine mammals). In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 58-74. (Supervising Scientist, Darwin.)

Pillans, R.D., Stevens, J.D., Kyne, P.M., and Salini, J. (2010). Observations on the distribution, biology, short-term movements and habitat requirements of river sharks *Glyphis* spp. in northern Australia. *Endangered Species Research* **10**, 321-332.

SPEARTOOTH SHARK *Glyphis glyphis*

NOTE: Until recent taxonomic review, this species was called *Glyphis* sp. A.

Conservation status
AUSTRALIA: Critically Endangered
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Endangered

Target for 2025:
1. Robust monitoring program indicates population is stable or increasing over three successive monitoring episodes.

Key management prescriptions:
Note that most major threats probably operate outside Kakadu, but affect Kakadu populations because of broad-scale dispersal patterns.

1. Maintain or enhance protocols and constraints on take (including bycatch) in recreational fishing.
2. Maintain integrity of estuarine-river-floodplain connectivity.
3. Engage with relevant fisheries and other agencies in surrounding areas to enhance conservation management actions at regional scale.

Key research needed to enhance management effectiveness:
1. Undertake study to define critical habitat (nursery sites, foraging and predator avoidance).
2. Assess relative impacts of putative threats within Kakadu, including level of take.
3. Examine possible consequences of changing climate.
4. Survey to better resolve status, habitat requirements and distribution (research currently underway: Kyne 2014).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. (In collaboration), extent of bycatch in commercial fisheries in region around Kakadu

Direct monitoring parameter(s)
1. Annual assessment of extent of take (including bycatch) in recreational and Indigenous fishing.
2. Assessment of abundance and population structure through targeted sampling across range, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but a national multi-species recovery plan is expected to be released in 2014.

Is there an existing monitoring standard operating protocol?
No current monitoring protocol, but current survey (Kyne 2014) may provide appropriate methodology.

Distribution
Total range The Speartooth Shark is known only from the Top End, Cape York Peninsula and southern Papua New Guinea (Compagno *et al*. 2008; Pillans *et al*. 2010).
Kakadu Known from the South, East and West Alligator Rivers and the Wildman River (Kyne 2014; *unpubl*.).
% Kakadu c. 20% (Recent survey indicates that the abundance in the Adelaide River system is greater than in the Kakadu rivers: Kyne 2014; *unpubl*.).

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
Nursery areas may be critical for population viability.

Ecology
The Speartooth Shark occurs in tidal stretches of rivers, estuaries and probably other marine environments (Kyne 2014). This species uses river systems as nursery areas, with adults thought to occur mostly in marine and estuarine areas (Kyne 2014).

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact

Impacts of weeds
No impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Some Indigenous take, and some bycatch and illegal take (due to confusion with similar-looking Bull Shark) in recreational fishing, but level of harvest and hence impact has not been quantified (Kyne 2014).

Estimate of population size in Kakadu
Not known; however current research will provide robust information on population status (Kyne 2014).

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Limited targeted management (some constraints on recreational fishing, and prohibition of commercial fishing and netting).

Options/needs for ex situ breeding and/or assisted re-introduction
Not feasible

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Compagno, L.J.V., White, W.T., and Last, P.R. (2008). *Glyphis garricki* sp. nov., a new species of river shark (Carcharhiniformes: Carcharhinidae) from northern Australia and Papua New Guinea, with a redescription of *Glyphis glyphis* (Müller & Henle, 1839). In *Descriptions of New Australian Chondrichthyans*. (Eds P.R. Last. W.T. White and J.J. Pogonoski.) pp. 203-225. CSIRO Marine and Atmospheric Research Paper No. 022. (CSIRO Publishing, Melbourne.)

Kyne, P.M. (2014). Threatened fish and marine turtles of Kakadu National Park (with notes on marine mammals). In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 58-74. (Supervising Scientist, Darwin.)

Pillans, R.D., Stevens, J.D., Kyne, P.M., and Salini, J. (2010). Observations on the distribution, biology, short-term movements and habitat requirements of river sharks *Glyphis* spp. in northern Australia. *Endangered Species Research* **10**, 321-332.

DWARF SAWFISH
Pristis clavata

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Endangered

Target for 2025:
1. Robust monitoring program indicates population is stable or increasing over three successive monitoring episodes.

Key management prescriptions:
Note that most major threats probably operate outside Kakadu, but affect Kakadu populations because of broad-scale dispersal patterns.

1. Maintain or enhance protocols and constraints on take (including bycatch) in recreational fishing.
2. Maintain integrity of estuarine-river-floodplain connectivity.
3. Engage with relevant fisheries and other agencies in surrounding areas to enhance conservation management actions at regional scale.

Key research needed to enhance management effectiveness:
1. Undertake study to define critical habitat (nursery sites, foraging and predator avoidance).
2. Assess relative impacts of putative threats within Kakadu, including level of take.
3. Examine possible consequences of changing climate.
4. Survey to better resolve status, habitat requirements and distribution (research currently underway: Kyne 2014).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. (In collaboration), extent of bycatch in commercial fisheries in region around Kakadu

Direct monitoring parameter(s)
1. Annual assessment of extent of take (including bycatch) in recreational and Indigenous fishing.
2. Assessment of abundance and population structure through targeted sampling across range, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but a national multi-species recovery plan is expected to be released in 2014.

Is there an existing monitoring standard operating protocol?
No current monitoring protocol, but current survey (Kyne 2014) may provide appropriate methodology.

Distribution
Total range The Dwarf Sawfish formerly occurred extensively in the Indo-West Pacific, but now appears to be restricted to northern Australia, from the Gulf of Carpentaria to the northern Pilbara (Kyne 2014).
Kakadu Relatively few records, from the South Alligator River system (Kyne 2014).
% Kakadu c. 10%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No known specific habitat requirements relevant to management.

Ecology
The Dwarf Sawfish occurs in lower tidal stretches of rivers, estuaries and marine environments (Kyne 2014).

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact

Impacts of weeds
No impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known

Exploitation Some Indigenous take possible but unlikely, and some bycatch in recreational fishing, but level of harvest and hence impact has not been quantified (Kyne 2014).

Estimate of population size in Kakadu
Not known; however current research will provide robust information on population status (Kyne 2014).

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Limited targeted management (some constraints on recreational fishing, and prohibition of commercial fishing and netting).

Options/needs for ex situ breeding and/or assisted re-introduction
Not feasible

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Kyne, P.M. (2014). Threatened fish and marine turtles of Kakadu National Park (with notes on marine mammals). In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 58-74. (Supervising Scientist, Darwin.)

LARGETOOTH SAWFISH
Pristis pristis

NOTE: Recent taxonomic review (Faria *et al*. 2013) has resulted in change of name from Freshwater Sawfish *P. microdon*.

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Critically Endangered

Target for 2025:
1. Robust monitoring program indicates population is stable or increasing over three successive monitoring episodes.

Key management prescriptions:
Note that most major threats probably operate outside Kakadu, but affect Kakadu populations because of broad-scale dispersal patterns.

1. Maintain or enhance protocols and constraints on take (including bycatch) in recreational fishing.
2. Maintain integrity of estuarine-river-floodplain connectivity.
3. Engage with relevant fisheries and other agencies in surrounding areas to enhance conservation management actions at regional scale.

Key research needed to enhance management effectiveness:
1. Undertake study to define critical habitat (nursery sites, foraging and predator avoidance).
2. Assess relative impacts of putative threats within Kakadu, including level of take.
3. Examine possible consequences of changing climate.
4. Survey to better resolve status, habitat requirements and distribution (research currently underway: Kyne 2014).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. (In collaboration), extent of bycatch in commercial fisheries in region around Kakadu

Direct monitoring parameter(s)
1. Annual assessment of extent of take (including bycatch) in recreational and Indigenous fishing.
2. Assessment of abundance and population structure through targeted sampling across range, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but a national multi-species recovery plan is expected to be released in 2014.

Is there an existing monitoring standard operating protocol?
No current monitoring protocol, but current survey (Kyne 2014) may provide appropriate methodology.

Distribution
Total range The Largetooth Sawfish occurs in four separate populations, the Indo-West pacific, Eastern Pacific, Western Atlantic and Eastern Atlantic. In Australia, it occurs from the north-eastern Queensland coast to the Kimberley (Kyne 2014).
Kakadu Known from the East and South Alligator River systems.
% Kakadu <5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☒ floodplain
☒ marine and estuaries

Particular habitat requirements
Nursery areas in upstream river reaches and billabongs.

Ecology
The Largetooth Sawfish uses a wide range of habitats, including tidal and freshwater sections of rivers, floodplains, billabongs, estuaries and marine environments (Kyne 2014). Adult females give birth in estuarine waters, and juveniles then disperse upstream into freshwater reaches where they spend c. 4-5 years before returning to coastal and marine waters (Thorburn *et al*. 2007).

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact

Impacts of weeds
No impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Some Indigenous take, and some bycatch in recreational fishing, but level of harvest and hence impact has not been quantified (Kyne 2014).

This species may also be affected by disruption of river connectivity (e.g. through construction of barrages) that could constrain migration patterns (Kyne 2014).

Estimate of population size in Kakadu
Not known; however current research indicates that it is now rare in Kakadu (Kyne 2014).

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known
Kyne (2014) considered that 'there is little doubt that the population was once more robust in the Park'.

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Limited targeted management (some constraints on recreational fishing, and prohibition of commercial fishing and netting).

Options/needs for ex situ breeding and/or assisted re-introduction
Not feasible

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Faria, V.V., McDavitt, M.T., Charvet, P., Wiley. T.R., Simpfendorfer, C.A., and Naylor, G.J.P. (2013). Species delineation and global population structure of Critically Endangered sawfishes (Pristidae). *Zoological Journal of the Linnean Society* **167**, 136–164.

Kyne, P.M. (2014). Threatened fish and marine turtles of Kakadu National Park (with notes on marine mammals). In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 58-74. (Supervising Scientist, Darwin.)

Thorburn, D.C., Morgan, D.L., Rowland, A.J., and Gill, H.S. (2007). Freshwater sawfish *Pristis microdon* Latham, 1794 (Chondrichthyes: Pristidae) in the Kimberley region of Western Australia. *Zootaxa* **1471**, 27-41.

NARROW SAWFISH
Anoxypristis cuspidata

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Near Threatened
IUCN Red List: Critically Endangered

Target for 2025:
1. Robust monitoring program indicates population is stable or increasing over three successive monitoring episodes.

Key management prescriptions:
Note that most major threats probably operate outside Kakadu, but affect Kakadu populations because of broad-scale dispersal patterns.

1. Maintain or enhance protocols and constraints on take (including bycatch) in recreational fishing.
2. Maintain integrity of estuarine-river-floodplain connectivity.
3. Engage with relevant fisheries and other agencies in surrounding areas to enhance conservation management actions at regional scale.

Key research needed to enhance management effectiveness:
1. Undertake study to define critical habitat (nursery sites, foraging and predator avoidance).
2. Assess relative impacts of putative threats within Kakadu, including level of take.
3. Examine possible consequences of changing climate.
4. Survey to better resolve status, habitat requirements and distribution (research currently underway: Kyne 2014).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. (In collaboration), extent of bycatch in commercial fisheries in region around Kakadu

Direct monitoring parameter(s)
1. Annual assessment of extent of take (including bycatch) in recreational and Indigenous fishing.
2. Assessment of abundance and population structure through targeted sampling across range, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No specific management protocol, but a national multi-species recovery plan is expected to be released in 2014.

Is there an existing monitoring standard operating protocol?
No current monitoring protocol, but current survey (Kyne 2014) may provide appropriate methodology.

Distribution
Total range The Narrow Sawfish has an extensive distribution from the northern Persian Gulf across southern Asian marine areas to Australia and Japan (D'Anastasi *et al*. 2013).
Kakadu The Narrow Sawfish has been recorded from estuarine areas of Kakadu, with juvenile (neonate) records from the Suth Alligator River estuary, suggesting that the area is a pupping ground and nursery area for this species (Kyne 2014).
% Kakadu <5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
Nursery areas in estuarine habitats.

Ecology
The Narrow Sawfish is a bentho-pelagic fish, occurring in estuarine, inshore and offshore waters to at least 40 m depth (D'Anastasi *et al*. 2013). Estuarine and inshore waters are critical habitat for breeding and juveniles.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact

Impacts of weeds
No impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Across its range, this species is most detrimentally affected by commercial fishing operations. There is no information on exploitation in Kakadu, but sawfish species generally are subject to ome Indigenous take, and some bycatch in recreational fishing (Kyne 2014).

This species may also be affected by disruption of river connectivity (e.g. through construction of barrages) that could constrain migration patterns (Kyne 2014).

Estimate of population size in Kakadu
Not known (Kyne 2014).

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known
Trends in Kakadu are not known, but this species has generally declined across its range.

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Limited targeted management (some constraints on recreational fishing, and prohibition of commercial fishing and netting).

Options/needs for ex situ breeding and/or assisted re-introduction
Not feasible

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
D'Anastasi, B., Simpfendorfer, C., and van Herwerden, L. (2013). *Anoxypristis cuspidata*. In IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Accessed 4 May 2014.

Kyne, P.M. (2014). Threatened fish and marine turtles of Kakadu National Park (with notes on marine mammals). In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 58-74. (Supervising Scientist, Darwin.)

FLATBACK TURTLE
Natator depressus

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Data Deficient

Target for 2025:
1. Nesting population and nesting success stable or increasing over at least three successive monitoring periods, at Field Island and mainland beaches.

Key management prescriptions:
1. Where appropriate and cost-effective, reduce ghost nets and other marine debris.
2. Reduce the abundance of feral pigs and wild dogs at and around potential and actual mainland breeding areas.

Key research needed to enhance management effectiveness:
1. Cost-benefit analysis of options to increase reproductive success.
2. Assessment of optimal cost-effective monitoring regime.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of marine debris in Kakadu coastal areas.
2. Abundance of feral pigs and wild dogs at and around actual and potential breeding sites.

Direct monitoring parameter(s)
1. Assessment of abundance of nesting attempts and success (currently undertaken annually)

Is there an existing management standard operating plan or protocol?
This species is included within a current Recovery Plan (Environment Australia 2003), which provides a broad management framework.

Is there an existing monitoring standard operating protocol?
Protocol for monitoring of breeding has been reported in Schäuble *et al*. (2006). Monitoring has extended since about 1990 (Vanderlely 1995; Winderlich 1998; Schäuble *et al*. 2006), with stability of the breeding population n Field Island over this period.

Distribution
Total range Flatback Turtles largely occur in Australian continental waters but can be found in low numbers in Indonesia and Papua New Guinea. Flatback Turtles only breed in Australia and breed all around the coastline and offshore Islands of the Northern Territory (Chatto and Baker 2008).
Kakadu Flatback Turtles are common in coastal waters of Kakadu, with substantial nesting on Field Island, and, in smaller numbers, on some mainland beaches.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No specific requirements relevant to management.

Ecology
Flatback Turtles inhabit shallow, soft bottomed sea beds. They are carnivores, feeding mainly on soft corals and soft bodied animals such as jellyfish and sea cucumbers.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
Feral pigs and wild dogs dig up nests and consume eggs and hatchlings, leading to greatly reduced reproductive success.

Impacts of weeds
No impact

Impacts of other threatening processes
Disease No known or likely impact
Climate change Possible impacts, but unlikely to be realised in a 10-year period.
Exploitation No significant exploitation in Kakadu.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☒ stable
☐ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
Annual monitoring (and tagging) of nesting individuals (and some nest success) on Field Island, described in Winderlich (1998) and Schäuble *et al*. (2006). These counts will be complemented by satellite tracking and sand temperature monitoring (A. O'Dea *pers. comm*.) There is less systematic monitoring on mainland beaches. The national recovery plan for marine turtles (Environment Australia 2003) listed Field Island as one of Australia's 12 'key monitoring sites' for Flatback Turtles.

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Chatto, R., and Baker, B. (2008). *The distribution and status of marine turtle nesting in the Northern Territory*. Technical Report 77/2008, (Northern Territory Parks and Wildlife Service, Darwin.)

Environment Australia (2003). *Recovery Plan for marine turtles in Australia*. (Environment Australia, Canberra.)

Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)

Schäuble, C., Kennett, R., and Winderlich, S. (2006). Flatback turtle (*Natator depressus*) nesting at Field Island, Kakadu National Park, Northern Territory, Australia, 1990–2001. *Chelonian Conservation and Biology* **5**, 188-194.

Vanderlely, R. (1995). *An ecological survey of the sea turtles of West Alligator Head and Field Island.* Report to ANCA.

Winderlich, S. (1998). An overview of the sea turtle research in Kakadu National Park and the surrounding area. In *Marine turtle conservation and management in northern Australia. Proceedings of a workshop held at the Northern Territory University Darwin, 3–4 June 1997*. (Eds. R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 110-114. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

GREEN TURTLE
Chelonia mydas

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Least Concern
IUCN Red List: Endangered

Target for 2025:
1. Establish and maintain consolidated data base of sightings, to better resolve distribution and status (including occurrence if any of breeding in Kakadu area).

Key management prescriptions:
1. Where appropriate and cost-effective, reduce ghost nets and other marine debris.

Key research needed to enhance management effectiveness:
1. Survey to assess distribution (including significant populations or foraging sites, and any breeding sites) in Kakadu.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of marine debris in Kakadu coastal areas.

Direct monitoring parameter(s)
1. Abundance of foraging individuals in sampled transects.

Is there an existing management standard operating plan or protocol?
This species is included within a current Recovery Plan (Environment Australia 2003), which provides a broad management framework.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol for Kakadu. Some 'rodeo' capture survey and monitoring was conducted in previous decades, but results have not been reported (A. O'Dea *pers. comm*.).

Distribution
Total range Green turtles occur in tropical and subtropical waters throughout the world. In Australia, the main breeding distribution includes the Great Barrier Reef, the northwest shelf of Western Australia, Wellesley Island group in the southern Gulf of Carpentaria and the Top End coast.
Kakadu Winderlich (1998) noted that Green Turtles were common around reefs adjacent to Field Island, counting 20 individuals over a 2 hr search period. In contrast, Roeger and Russell-Smith (1995) noted that they are rare in the waters off Field Island and West Alligator Head. Winderlich (1998) noted previous reports of Green Turtles 'nesting along the Kakadu coastline' but that no breeding was reported in recent monitoring studies (i.e. since 1995). Other parts of the Northern Territory coastline are appreciably more significant as nesting and feeding sites (Chatto and Baker 2008).
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No specific requirements relevant to management.

Ecology
Green Turtles are primarily herbivorous, mostly eating seagrass and algae. Juveniles are carnivorous. Green Turtles undertake long-distance dispersal around feeding areas and to and from nesting beaches.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
Feral pigs and wild dogs dig up nests and consume eggs and hatchlings, leading to greatly reduced reproductive success.

Impacts of weeds
No impact

Impacts of other threatening processes
Disease No known or likely impact
Climate change Possible impacts, but unlikely to be realised in a 10-year period.
Exploitation No significant exploitation in Kakadu.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring in Kakadu

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Chatto, R., and Baker, B. (2008). *The distribution and status of marine turtle nesting in the Northern Territory*. Technical Report 77/2008, (Northern Territory Parks and Wildlife Service, Darwin.)
Environment Australia (2003). *Recovery Plan for marine turtles in Australia*. (Environment Australia, Canberra.)
Limpus, C., and Chatto, R. (2004). Marine turtles. In *Description of key species groups in the northern planning area*. pp. 113-136. (National Oceans Office, Hobart.)
Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)
Winderlich, S. (1998). An overview of the sea turtle research in Kakadu National Park and the surrounding area. In *Marine turtle conservation and management in northern Australia. Proceedings of a workshop held at the Northern Territory University Darwin, 3–4 June 1997*. (Eds. R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 110-114. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

OLIVE RIDLEY
Lepidochelys olivacea

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Data Deficient
IUCN Red List: Vulnerable

Target for 2025:
1. Increase in successful breeding of this species occurring on Kakadu coastline.

Key management prescriptions:
1. Where appropriate and cost-effective, reduce ghost nets and other marine debris.
2. Reduce the abundance of feral pigs and wild dogs at and around potential breeding areas.

Key research needed to enhance management effectiveness:
1. Survey to assess status, distribution and extent of breeding in Kakadu waters.
2. Cost-benefit analysis of options to increase reproductive success.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of marine debris in Kakadu coastal areas.
2. Abundance of feral pigs and wild dogs at and around actual and potential breeding sites.

Direct monitoring parameter(s)
1. Annual assessment of abundance of nesting attempts and success.

Is there an existing management standard operating plan or protocol?
This species is included within a current Recovery Plan (Environment Australia 2003), which provides a broad management framework.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol for Kakadu. A breeding marine turtle monitoring program was commenced at West Alligator Head in 1987, with ranger staff involved from 1989-90 (Roeger and Russell-Smith 1995). Numbers of Olive Ridleys nesting on the Kakadu mainland were very low (<10 per year), and hence the monitoring program for this species was discontinued around 1990.

Distribution
Total range Olive Ridleys occur in tropical and subtropical waters throughout the world. Most of the nesting population in Australian waters occurs in the Northern Territory. Nesting has been recorded from Melville Island to Groote Eylandt with the highest nesting occurring on Melville Island, islands to the east of Croker Island and some islands off northeast Arnhem Land (Chatto 1998; Chatto and Baker 2008).
Kakadu There is little information on the status of the species in Kakadu. Roeger and Russell-Smith (1995) noted Olive Ridleys nested on beaches of Field Island and West Alligator Head. Winderlich (1998) noted previous reports of the species nesting along the Kakadu coastline, but that no breeding was reported in recent monitoring studies (i.e. since 1995). Other parts of the Northern Territory coastline are appreciably more significant as nesting and feeding sites (Chatto and Baker 2008).
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No specific requirements relevant to management.

Ecology
Olive Ridleys live in shallow protected waters and feed on benthic molluscs, crabs, echinoderms and gastropods. Clutches comprise about 100 large round parchment-shelled eggs.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
Feral pigs and wild dogs dig up nests and consume eggs and hatchlings, leading to greatly reduced reproductive success.

Impacts of weeds
No impact

Impacts of other threatening processes
Disease No known or likely impact
Climate change Possible impacts, but unlikely to be realised in a 10-year period.
Exploitation No significant exploitation in Kakadu.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring in Kakadu

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. In *Marine turtle conservation and management in northern Australia*. (Eds R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 33-40. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

Chatto, R., and Baker, B. (2008). *The distribution and status of marine turtle nesting in the Northern Territory*. Technical Report 77/2008, (Northern Territory Parks and Wildlife Service, Darwin.)

Environment Australia (2003). *Recovery Plan for marine turtles in Australia*. (Environment Australia, Canberra.)

Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)

Winderlich, S. (1998). An overview of the sea turtle research in Kakadu National Park and the surrounding area. In *Marine turtle conservation and management in northern Australia. Proceedings of a workshop held at the Northern Territory University Darwin, 3–4 June 1997*. (Eds. R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 110-114. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

HAWKSBILL TURTLE
Eretmochelys imbricata

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Critically Endangered

Target for 2025:
1. Successful breeding of this species occurring on Kakadu coastline.

Key management prescriptions:
1. Where appropriate and cost-effective, reduce ghost nets and other marine debris.
2. Reduce the abundance of feral pigs and wild dogs at and around potential breeding areas.

Key research needed to enhance management effectiveness:
1. Survey to assess status, distribution and extent of breeding in Kakadu waters.
2. Cost-benefit analysis of options to increase reproductive success.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of marine debris in Kakadu coastal areas.
2. Abundance of feral pigs and wild dogs at and around actual and potential breeding sites.

Direct monitoring parameter(s)
1. Annual assessment of abundance of nesting attempts and success.

Is there an existing management standard operating plan or protocol?
This species is included within a current Recovery Plan (Environment Australia 2003), which provides a broad management framework.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol for Kakadu.

Distribution
Total range Hawksbill Turtles occur in tropical, subtropical and temperate waters of all oceans of the world.

Kakadu There is little information on the status of the species in Kakadu. Winderlich (1998) noted previous reports of the species nesting along the Kakadu coastline, but that no breeding was reported in recent monitoring studies (i.e. since 1995). Other parts of the Northern Territory coastline are appreciably more significant as nesting and feeding sites (Chatto and Baker 2008).
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No specific requirements relevant to management.

Ecology
Hawksbill turtles are omnivorous, eating a wide variety of plants and animals including sponges, gastropods, seagrass and algae.

Hawksbill turtles may undertake long-distance dispersal around feeding areas and to and from nesting beaches, although individuals may also be largely resident around preferred feeding areas. In the Northern Territory, Hawksbill Turtles nest mainly on narrow beaches where they frequently go under vegetation to nest; and nesting occurs mainly in the latter half of the year (Chatto 1998).

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
Feral pigs and wild dogs dig up nests and consume eggs and hatchlings, leading to greatly reduced reproductive success.

Impacts of weeds
No impact

Impacts of other threatening processes
Disease No known or likely impact
Climate change Possible impacts, but unlikely to be realised in a 10-year period.

Exploitation No significant exploitation in Kakadu.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring in Kakadu

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. In *Marine turtle conservation and management in northern Australia*. (Eds R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 33-40. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

Chatto, R., and Baker, B. (2008). *The distribution and status of marine turtle nesting in the Northern Territory*. Technical Report 77/2008, (Northern Territory Parks and Wildlife Service, Darwin.)

Environment Australia (2003). *Recovery Plan for marine turtles in Australia*. (Environment Australia, Canberra.)

Limpus, C., and Chatto, R. (2004). Marine turtles. In *Description of key species groups in the northern planning area*. pp. 113-136. (National Oceans Office, Hobart.)

Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)

Winderlich, S. (1998). An overview of the sea turtle research in Kakadu National Park and the surrounding area. In *Marine turtle conservation and management in northern Australia. Proceedings of a workshop held at the Northern Territory University Darwin, 3–4 June 1997*. (Eds. R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill.) pp. 110-114. (Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.)

LOGGERHEAD TURTLE
Caretta caretta

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Endangered

Target for 2025:
1. Establish and maintain consolidated data base of sightings, to better resolve distribution and status.

Key management prescriptions:
1. Where appropriate and cost-effective, reduce ghost nets and other marine debris.

Note that threats occur mostly elsewhere in the species' broad range.

Key research needed to enhance management effectiveness:
1. Survey to assess status and distribution in Kakadu waters

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of marine debris in Kakadu coastal areas.

Direct monitoring parameter(s)
No monitoring recommended.

Is there an existing management standard operating plan or protocol?
This species is included within a current Recovery Plan (Environment Australia 2003), which provides a broad management framework.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol for Kakadu.

Distribution
Total range The species has a global distribution. In Australia, breeding is centred in the southern Great Barrier Reef and adjacent mainland, on Dirk Hartog Island (Shark Bay) and Muiron Island (North West Cape) in Western Australia. The eastern and western populations are genetically distinct. No breeding is known to occur in the Northern Territory, or elsewhere in northern Australia (Limpus and Chatto 2004). Loggerheads from Australia migrate to the Pacific Islands and southern Asia. The animals that feed in Northern Territory waters appear to come from both the eastern and western breeding populations. When feeding in inshore areas they inhabit subtidal and intertidal coral and rocky reefs and seagrass meadows, as well as deeper, soft bottomed habitats. Feeding Loggerheads are known to occur in Northern Territory waters but are infrequently encountered.
Kakadu There is little information on the status of the species in Kakadu. Roeger and Russell-Smith (1995) reported that it was rare in Kakadu's coastal waters. Given the preference of this species for deeper water, it probably only occurs rarely in Kakadu waters.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No specific requirements relevant to management.

Ecology
Loggerhead Turtles eat shellfish, crabs, sea urchins and jellyfish. Females migrate up to 2600 km from feeding areas to traditional nesting beaches. Females lay up to six clutches of around 125 eggs each season with 3-4 years between breeding.

Impacts of fire
How fire affects the species No impact
Preferred fire regime Not applicable

Impacts of feral animals
No impact in Kakadu

Impacts of weeds
No impact

Impacts of other threatening processes
Disease No known or likely impact

Climate change Possible impacts, but unlikely to be realised in a 10-year period.
Exploitation No significant exploitation in Kakadu.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring in Kakadu (although monitoring at breeding sites elsewhere may indicate trends in abundance for Kakadu)

Extent of current targeted management in Kakadu
No specific management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Environment Australia (2003). *Recovery Plan for marine turtles in Australia*. (Environment Australia, Canberra.)
Limpus, C., and Chatto, R. (2004). Marine turtles. In *Description of key species groups in the northern planning area*. pp. 113-136. (National Oceans Office, Hobart.)
Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)

YELLOW-SNOUTED GECKO *Lucasium occultum*

NOTE: Recent taxonomic review has resulted in renaming from *Diplodactylus occultus*.

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable

Target for 2025
1. A robust monitoring program demonstrates population stability or increase over at least 3 successive monitoring episodes.
2. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire; most fire-age patches are <1 km^2.

Key management prescriptions:
1. Reduce extent, intensity and frequency of fires, but increase fine-scale patchiness.
2. Reduce feral cat abundance.
3. Reduce extent of invasive pasture grasses.

Key research needed to enhance management effectiveness:
1. Assessment of the relative impact of predation by feral predators.
2. Assessment of impacts of wet season fires.
3. Study and modelling to assess and predict population viability across a range of fire management scenarios (including wet season burning).
4. Survey to resolve status, habitat requirements and distribution (including locations of any significant populations).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in lowland woodlands.
2. Annual monitoring of abundance of feral cats.
3. Annual monitoring of extent of invasive pasture grasses.

Direct monitoring parameter(s)
Annual assessment of abundance at a series of permanent sampling sites (pit-traps and timed spotlight censuses).

Is there an existing management standard operating plan or protocol?
No existing management protocol.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol.

Distribution
Total range The known distribution of the Yellow-snouted Gecko is restricted to a small area of north-western Kakadu (Kapalga area) and the Mary River and Wildman catchments (including Mt Bundey military training area, Annaburroo pastoral station and Wildman reserve) (Armstrong *et al*. 2002; Johansen 2006, 2012).
Kakadu Known from several sites in the Kapalga area (King *et al*. 1982). Gillespie and Fisher (2014) note that there have been only five confirmed records in Kakadu since 1988 (and few before then).
% Kakadu c. 50%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements Not well known, but may require a relatively extensive ground litter layer.

Ecology
Little is known of the ecology of this species. It is a terrestrial gecko, sheltering during the day under leaf litter or in shallow burrows. Most individuals captured to date have occurred in conjunction with well-developed leaf litter and grasses in open forests dominated by *Eucalyptus miniata* and *E. tetrodonta*, mostly on deep sandy-loam soils.

Impacts of fire
How fire affects the species Fire may destroy the leaf litter in which eggs are laid, and which provide shelter for this species. Extensive fire may also make the species more susceptible to predation.
Preferred fire regime Not well known, but probably fine-scale patchy and infrequent fire.

Impacts of feral animals
Feral cats may be a major predator.

Impacts of weeds
Invasive pasture grasses may exacerbate fire impacts; however some records are from sites with some gamba grass (Armstrong *et al*. 2002).

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
Population trends poorly resolved, but probably declining.
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
There is no ongoing monitoring program for this species in Kakadu. Johansen (2006) undertook some surveys and these may be useful as a baseline.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Some individuals have been held in a captive breeding program at the Territory Wildlife Park, but options and need for captive breeding and reintroduction may require more information on status and degree of threat to wild populations.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Armstrong, M., Woinarski, J., Hempel, C., Connors, G., and Beggs, K. (2002). *A plan for the conservation of biodiversity in the Mary River catchment, Northern Territory*. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Gillespie, G., and Fisher, A. (2014). Threatened reptile and frog species of Kakadu National Park: current status; known and potential threats; and what needs to be done for them? In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 75-84. (Supervising Scientist, Darwin.)

Johansen, T. (2006). The yellow-snouted gecko (*Diplodactylus occultus*), a little known endemic species of northern Australia. Report to NT Department of Natural Resources and Environment and the Arts.

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King, M., Braithwaite, R. W., Wombey, J. C. (1982). A new species of *Diplodactylus* (Reptilia: Gekkonidae) from the Alligator Rivers region, Northern Territory. *Transactions of the Royal Society of South Australia* **106**, 15-18.

ARNHEMLAND SKINK
Bellatorias obiri

NOTE: Recent taxonomic revision has resulted in change in the scientific name of this species from *Egernia obiri* (and prior to that from *Egernia arnhemensis*)

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Population(s) relocated.
2. A robust monitoring program demonstrates stable or increasing population size over at least three successive monitoring periods.
2. >10% of Stone Country is >10 years since last fire; >30% is >3 years since last fire.

Key management prescriptions:
1. Implement enhanced Stone Country fire management plan (Petty *et al*. 2007), with known subpopulations protected from frequent high intensity fire.
2. Reduce the abundance of feral cats at sites known to contain any Arnhemland Skinks.

Key research needed to enhance management effectiveness:
1. Survey to more reliably assess status, habitat requirements and distribution (including important populations).
2. Study to assess relative impacts of different threats and responses to management.
3. Assess the cost-benefits of a captive breeding program.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics for Stone Country

Direct monitoring parameter(s)
If any population is located, design and implement a monitoring program that assesses abundance, at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
No standard management protocol, but broadly included within Stone Country fire plan (Petty *et al*. 2007).

Is there an existing monitoring standard operating protocol?
No monitoring protocol, and current sparseness will make any monitoring challenging (Armstrong and Dudley 2004).

Distribution
Total range Restricted to the western Arnhem Land plateau and outliers (e.g. Jabiluka). Within this range, it has been recorded at relatively few locations, including Nawurlandja, Jabiluka, near Oenpelli, near El Sherana, Moline Ikywmarra) rockhole, Twin Falls and Koolpin Gorge.
Kakadu as above
% Kakadu c. 60%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No known specialised habitat requirements relevant for management.

Ecology
This species is largely restricted to sandstone outcrops, typically with extensive fissures and cave systems. It is probably at least partly nocturnal or crepuscular (Sadlier 1990). Most lizards in the *Egernia* group are communal, or have complex social systems.

Impacts of fire
How fire affects the species Not known, but frequent and high intensity fires may be detrimental.
Preferred fire regime Not known.

Impacts of feral animals
Predation by feral cats may be a primary cause of recent decline.

Poisoning by cane toads may be a threat, but severe decline is known to have occurred before the arrival of toads (Watson and Woinarski 2003).

Impacts of weeds
Not a major current threat, but feasibly may exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing (low reliability)
☐ severely decreasing
☐ not known

Current monitoring programs
No current monitoring program (although some recent mostly unsuccessful searches). The most substantial monitoring baseline is from substantial 'by-catch' in mammal trapping at Nawurlandja in the late 1970s (Begg *et al*. 1981), but none were captured using similar sampling in 2002 (Watson and Woinarski 2003), so that protocol is no longer useful.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Given recent severe decline and presumed low population, a captive breeding program would provide a valuable insurance.

Feasibility of applying preferred management
Feasible for fire; challenging for feral cats.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Armstrong, M., and Dudley, A. (2004). The Arnhem Land Egernia *Egernia obiri* in Kakadu National Park. Report to Parks Australia North. (NT Department of Infrastructure, Planning and Environment, Darwin.)

Begg, R.J., Martin, K.C., and Price, N.F. (1981). The small mammals of Little Nourlangie Rock, N.T. V. The effects of fire. *Australian Wildlife Research* **8**, 515-527.

Gillespie, G., and Fisher, A. (2014). Threatened reptile and frog species of Kakadu National Park: current status; known and potential threats; and what needs to be done for them? In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 75-84. (Supervising Scientist, Darwin.)

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Sadlier, R.A. (1990). A new species of scincid lizard from western Arnhem Land, Northern Territory. *The Beagle* **7**, 29-33.

Watson, M., and Woinarski, J. (2003). *Vertebrate monitoring and resampling in Kakadu National Park, 2002*. Report to Parks Australia North. (Parks and Wildlife Commission of the Northern Territory: Darwin.)

MERTEN'S WATER MONITOR *Varanus mertensi*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
Population stable or increasing over three successive monitoring episodes.

Key management prescriptions:
There is no feasible and cost-effective management prescription to address its principal threat (poisoning by cane toads).

However, reduction in the abundance of feral pigs and wild dogs may reduce loss of egg clutches.

Key research needed to enhance management effectiveness:
Assessment of population-level impacts of predation on eggs by wild dogs and feral pigs, and of mechanisms that may reduce such losses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Abundance of feral pigs.
2. Abundance of cane toads.

Direct monitoring parameter(s)
1. Annual sampling of abundance at a series of sites.
2. Annual sampling of reproductive success.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No existing standard monitoring protocol for Kakadu; however there are monitoring protocols elsewhere that may be appropriate (e.g. Doody *et al*. 2009).

Distribution
Total range Merten's Water Monitor occurs across higher rainfall areas of northern Australia, from western Cape York Peninsula to the Kimberley.
Kakadu Prior to the arrival of cane toads, Merten's Water Monitor was widespread along watercourses throughout Kakadu.
% Kakadu <5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Merten's Water Monitor is associated with rivers and wetlands.

Ecology
Merten's Water Monitor is aquatic. It feeds mostly on fish and frogs, but also eats carrion and invertebrates.

Females lay a single clutch (of c. 10 eggs) in an excavated nesting chamber on the ground, with breeding in the late wet and early dry season (Shine 1986).

Impacts of fire
How fire affects the species Not well known; high intensity fires may reduce quality of riparian habitat.
Preferred fire regime Not well known; relatively low intensity patchy burning regime may be appropriate.

Impacts of feral animals
Poisoning by cane toads was the factor that caused recent severe decline (Griffiths and Holland 2004; Griffiths and McKay 2007; Doody *et al*. 2009).

Clutches of eggs may be predated on by feral pigs and, possibly, wild dogs; and such predation may inhibit any population recovery.

Impacts of weeds
No known impact and unlikely

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Some individuals are taken as 'bush tucker', but unlikely to be with population-level impact.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known
Note that it is possible that decline may have stabilised, as toads become less abundant post-invasion or if monitors learn to avoid toads, or toad-averse monitors are selected for.

Current monitoring programs
No current effective monitoring. The species is recorded in small numbers in the fire-plot monitoring program, but – unless there is a marked increase in abundance – this is inadequate to assess trends. Some monitoring was undertaken to assess the extent of decline around the time of toad invasion (Griffiths and Holland 2004), and this could form an ongoing baseline.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Ex situ breeding and intensively managed reintroduction may be of limited feasibility, but is probably not cost-effective.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Doody, J.S., Green, B., Rhind, D., Castellano, C.M., Sims, R., and Thompson, T. (2009). Population-level declines in Australian predators caused by an invasive species. *Animal Conservation* **12**, 46-53.
Griffiths, A.D., and Holland, D.C. (2004). *Impacts of the exotic cane toad (Bufo marinus) on the survival of lowland Varanus species in Kakadu National Park*. Report to Kakadu National Park. Charles Darwin University, Darwin.
Griffiths, A.D., and McKay, J.L. (2007). Cane toads reduce the abundance and site occupancy of Merten's water monitor (*Varanus mertensi*). *Wildlife Research* **34**, 609-615.
Shine, R. (1986). Food habits, habitats and reproductive biology of four sympatric species of varanid lizards in tropical Australia. *Herpetologica* **42**, 346-360.

MITCHELL'S WATER MONITOR *Varanus mitchelli*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
Population stable or increasing over three successive monitoring episodes.

Key management prescriptions:
There is no feasible and cost-effective management prescription to address its principal threat (poisoning by cane toads).

However, reduction in the abundance of feral pigs and wild dogs may reduce loss of egg clutches.

Key research needed to enhance management effectiveness:
Assessment of population-level impacts of predation on eggs by wild dogs and feral pigs, and of mechanisms that may reduce such losses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Abundance of feral pigs.
2. Abundance of cane toads.

Direct monitoring parameter(s)
1. Annual sampling of abundance at a series of sites.
2. Annual sampling of reproductive success.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No existing standard monitoring protocol for Kakadu.

Distribution
Total range Mitchell's Water Monitor occurs in the Top End and Kimberley.
Kakadu Prior to the arrival of cane toads, Mitchell's Water Monitor was widespread along watercourses throughout Kakadu.
% Kakadu <5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Mitchell's Water Monitor is associated with rivers and wetlands; often smaller watercourses than those used by Merten's Water Monitor.

Ecology
Mitchell's Water Monitor is aquatic. It feeds mostly on fish, frogs and invertebrates.

Females lay a single clutch (of c. 10 eggs) in an excavated nesting chamber on the ground, with breeding in the late wet and early dry season (Shine 1986).

Impacts of fire
How fire affects the species Not well known; high intensity fires may reduce quality of riparian habitat.
Preferred fire regime Not well known; relatively low intensity patchy burning regime may be appropriate.

Impacts of feral animals
Poisoning by cane toads was the factor that caused recent severe decline (Griffiths and Holland 2004).

Clutches of eggs may be predated on by feral pigs and, possibly, wild dogs; and such predation may inhibit any population recovery.

Impacts of weeds
No known impact and unlikely

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely

Exploitation Some individuals are taken as 'bush tucker', but unlikely to be with population-level impact.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known
Note that it is possible that decline may have stabilised, as toads become less abundant post-invasion, or if monitors learn to avoid toads, or toad-averse monitors are selected for

Current monitoring programs
No current effective monitoring. The species is recorded in small numbers in the fire-plot monitoring program, but – unless there is a marked increase in abundance – this is inadequate to assess trends. Some monitoring was undertaken to assess the extent of decline around the time of toad invasion (Griffiths and Holland 2004), and this could form an ongoing baseline.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Ex situ breeding and intensively managed reintroduction may be of limited feasibility, but is probably not cost-effective.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Griffiths, A.D., and Holland, D.C. (2004). *Impacts of the exotic cane toad (Bufo marinus) on the survival of lowland Varanus species in Kakadu National Park*. Report to Kakadu National Park. Charles Darwin University, Darwin.

Shine, R. (1986). Food habits, habitats and reproductive biology of four sympatric species of varanid lizards in tropical Australia. *Herpetologica* **42**, 346-360.

YELLOW-SPOTTED MONITOR *Varanus panoptes*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
Population stable or increasing over three successive monitoring episodes.

Key management prescriptions:
There is no feasible and cost-effective management prescription to address its principal threat (poisoning by cane toads). It may be feasible to reintroduce individuals from sites in Queensland where this species is common in the presence of toads (and apparenty does not seek to eat toads), but such action may need careful consideration.

Reduction in the abundance of feral pigs and wild dogs may reduce loss of egg clutches.

Key research needed to enhance management effectiveness:
Assessment of population-level impacts of predation on eggs by wild dogs and feral pigs, and of mechanisms that may reduce such losses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Abundance of feral pigs.
2. Abundance of cane toads.

Direct monitoring parameter(s)
1. Annual sampling of abundance at a series of sites.
2. Annual sampling of reproductive success.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No existing standard monitoring protocol for Kakadu; however there are monitoring protocols elsewhere that may be appropriate (e.g. Doody *et al*. 2009).

Distribution
Total range The Yellow-spotted Monitor occurs across higher rainfall areas of northern Australia, from Cape York Peninsula to the Kimberley, and in the Pilbara.
Kakadu Prior to the arrival of cane toads, Yellow-spotted Monitors were widespread in Kakadu lowlands.
% Kakadu <5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
No particular habitat requirements.

Ecology
The Yellow-spotted Monitor is a large terrestrial monitor. It feeds mostly on small vertebrates, but also takes some carrion and invertebrates.

Females lay a single clutch (of c. 10 eggs) in an excavated nesting chamber on the ground, with breeding in the late wet and early dry season (Shine 1986).

Impacts of fire
How fire affects the species Not well known; high intensity fires may reduce quality of riparian habitat.
Preferred fire regime Not well known; relatively low intensity patchy burning regime may be appropriate.

Impacts of feral animals
Poisoning by cane toads was the factor that caused recent severe decline (Griffiths and Holland 2004; Doody *et al*. 2009).

Clutches of eggs may be predated on by feral pigs and, possibly, wild dogs; and such predation may inhibit any population recovery.

Impacts of weeds
No known impact and unlikely

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Some individuals are taken as 'bush tucker', but unlikely to be with population-level impact.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known
Note that it is possible that decline may have stabilised, as toads become less abundant post-invasion, or if monitors learn to avoid toads, or toad-averse monitors are selected for.

Current monitoring programs
No current effective monitoring. The species is recorded in small numbers in the fire-plot monitoring program, but – unless there is a marked increase in abundance – this is inadequate to assess trends. Some monitoring was undertaken to assess the extent of decline around the time of toad invasion (Griffiths and Holland 2004), and this could form an ongoing baseline.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
It may be feasible to introduce individuals from populations that have persisted in toad-invaded areas in Queensland.

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Doody, J.S., Green, B., Rhind, D., Castellano, C.M., Sims, R., and Thompson, T. (2009). Population-level declines in Australian predators caused by an invasive species. *Animal Conservation* **12**, 46-53.
Griffiths, A.D., and Holland, D.C. (2004). *Impacts of the exotic cane toad (Bufo marinus) on the survival of lowland Varanus species in Kakadu National Park*. Report to Kakadu National Park. Charles Darwin University, Darwin.
Shine, R. (1986). Food habits, habitats and reproductive biology of four sympatric species of varanid lizards in tropical Australia. *Herpetologica* **42**, 346-360.

PLAINS DEATH ADDER *Acanthophis hawkei*

NOTE: Taxonomy of this genus has been unsettled (Wells and Wellington 1985; Wüster *et al*. 2005), but it is now generally accepted that this species is distinct from the Northern Death Adder *A. praelongus*, which also occurs broadly in the region (including in Kakadu).

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable

Target for 2025:
Population stable or increasing over three successive monitoring episodes.

Key management prescriptions:
The main threat to this species is poisoning by cane toads (Phillips *et al*. 2010), which is largely unmanageable. However, management of some secondary threats may assist recovery.
1. Reduce incidence of extensive and high intensity fire in floodplain environments.
2. Reduce abundance of feral cats in at least some floodplain locations.
3. Stabilise or reduce abundance and extent of invasive grasses in floodplain areas.

Key research needed to enhance management effectiveness:
1. Survey to more reliably assess status, habitat requirements and distribution (including important populations).
2. Study to assess relative impacts of different threats and responses to management.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics for floodplains.
2. Annual assessment of abundance of feral cats in floodplain areas.
3. Annual assessment of abundance and extent of invasive grasses in floodplain areas.

Direct monitoring parameter(s)
1. Annual road-based index of abundance, and population structure.

Is there an existing management standard operating plan or protocol?
No management plan.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol, but comparable protocols elsewhere would be readily transferrable (e.g. Brown *et al*. 2013).

Distribution
Total range Partly because of recent taxonomic uncertainty, the distribution of this species is poorly resolved. It occurs in clay plains from western Queensland to north-eastern Western Australia.
Kakadu Poorly known, but probably widely across all floodplain areas.
% Kakadu <5%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements relevant to management.

Ecology
The Plains Death Adder is restricted to cracking clay areas. It is nocturnal and is an ambush predator, typically lying partly concealed under leaf litter. Younger adders consume mostly frogs and lizards, but larger adults (particularly females) mostly consume mammals (particularly rodents) (Webb *et al*. 2005).

Impacts of fire
How fire affects the species Extensive and high intensity fires may cause direct mortality, and substantially reduce habitat suitability and hunting efficiency; repeated extensive fires may also reduce prey availability.
Preferred fire regime Not well known, but probably fine-scale patchy fires of low intensity.

Impacts of feral animals
The major direct cause of current decline is poisoning by cane toads (Hagman *et al*. 2009; Phillips *et al*. 2010), but the extent of impact may be variable (Brown *et al*. 2011).

Predation by feral cats may be a threat, but there is no evidence of the relative extent of its population-level impact.

High densities of buffalo and feral pigs may cause habitat degradation.

Impacts of weeds
invasive grasses in floodplain environments may exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known
Note that it is possible that decline may have stabilised, as toads become less abundant post-invasion, or if death adders learn to avoid toads, or toad-averse adders are selected for.

Current monitoring programs
No current monitoring, but some monitoring in nearby areas (e.g. Brown *et al*. 2013).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Currently, low priority; but may require reviewing depending upon ongoing assessment of trends in wild population.

Feasibility of applying preferred management
Feasible for fire management; challenging for cats and weeds.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Brown, G.P., Phillips, B.L., and Shine, R. (2011). The ecological impact of invasive cane toads on tropical snakes: field data do not support laboratory-based predictions. *Ecology* **92**, 422–431.

Brown, J.P., Greenlees, M.J., Phillips, B.L., and Shine, R. (2013). Road transect surveys do not reveal any consistent effects of a toxic invasive species on tropical reptiles. *Biological Invasions* **15**, 1005-1015.

Gillespie, G., and Fisher, A. (2014). Threatened reptile and frog species of Kakadu National Park: current status; known and potential threats; and what needs to be done for them? In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 75-84. (Supervising Scientist, Darwin.)

Hagman, M., Phillips, B.L., and Shine, R. (2009). Fatal attraction: adaptations to prey on native frogs imperil snakes after invasion of toxic prey. *Proceedings of the Royal Society B-Biological Sciences* **276**, 2813-2818.

Phillips, B.L., Greenlees, M.J., Brown, G.P., and Shine, R. (2010). Predator behaviour and morphology mediates the impact of an invasive species: cane toads and death adders in Australia. *Animal Conservation* **13**, 53-59.

Webb, J.K., Shine, R., and Christian, K.A. (2005). Does intraspecific niche partitioning in a native predator influence its response to an invasion by a toxic prey species? *Austral Ecology* **30**, 201-209.

Wells, R.W., and Wellington, C.R. (1985). A classification of the Amphibia and Reptilia of Australia. *Australian Journal of Herpetology, Supplementary Series* **1**, 1–61.

Wüster, W., Dumbrell, A.J., Hay, C., Pook, C.E., Williams, D.J., and Fry, B.G. (2005). Snakes across the Strait: trans-Torresian phylogeographic relationships in three genera of Australasian snakes (Serpentes: Elapidae: *Acanthophis*, *Oxyuranus*, and *Pseudechis*). *Molecular Phylogenetics and Evolution* **34**, 1–14.

OENPELLI PYTHON
Morelia oenpelliensis

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates stable or increasing population size over at least three successive monitoring periods.
2. >10% of Stone Country is >10 years since last fire; >30% is >3 years since last fire.

Key management prescriptions:
1. Implement enhanced Stone Country fire management plan (Petty *et al*. 2007), with known subpopulations protected from frequent high intensity fire.

Key research needed to enhance management effectiveness:
1. Survey to more reliably assess status, habitat requirements and distribution (including important populations).
2. Study to assess relative impacts of different threats and responses to management.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics for Stone Country

Direct monitoring parameter(s)
1. If feasible, design and implement a monitoring program based on an index of detections per sampling effort.

Is there an existing management standard operating plan or protocol?
No standard management protocol, but broadly included within Stone Country fire plan (Petty *et al*. 2007).

Is there an existing monitoring standard operating protocol?
No monitoring protocol, and current sparseness and/or low detectability will make any monitoring challenging (Gillespie and Fisher 2014).

Distribution
Total range The Oenpelli Python is restricted to the sandstone massif of western Arnhem Land. Within this area, it has been reported from the upper catchments of the Cadell, South Alligator and East Alligator River systems.
Kakadu Records of the Oenpelli Python are scattered sparsely through the main sandstone massif and some outliers.
% Kakadu c. 40%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No known specialised habitat requirements relevant to management.

Ecology
There have been no detailed studies of this species. It shelters in cracks, caves and crevices of rugged broken sandstone escarpments and gorges. Within this environment, it has been reported from monsoon rainforest patches, riparian areas, woodlands, open heathlands and bare rock pavements. Its diet comprises mostly large mammals, particularly possums and macropods.

Impacts of fire
How fire affects the species Not known, but high intensity fire may cause some mortality, reduce habitat suitability, and lead to decline in food resources.
Preferred fire regime Not known, but possibly any regime other than frequent, extensive and high intensity fire.

Impacts of feral animals
Directly, feral cats may prey on juvenile pythons.
Indirectly, predation by feral cats may have contributed to depletion of native mammal prey.
Indirectly, poisoning by cane toads may have led to depletion of some native mammal prey (such as quolls).

Impacts of weeds
No current impact.

Impacts of other threatening processes
Disease Not known
Climate change Not known or likely
Exploitation Previously, some limited illicit collection

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
There is a current ex situ breeding program, whose aims include increase in knowledge of the life history and ecology of the species, sating the collection pressure, and provision of some resources for conservation actions.

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Gillespie, G., and Fisher, A. (2014). Threatened reptile and frog species of Kakadu National Park: current status; known and potential threats; and what needs to be done for them? In *Kakadu National Park Symposia Series. Symposium 7: Conservation of threatened species*. (eds S. Winderlich and J. Woinarski.) Supervising Scientist Internal report 623, pp. 75-84. (Supervising Scientist, Darwin.)

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

PIG-NOSED TURTLE *Carettochelys insculpta*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Near Threatened
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates stable or increasing population size over at least three successive monitoring periods.

Key management prescriptions:
1. Control of feral pigs at major breeding sites;
2. Any exploitation is at sustainable levels.
3. Regulation of recreational fishing to minimise bycatch.

Key research needed to enhance management effectiveness:
1. Survey to more reliably assess status and distribution, and important breeding sites.
2. Life history analysis (based on new research or application of data from existing research at the Daly River) to model sustainable levels of take and of loss to predators of clutches.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Incidence and abundance of feral pigs at key breeding sites

Direct monitoring parameter(s)
1. Assessment of nesting activity and success.
2. Extent of hunting effort, hunting success rates and overall take.

Is there an existing management standard operating plan or protocol?
No standard management protocol.

Is there an existing monitoring standard operating protocol?
No currently applied monitoring protocol, but feasible to apply protocols establishd for research and monitoring of this species at the Daly River (e.g. Doody *et al*. 2003, 2006), and some previous survey work at Kakadu (Georges and Kennett 1989).

Distribution

Total range The Pig-nosed Turtle has an unusual distribution, restricted to the Fly River drainage of New Guinea and a few river systems in the Northern Territory.
Kakadu The Pig-nosed Turtle is known from the upper reaches of the South and East Alligator River systems (Georges and Kennett 1989).
% Kakadu c. 20%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Pig-nosed Turtles require sandy beaches for nesting (Doody *et al*. 2003, 2006), and typically occur in large pools, often with riparian vegetation that includes fleshy fruits.

Ecology
Pig-nosed turtles are entirely aquatic, and have a diet that comprises a mix of aquatic invertebrates, small fish and vegetation (including fruits). They nest on sandy beaches, and nesting incidence and timing may be dependent upon rainfall. Goannas and feral pigs are major predators of nest contents.

Impacts of fire
How fire affects the species Unlikely to be substantially affected by fire regimes, but frequent or high intensity fire may reduce riparian vegetation and reduce water quality.

Preferred fire regime Not known, but possibly any regime other than frequent, extensive and high intensity fire.

Impacts of feral animals
Feral pigs can consume nest contents, but the incidence is not well established.

Pig-nosed turtles have benefitted from cane toads, because toad invasion has reduced the abundance of goannas, another major source of nest predation (Doody *et al*. 2006).

Impacts of weeds
No current impact.

Impacts of other threatening processes
Disease Not known
Climate change Climate change may affect this species by altering flooding regimes. Changed flow regimes may lead to reduced breeding success due to destruction or reduced establishment of sandbanks, or by failing to provide the wetting trigger for hatchling emergence. Changed flow regimes may also reduce the dry season refugial value of some pools, reduce dispersal options, and reduce the capability of females to build up fat reserves required for egg production. Changes in temperature may affect hatchling sex ratios, because this species has temperature-dependent sex determination. Saltwater intrusion may increase the isolation of some subpopulations.
Exploitation There is some take of Pig-nosed Turtles by Aboriginal land-owners.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring for Kakadu, but some monitoring in the Daly River (e.g. Doody *et al*. 2006).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
There is a current ex situ breeding program operated privately.

Feasibility of applying preferred management
Medium-high feasibility of pig control at key sites

Likelihood that such management may benefit other threatened species
Medium (reduction in pig abundance may benefit other species)

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Doody, J.S., West, P., and Georges, A. (2003). Beach selection in nesting pig-nosed turtles, *Carettochelys insculpta*. *Journal of Herpetology* **37**, 178-182.
Doody, J.S., Green, B., Sims, R., Rhind, D., West, P., and Steer, D. (2006). Indirect impacts of invasive cane toads (*Bufo marinus*) on nest predation in pig-nosed turtles (*Carettochelys insculpta*). *Wildlife Research* **33**, 349-354.
Georges, A., and Kennett, R. (1989). Dry-season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, northern Australia. *Australian Wildlife Research* **16**, 323-335

PARTRIDGE PIGEON (eastern subspecies) *Geophaps smithii smithii*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable (for the species as a whole)
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population stability or increase over at least 3 successive monitoring episodes.
2. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire; most fire-age patches are <1 km^2.

Key management prescriptions:
1. Reduce extent, intensity and frequency of fires, but increase fine-scale patchiness.
2. Reduce feral cat abundance.
3. Reduce extent of invasive pasture grasses.

Key research needed to enhance management effectiveness:
1. Assessment of the relative impact of predation (including of eggs and young) by feral predators.
2. Assessment of impacts of wet season fires.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in lowland woodlands.
2. Annual monitoring of abundance of feral cats.
3. Monitoring of extent of key food resources (notably including Cockatoo Grass).
4. Annual monitoring of extent of invasive pasture grasses.

Direct monitoring parameter(s)
Annual walking (or driving) transects reporting Partridge Pigeon abundance across representative sections of Kakadu lowlands, linked to assessments of fire management.

Is there an existing management standard operating plan or protocol?
Not specifically for Kakadu. A national Recovery Plan provides a management framework (Woinarski 2004).

Is there an existing monitoring standard operating protocol?
Fraser *et al*. (2003) provided a protocol and initial results for monitoring the response of Partridge Pigeons to mosaic fire management.

A transect-based monitoring protocol was established on Melville Island specifically for this species, and would be an appropriate protocol (D. Baker-Gabb *unpubl*.)

Distribution
Total range The Partridge Pigeon occurs across the Top End of the Northern Territory and Kimberley. However it has declined or disappeared from much of the lower rainfall parts of this range over the last century.
Kakadu Extensively across lowlands.
% Kakadu c. 5-10%. Kakadu is one of the few major strongholds for the species.

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
During the dry season, this species may require a mix of burnt and unburnt areas (Fraser 2001).

Ecology
The diet of the Partridge Pigeon comprises seeds, mostly of grasses but also from *Acacia* and other woody plants (Higgins and Davies 1996). It is largely sedentary, although may make local-scale movements (up to 5-10 km) in response to seasonal variations in water and food availability (Fraser 2001). It typically occurs singly or in small family groups, but larger aggregations may occur, especially in the late dry season, around water sources. It nests on the ground, mostly in the early dry season (Fraser 2001), with "nest" location preferentially in sites with relatively dense grass cover. Such sites contrast to the relatively open (typically burnt) areas preferred for feeding, and suggest that the species may be much affected by fire regimes.

Partridge pigeons occur principally in lowland eucalypt open forests and woodlands, with grassy understoreys; but also occur in some other vegetation types including paperbark woodlands and around plantation edges.

Impacts of fire
How fire affects the species. Extensive early dry season fires may destroy eggs and young, but some early fire may be required to enhance its foraging. Extensive fire is likely to increase impacts of predation. Long-term imposition of frequent fire may change understorey composition and reduce resource availability. Impacts of wet season fires are unknown.

Preferred fire regime
A mosaic of small, patchy fires and unburnt areas has been recommended for the management of this species (Fraser 2001).

Impacts of feral animals
Feral cats, wild dogs and feral pigs probably take at least eggs and young, and cats probably also take adults; but the population-level impact is unknown.

High densities of stock probably reduce habitat suitability, but impacts of lower densities of buffalo are uncertain. Feral pigs may reduce abundance of some key food resources (e.g. Cockatoo Grass).

Impacts of weeds
Invasive grass species will exacerbate impacts of fire, change understorey composition and may reduce the foraging efficiency of Partridge Pigeons.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Now very little, and unlikely to be population-level impact.

Estimate of population size in Kakadu
Not known.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
Currently, the Partridge Pigeon is included within the fire plot monitoring program (Woinarski *et al*. 2012), however it is recorded from relatively few plots in that program, and the sampling interval (5+ years) is suboptimal for reporting on management responses.

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not applicable

Feasibility of applying preferred management
Enhanced fire management should be achievable.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references

Fraser, F.J. (2001). *The impacts of fire and grazing on the Partridge Pigeon: the ecological requirements of a declining tropical granivore*. PhD thesis. Australian National University: Canberra.

Fraser, F., Lawson, V., Morrison, S., Christophersen, P., McGreggor, S., and Rawlinson, M. (2003). Fire management experiment for the declining Partridge Pigeon, Kakadu National Park. *Ecological Management & Restoration* **4**, 94-102.

Higgins, P.J., and Davies, S.J.J.F. (1996). *Handbook of Australian, New Zealand & Antarctic Birds. Volume 3. Snipe to Pigeons*. (Oxford University Press, Melbourne.)

Woinarski, J. (2004). National multi-species recovery plan for the Partridge Pigeon [eastern subspecies] *Geophaps smithii smithii*; Crested Shrike-tit [northern (sub)species] *Falcunculus (frontatus) whitei*; Masked Owl [north Australian mainland subspecies] *Tyto novaehollandiae kimberli*; and Masked Owl [Tiwi Islands subspecies] *Tyto novaehollandiae melvillensis*. (NT Department of Infrastructure Planning and Environment, Darwin.)

Woinarski, J.C.Z., Fisher, A., Armstrong, M., Brennan, K., Griffiths, A.D., Hill, B., Low Choy, J., Milne, D., Stewart, A., Young, S., Ward, S., Winderlich, S., and Ziembicki, M. (2012). Monitoring indicates greater resilience for birds than for mammals in Kakadu National Park, northern Australia. *Wildlife Research* **39**, 397-407.

RED GOSHAWK
Erythrotriorchis radiatus

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Population at least stable over three successive monitoring episodes.

Key management prescriptions:
(Note that there is limited information on threats)
1. Reduce extent, intensity and frequency of fires, but increase fine-scale patchiness.
2. Reduce extent of invasive pasture grasses.

Key research needed to enhance management effectiveness:
1. Undertake survey to assess population size (or abundance), distribution, and key sites (e.g. nest sites).
2. Establish a monitoring program (probably based on known nest sites).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in lowland woodlands.
2. Annual monitoring of extent of invasive pasture grasses.

Direct monitoring parameter(s)
1. No nests producing young per year.

Is there an existing management standard operating plan or protocol?
No specific management protocol for Kakadu, but a national recovery plan provides a general framework (DERM 2012).

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol for Kakadu, but relevant protocols were developed for monitoring Red Goshawks on Melville Island (D. Baker-Gabb *unpubl*.).

Distribution
Total range The Red Goshawk occurs across much of northern Australia, from near Broome in the south-west Kimberley to south-eastern Queensland. Within this range it generally occurs in taller forests characteristic of higher rainfall areas, but there are some isolated recent records from central Australia.
Kakadu There is a somewhat sparse set of records, scattered widely across lowlands and along some riparian areas in the Stone Country.
% Kakadu <5%: the total population is estimated at c. 700 pairs (Garnett *et al*. 2011) and there are probably c. 10-20 pairs in Kakadu.

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
The Red Goshawk mostly forages in eucalypt forests and woodlands, but breeding tends to occur mostly in large trees along watercourses (Aumann and Baker-Gabb 1991).

Ecology
The Red Goshawk hunts mainly for medium-sized birds (up to the size of kookaburras and black cockatoos). Territory size is typically very large (up to 200 km^2) (Debus and Czechura 1988; Czechura and Hobson 2000). The preferred habitat is tall open eucalypt forest and riparian areas (including paperbark forest and gallery forests).

Impacts of fire
How fire affects the species High intensity fires may reduce the abundance of large trees favoured for nesting.
Preferred fire regime Fine-scale patchy fires, with low incidence of high intensity and extensive fire.

Impacts of feral animals
No known direct impact, although in the long-term high densities of buffalo may damage and kill large riparian trees.

Impacts of weeds
No known direct impacts, but invasive grasses exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known or likely
Exploitation Some minor illicit egg collection in past

Estimate of population size in Kakadu
20-50 individuals (with low reliability): Roeger and Russell-Smith (1995) noted that there were then three known breeding pairs in Kakadu.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring, but some baseline information available from studies in the 1980s (Aumann and Baker-Gabb 1991).

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed

Feasibility of applying preferred management
Feasible

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Aumann, T., and Baker-Gabb, D.J. (1991). *The ecology and status of the Red Goshawk in Northern Australia*. Report no. 75. (Royal Australasian Ornithologists Union, Melbourne.)

Czechura, G.V., and Hobson, R.G. (2000). *The red goshawk* Erythrotriorchis radiatus *in northern Queensland: status and distribution*. Report to Queensland Parks and Wildlife Service.

Debus, S.J., and Czechura, G.V. (1988). The red goshawk *Erythrotriorchis radiatus*: a review. *Australian Bird Watcher* **12**, 175-199.

DERM (Queensland Department of Environment and Resource Management) (2012). *National Recovery Plan for the Red Goshawk Erythrotriorchis radiatus*. (Queensland Department of Environment and Resource Management, Brisbane.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Roeger, L., and Russell-Smith, J. (1995). *Developing an endangered species program for Kakadu National Park. Key issues 1995-2002*. (Australian Nature Conservation Agency, Jabiru.)

GREY FALCON
Falco hypoleucos

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. Status in Kakadu resolved through targeted survey or development of incidental data base.

Key management prescriptions:
Based on the limited current information, this species is likely to be only an occasional visitor to Kakadu, and no particular management actions are required. To the extent that threats are known for the species, these probably mostly operate elsewhere in its range (Garnett *et al*. 2011).

Key research needed to enhance management effectiveness:
1. Consolidation of incidental records, where appropriate prompted by alerts for the species.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
n/a

Direct monitoring parameter(s)
Based on current information, no monitoring is required. If a more substantial or resident population is located, this conclusion should be reviewed.

Is there an existing management standard operating plan or protocol?
No management plan.

Is there an existing monitoring standard operating protocol?
No current standard monitoring protocol.

Distribution
Total range The Grey Falcon occurs sparsely across a wide distribution including much o inland and northern Australia, but mostly in arid and semi-arid areas (Garnett *et al*. 2011).
Kakadu There are very few confirmed records for Kakadu.
% Kakadu <1%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirement known.

Ecology
The Grey Falcon occurs mostly in open woodlands, shrublands and grasslands. Its main prey is birds, but it also takes some mammals, reptiles and insects.

Impacts of fire
How fire affects the species Not known
Preferred fire regime Not known

Impacts of feral animals
Not known; in arid and semi-arid Australia, habitat degradation due to livestock and feral animals has been reported (Garnett *et al*. 2011).

Impacts of weeds
No known impact

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Not known or likely

Estimate of population size in Kakadu
<50, but probably variable and non-resident

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
None

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
No need

Feasibility of applying preferred management
Not applicable

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

GREATER SAND-PLOVER (Mongolian) *Charadrius leschenaultii leschenaultii*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010).

Distribution
Total range Breeds in north-eastern Asia and migrates to Japan, south-eastern Asia and Australia (where it occurs extensively around the coastline) (Garnett *et al*. 2011).
Kakadu Coastal areas and some nearby wetlands.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in sheltered sandy, shelly or muddy, rocky beaches and salt-marshes, where it feeds on molluscs, worms, crustaceans and other invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

LESSER SAND-PLOVER *Charadrius mongolus*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to Japan, south-eastern Asia and Australia (where it occurs extensively around the coastline) (Garnett *et al*. 2011).

Kakadu Coastal areas and some nearby wetlands.
% Kakadu c. 1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal mudflats and sands, where it feeds on molluscs, worms, crustaceans and other invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

AUSTRALIAN PAINTED SNIPE *Rostratula australis*

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Endangered

Target for 2025:
1. Status of the species in Kakadu resolved.

Key management prescriptions:
Kakadu is likely to be only occasionally visited, marginal and relatively unimportant for the conservation of this species, so management investment is a low priority.
1. Control abundance of buffalo and feral pigs to levels at which they do not significantly affect habitat quality.
2. Control aquatic weeds to levels at which they do not significantly affect habitat quality.

Key research needed to enhance management effectiveness:
1. Collation of incidental records, wherever possible prompted by alerts for this species.
2. Broad-scale survey to assess status, distribution and habitat.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
nil

Direct monitoring parameter(s)
1. Number of incidental records

Is there an existing management standard operating plan or protocol?
No management protocol.

Is there an existing monitoring standard operating protocol?
No standard monitoring protocol.

Distribution
Total range The Australian Painted Snipe is patchily distributed across mainland Australia.
Kakadu There is only one (recent) record from Kakadu from near Cooinda.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No specific habitat requirements.

Ecology
Australian Painted Snipes occur around the fringes of shallow vegetated wetlands. They feed on seeds and invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species Poorly known; but in short term high intensity fires may reduce habitat quality and, over the longer term, some fire regimes may change wetland vegetation structure and floristics and thereby affect habitat suitability.
Preferred fire regime Not known

Impacts of feral animals
Habitat degradation by livestock and feral stock is recognised as a threat across its range (Garnett *et al*. 2011).

Predation by feral cats may be a threat, but there is no evidence to assess the extent of population-level impact (Garnett *et al*. 2011).

Impacts of weeds
Aquatic weeds may reduce habitat quality (Garnett *et al*. 2011)

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Nil

Across its range, the main factor driving decline has been loss of wetlands and disruption of hydrological processes (Garnett *et al*. 2011).

Estimate of population size in Kakadu
<100; perhaps generally zero.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
Nil

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not required

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

BAR-TAILED GODWIT
Limosa lapponica

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to mostly coastal areas of Australia and New Zealand (Garnett *et al*. 2011).
Kakadu Coastal areas and some nearby wetlands.

% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal mudflats, sandy beaches and lagoons, where it feeds on annelids, bivalves and crustaceans (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

EASTERN CURLEW
Numenius madagascariensis

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to coastal East Asia and, mostly, coastal Australia (Garnett *et al*. 2011).

Kakadu Coastal areas and some nearby wetlands.
% Kakadu c. 1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal mudflats, mangroves, estuaries and saltmarshes, where it feeds on crabs, small molluscs and other marine invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

ASIAN DOWITCHER
Limnodromus semipalmatus

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Occurrence in Kakadu confirmed.
2. Kakadu site(s) included in national monitoring program.
3. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to southeastern Asia and, less commonly, coastal Australia: most of the relatively few Australian records are from the north coast (Garnett *et al*. 2011).
Kakadu There are few, if any, records in Kakadu, but scattered records from nearby coastal areas (Chatto 2003).
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal mudflats, where it feeds on polychaetes, molluscs and insect larvae (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
unknown, possibly zero (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

RED KNOT
Calidris canutus

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates mostly to coastal Australia and New Zealand (Garnett *et al*. 2011).
Kakadu Coastal areas and some nearby wetlands.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal mudflats and sandflats, where it feeds on shellfish and other intertidal invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

GREAT KNOT
Calidris tenuirostris

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to southern Asia and Australia (Garnett *et al*. 2011).

Kakadu Coastal areas and some nearby wetlands.
% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in estuaries, inlets, lagoons with large intertidal mudflats and sand flats, where it feeds on bivalves, gastropods, crustaceans and other invertebrates (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

CURLEW SANDPIPER
Calidris ferruginea

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Kakadu site(s) included in national monitoring program.
2. No decrease in habitat suitability in Kakadu.

Key management prescriptions:
Limited options, because the principal driver of current decline lies beyond Australia (Garnett *et al*. 2011). Its coastal habitat in Kakadu is not likely to be subject to any threats readily amenable to management response.

Key research needed to enhance management effectiveness:
1. Predict and monitor changes in extent and suitability of habitat in Kakadu in response to sea level risk.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Image-based assessment of the extent of suitable habitat (coastal areas and saline wetlands) at c. 3 year intervals.

Direct monitoring parameter(s)
Population counts in Kakadu sites within national monitoring program (Scholten *et al*. 2012).

Is there an existing management standard operating plan or protocol?
No management standard.

Is there an existing monitoring standard operating protocol?
National monitoring protocol (Scholten *et al*. 2012), and some international monitoring protocols (e.g. Amano *et al*. 2010)

Distribution
Total range Breeds in north-eastern Asia and migrates to western Africa, southern Asia and Australia (Garnett *et al*. 2011).
Kakadu Coastal areas and some nearby wetlands.

% Kakadu <1%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☒ marine and estuaries

Particular habitat requirements
No relevant specific habitat requirements for Kakadu range.

Ecology
In non-breeding areas, it occurs in coastal lagoons, mudflats, sand flats, estuaries and swamps, where it feeds on polychaetes, molluscs and crustaceans (Garnett *et al*. 2011).

Impacts of fire
How fire affects the species No fire impact
Preferred fire regime not applicable

Impacts of feral animals
No major threat.

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Nil
Climate change Impacts may be substantial, but not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<1000 individuals (e.g. Chatto 2003)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
No current monitoring, although Chatto (2003) reported on some counts as part of a broader (Northern Territory coast) survey program; and there is some historic baseline information for Kakadu (e.g. Bamford 1990).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding is not feasible.

Feasibility of applying preferred management
Not feasible that management in Kakadu will substantially resolve the major conservation problem.

Likelihood that such management may benefit other threatened species
Not applicable

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references
Amano, T, Szekely, T., Koyama, K., Amano, H., and Sutherland, W.J. (2010). A framework for monitoring the status of populations: an example from wader populations in the East Asian – Australasian flyway. *Biological Conservation* **143**, 2238-2247.

Bamford, M.J. (1990). *RAOU survey of migratory waders in Kakadu National Park: phase III. Final report to the Australian National Parks and Wildlife Service*. RAOU Report no. 70. (RAOU, Melbourne.)

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Technical report 73. (Parks and Wildlife Commission of the Northern Territory, Darwin.)

Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Scholten, S., Costello, L., Milton, D.A., and Maurer, G. (2012). Report on Australian shorebird population counts winter 2009 and summer 2009-10. *Stilt* **62**, 33-53.

MASKED OWL (northern)
Tyto novaehollandiae kimberli

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Robust monitoring program established and implemented, that is capable of assessing population trends and response to management.
2. Population estimate for Kakadu derived from monitoring program.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. Reduce fire frequency, extent and intensity in the lowland woodlands

Key research needed to enhance management effectiveness:
1. Sampling to assess relationship between abundance and fire regimes.
2. Broad-scale distribution patterns in Kakadu.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in lowland woodlands.
2. Abundance and diversity of small to medium-sized mammals (monitored through fire-plot monitoring program or targeted monitoring for individual threatened mammal species).

Direct monitoring parameter(s)
Systematic broadcast call sampling at 2-3 year intervals

Is there an existing management standard operating plan or protocol?
Not specifically for Kakadu. A national Recovery Plan provides a management framework (Woinarski 2004).

Is there an existing monitoring standard operating protocol?
No established protocol. A single sampling episode was conducted by Ward (2010) in 2010, but masked owls were recorded from only one of 68 sites, suggesting either the sampling timing or protocol was suboptimal or that the abundance of this species in Kakadu is very low. Broadly comparable sampling has been undertaken more successfully on Melville Island (Great Southern 2009)

Distribution
Total range The Masked Owl has a very wide distribution across much of Australia. The subspecies *kimberli* occurs in mainland areas from the Kimberley to north-eastern Queensland.
Kakadu The distribution in Kakadu is poorly known, but records are mostly from lowland eucalypt forests and woodlands.
% Kakadu <5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
The Masked Owl usually roosts and nests in large tree hollows, in large trees.

Ecology
The Masked Owl occurs mainly in eucalypt tall open forests (especially those dominated by Darwin woollybutt *Eucalyptus miniata* and Darwin stringybark *E. tetrodonta*), but also roosts in monsoon rainforests, and forages in more open vegetation types, including grasslands. Although it may roost in dense foliage, it more typically roosts, and nests, in tree hollows (Debus 1993). Mammals, up to the size of possums, constitute the bulk of its diet (Higgins 1999).

Although there is no detailed information for this subspecies, masked owls of other subspecies occupy large home ranges, estimated at 1-10 km^2 (Debus 1993; Kavanagh and Murray 1996).

Impacts of fire
How fire affects the species. Frequent, extensive and high intensity fires are likely to lead to reduction in the availability of the large trees and large hollows on which this species depends (Williams *et al*. 2003).
Preferred fire regime. Probably one with less frequent and lower intensity fires. Some patchy fires may help hunting efficiency.

Impacts of feral animals
Feral cats are likely to reduce abundance of prey species.

Impacts of weeds
Invasive grass species are likely to reduce hunting efficiency, and to exacerbate fire impacts.

Impacts of other threatening processes
Disease Not known or likely.
Climate change Not known or likely.
Exploitation Nil

Estimate of population size in Kakadu

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
One monitoring episode was undertaken in 2010 (Ward 2010), based on broadcast of taped calls.

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
No requirement.

Feasibility of applying preferred management
Medium

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Debus, S.J.S. (1993). The mainland masked owl *Tyto novaehollandiae*: a review. *Australian Bird Watcher* **15**, 168-191.
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Kavanagh, R.P., and Murray, M. (1996). Home range, habitat and behaviour of the masked owl *Tyto novaehollandiae* near Newcastle, New South Wales. *Emu* **96**, 250-257.
Ward, S. (2010). *Survey protocol for masked owls in the NT* Tyto novaehollandiae *(north Australian mainland subspecies* T. n. kimberli *and Tiwi subspecies* T. n. melvillensis. Unpublished report. NT Department of Natural Resources, Environment, the Arts and Sport, Darwin.
Williams, R.J., Muller, W.J., Wahren, C-H., Setterfield, S.A., and Cusack, J. (2003). Vegetation. In *Fire in tropical savannas: The Kapalga experiment*. (eds. A.N. Andersen, G.D. Cook and R.J. Williams.) pp. 79-106. (Springer-Verlag, New York.)
Woinarski, J. (2004). National multi-species recovery plan for the Partridge Pigeon [eastern subspecies] *Geophaps smithii smithii*; Crested Shrike-tit [northern (sub)species] *Falcunculus (frontatus) whitei*; Masked Owl [north Australian mainland subspecies] *Tyto novaehollandiae kimberli*; and Masked Owl [Tiwi Islands subspecies] *Tyto novaehollandiae melvillensis*. (NT Department of Infrastructure Planning and Environment, Darwin.)

WHITE-THROATED GRASS-WREN *Amytornis woodwardi*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population stability or increase over at least 3 successive monitoring episodes.
2. >10% of Stone Country is >10 years since last fire; >30% is >3 years since last fire.

Key management prescriptions:
1. Implement enhanced Stone Country fire management plan (Petty *et al*. 2007), with known subpopulations protected from fire.

Key research needed to enhance management effectiveness:
1. Survey to assess status, habitat requirements and distribution (including significant populations). Ensure that locations of significant subpopulations are on management GIS, and pivotal in fire management planning.
2. Study and monitoring to assess and predict population viability under a range of fire management regimes.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics across Stone Country and at important subpopulations.

Direct monitoring parameter(s)
1. Assessment of abundance in fire-plot monitoring program (5+ year intervals).
2. Targeted sampling of abundance at known subpopulations (at 2-3 yr intervals).

Is there an existing management standard operating plan or protocol?
No specific management protocol, but broadly considered within the Stone Country fire plan.

Is there an existing monitoring standard operating protocol?
Standard operating protocol exists for fire-plot monitoring (Woinarski *et al*. 2012).

Recent targeted surveys (Mahney *et al*. 2011; Warddeken Land Management Limited 2013) in Kakadu and adjacent area (Warddeken IPA) provide a protocol for ongoing monitoring.

Distribution
Total range The White-throated Grass-wren is restricted to the sandstone plateau and escarpment of western Arnhem Land, extending south-west as far as Nitmiluk National Park and northeast as far as the Mann River (Noske 1992a).
Kakadu The White-throated Grass-wren occurs patchily across Kakadu's Stone Country. Surveys have delineated some important subpopulations (Noske 1992a; Mahney *et al*. 2011).
% Kakadu c. 30-50%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
The evidence is not substantial, but the White-throated Grass-wren probably requires mature spinifex (at least 3-5 years post-fire) (Woinarski 1992).

Ecology
The White-throated Grass-wren is confined to hummock grasslands ('spinifex'), sometimes with open shrubland or woodland overstorey, mixed among boulder fields and sandstone pavements (Schodde 1982; Noske 1992a). The diet comprises invertebrates, seeds and other vegetable matter (Noske 1992a). Like other grass-wrens and fairy-wrens, it often occurs in small family groups (typically of 3-6 birds), but also occurs singly or in pairs (Noske 1992a). Breeding occurs from December to June, and territory size is around 10 ha (Noske 1992a).

Impacts of fire
How fire affects the species The evidence is limited, but it is likely that this species prefers mature spinifex; so frequent, high intensity and extensive fires are likely to be detrimental, and hot fires may wipe out local populations.

Preferred fire regime Absence of fire; or fine-scale cool burns that leave substantial areas unburnt.

Impacts of feral animals
Predation by feral cats may be a threat.

Impacts of weeds
Currently, no significant impact from weeds.

Impacts of other threatening processes
Disease Not known or likely
Climate change Not known
Exploitation Nil

Estimate of population size in Kakadu
c. 1000 to 5000. Garnett *et al*. (2011) estimate that the total population is 10,000 mature individuals.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
The White-throated Grass-wren was recorded from initial sampling in the fire-plot monitoring program, but the most recent documented sampling (2007-09) failed to report it from any quadrats (Woinarski *et al*. 2011). There is some survey information from early (Noske 1992a) and more recent surveys (Mahney *et al*. 2011) that could provide a baseline for ongoing monitoring.

Extent of current targeted management in Kakadu
Some targeted management, within broader guidelines within the Stone Country fire plan.

Options/needs for ex situ breeding and/or assisted re-introduction
Not a high priority, but presumed limited dispersal may mean that extirpated subpopulations may not be readily repopulated naturally; and it may be feasible to restore them with captive-bred stock.

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)

Mahney, T., Brennan, K., Fegan, M., Trikojus, N., Young, S., and Fisher, A. (2011). *Yirlin-kirrk-kirr (White-throated Grasswren) Kakadu National Park survey 2011*. Report to Park Australia. (NT Department of Natural Resources, Environment, the Arts and Sport, Darwin.)

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Noske, R. (1992b). Do grasswrens have the numbers? Reply to Woinarski (1992). *Northern Territory Naturalist* **13**, 5-8.

Petty, A., Alderson, J., Muller, R., Scheibe, O., Wilson, K., and Winderlich, S. (2007). *Kakadu National Park: Arnhemland Plateau draft fire management plan*. (Kakadu National Park, Jabiru and Tropical Savannas Cooperative Research Centre, Darwin.)

Schodde, R. (1982). *The fairy-wrens. A monograph of the Maluridae*. (Landsdowne Editions: Melbourne.)

Warddeken Land Management Limited (2013). Yirlinkirrkirr responds to call for data. *Annual Report 2011-2012*. 19.

Woinarski, J.C.Z. (1992). The conservation status of the white-throated grass-wren *Amytornis woodwardi*, and example of problems in status designation. *Northern Territory Naturalist* **13**, 1-5.

Woinarski, J.C.Z., Fisher, A., Armstrong, M., Brennan, K., Griffiths, A.D., Hill, B., Low Choy, J., Milne, D., Stewart, A., Young, S., Ward, S., Winderlich, S., and Ziembicki, M. (2012). Monitoring indicates greater resilience for birds than for mammals in Kakadu National Park, northern Australia. *Wildlife Research* **39**, 397-407.

YELLOW CHAT (Alligator Rivers subspecies) *Epthianura crocea tunneyi*

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Endangered

Target for 2025:
1. Robust monitoring program established and implemented, that is capable of assessing population trends and response to management.
2. Abundance stable or increasing across three successive monitoring episodes.

Key management prescriptions:
1. Reduce abundance of feral pigs and buffalo in key floodplain locations supporting significant populations of Yellow Chat.
2. Maintain or enhance a regime of fine-scale patchy burns across floodplain areas.

Key research needed to enhance management effectiveness:
1. Survey to assess status, distribution, seasonal movements and habitat requirements.
2. Study to assess relative impacts of different threats, and responses to management.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in floodplain areas.
2. Annual monitoring of feral pigs and buffalos at key floodplain locations supporting significant populations of Yellow Chat.
3. Image-based monitoring of habitat suitability and extent in response to saltwater intrusion (climate change).

Direct monitoring parameter(s)
1. Monitoring of abundance at sites with significant populations of Yellow Chats (at 2-3 year intervals).

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No; although Armstrong (2004) provides a sampling protocol that could be used as a baseline.

Distribution
Total range Yellow Chats occur patchily across northern Australia, most typically in chenopod shrublands and grasslands around water sources in semi-arid areas. However, the subspecies *Epthianura crocea tunneyi* is known from few sites in a small geographic area encompassing the floodplains from the Mary River to the East Alligator River (Schodde and Mason 1999; Garnett *et al*. 2011).
Kakadu Reported from floodplains of the South and East Alligator. Armstrong (2004) collated all then known records.
% Kakadu c. 50%

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
The specific habitat requirements for Yellow Chat are not well known.

Ecology
In the floodplain area, Yellow Chats occur in tall grasslands and samphire shrublands (on coastal saltpans). The diet is mostly invertebrates (Higgins *et al*. 2001). Yellow chats typically occur in small groups of 2-10 individuals.

Impacts of fire
How fire affects the species Not known, but may likely to be disadvantaged by frequent extensive and high intensity fire.
Preferred fire regime Probably fine-scale patchy fire mosaic.

Impacts of feral animals
Not well known. Habitat degradation by feral pigs and buffalo is likely to be detrimental (Armstrong 2004).

Predation by feral cats may be a threat, but there is no relevant evidence.

Impacts of weeds
Not well known. Invasive pasture grasses, mimosa and other weeds may affect habitat suitability, and invasive grasses may exacerbate impacts of fire; however other subspecies are known to occur with a range of invasive grasses (Garnett *et al*. 2011).

Impacts of other threatening processes
Disease Not known or likely
Climate change Likely to result in some marked changes in habitat suitability and extent, although the likely impacts of such change are not well resolved.
Exploitation Nil

Estimate of population size in Kakadu
<300 (Armstrong 2004)

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring, although a baseline is available (Armstrong 2004).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
No immediate need.

Feasibility of applying preferred management
Feasible, but may be challenging to sustainably reduce feral pigs and buffalo.

Likelihood that such management may benefit other threatened species
Medium

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Armstrong, M. (2004). *The Yellow Chat* Epthianura crocea tunneyi *in Kakadu National Park*. (NT Department of Infrastructure Planning and Environment, Darwin.)
Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The action plan for Australian birds 2010*. (CSIRO Publishing, Melbourne.)
Higgins, P.J., Peter, J.M. and Steele, W.K. (2001). *Handbook of Australian, New Zealand and Antarctic birds. Volume 5. Tyrant-flycatchers to Chats*. (Oxford University Press: Melbourne.)
Schodde, R. and Mason, I.J. (1999). *The Directory of Australian Birds: Passerines*. (CSIRO, Melbourne.)

NORTHERN SHRIKE-TIT *Falcunculus frontatus whitei*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Data Deficient

Target for 2025:
1. Robust monitoring program established and implemented, that is capable of assessing population trends and response to management.
2. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. Reduce fire frequency, extent and intensity in the lowland woodlands

Key research needed to enhance management effectiveness:
1. Sampling to assess relationship between abundance and fire regimes.
2. Broad-scale distribution patterns in Kakadu.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in lowland woodlands.

Direct monitoring parameter(s)
1. Broadcast call-based monitoring program across lowland woodlands, implemented at 2-3 year intervals.

Is there an existing management standard operating plan or protocol?
Not specifically for Kakadu. A national Recovery Plan provides a broad management framework (Woinarski 2004).

Is there an existing monitoring standard operating protocol?
No established protocol. Ward (2009) provides a protocol for monitoring.

Distribution
Total range The species is widely distributed in eastern, south-western and northern Australia. The northern subspecies is known from relatively few records, mostly across the Top End (although less commonly in higher rainfall areas), and the east Kimberley (Robinson and Woinarski 1992; Ward 2008).
Kakadu There are very few records from Kakadu; one is from 1976, at Kapalga (Robinson and Woinarski 1992).
% Kakadu <5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No particular habitat requirements known.

Ecology
There have been no detailed studies on the northern shrike-tit. A review of records (Robinson and Woinarski 1992) suggested that it occurred across a range of eucalypt forests and woodlands.

They forage in tree canopies, generally quietly and slowly seeking invertebrates on foliage or under bark. The massive bill is extremely strong, and is used for chiselling and tearing bark and branches to access invertebrates sheltering within.

Most of the few records of the Northern Shrike-tit refer to small parties of 2-5 birds.

Impacts of fire
How fire affects the species Not known.
Preferred fire regime Not known.

Impacts of feral animals
Not known but unlikely.

Impacts of weeds
Invasive pasture grasses may exacerbate fire regimes.

Impacts of other threatening processes
Disease Not known and unlikely.
Climate change Not known and unlikely
Exploitation Nil

Estimate of population size in Kakadu
Not known.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
Currently no monitoring program. In 2009, Simon Ward undertook a survey using broadcast calls, but did not report any birds.

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Not applicable.

Feasibility of applying preferred management
Enhanced fire management should be feasible.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Robinson, D. and Woinarski, J.C.Z. (1992). A review of records of the Northern Shrike-tit *Falcunculus frontatus whitei* in northwestern Australia. *South Australian Ornithologist* **31**: 111-117.
Ward, S.J (2008). *Habitat-use, foraging and breeding ecology of the northern shrike-tit Falcunculus frontatus whitei* (Department of Natural Resources, Environment, The Arts & Sport, Darwin.)
Ward, S. (2009). *Survey protocol for the northern shrike-tit*. Darwin, N.T: (Department of Natural Resources, Environment, The Arts & Sport.)
Woinarski, J. (2004). National multi-species recovery plan for the Partridge Pigeon [eastern subspecies] *Geophaps smithii smithii*; Crested Shrike-tit [northern (sub)species] *Falcunculus (frontatus) whitei*; Masked Owl [north Australian mainland subspecies] *Tyto novaehollandiae kimberli*; and Masked Owl [Tiwi Islands subspecies] *Tyto novaehollandiae melvillensis*. (NT Department of Infrastructure Planning and Environment, Darwin.)

GOULDIAN FINCH
Erythrura gouldiae

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Key breeding sites for the species in Kakadu resolved.
2. Status in Kakadu well resolved.
3. A robust monitoring program demonstrates population stability or increase over three successive monitoring episodes.
4. In at least important areas for this species, most fire patches are <1 km^2, >10% of area is >10 years since last fire; >30% of area is >3 years since last fire

Key management prescriptions:
1. Reduce incidence and extent of fires in lowland woodlands and stone country.
2. Stabilise incidence, extent and abundance of invasive pasture grasses, across the extent of lowland woodlands.
3. Reduce abundance of feral pigs at locations with significant Gouldian Finch populations.

Key research needed to enhance management effectiveness:
1. Survey to assess status and distribution, particularly to locate significant breeding sites.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual monitoring of fire metrics in relevant areas.
2. Annual monitoring of feral pig abundance and/or of grass species that provide key resources.

Direct monitoring parameter(s)
1. Assessment of number of individuals breeding in significant breeding areas *or* assessment of number of individuals drinking at monitored water holes in the late wet season.

Is there an existing management standard operating plan or protocol?
No Kakadu-specific management protocol, but a national Recovery Plan provides a broad management framework (O'Malley 2006).

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol for Kakadu. A perhaps relevant monitoring program exists for the Yinberrie Hills area (Price *et al*. unpubl.), based on counts at water holes in the late dry season, but it has very high variability.

Distribution
Total range Formerly the Gouldian Finch was distributed extensively throughout the tropical savannas of northern Australia. It is now restricted to isolated areas mostly within the Northern Territory and the Kimberley.
Kakadu The distribution of the Gouldian Finch in Kakadu is not well resolved. It has been recorded only infrequently in general wildlife surveys, there has been no specific search, and most records are largely anecdotal and fleeting. Most records are from stony woodland areas in the south of the Park, but there are also known records from areas adjacent to the west of the Park (Mary River area and Mt Bundey).
% Kakadu <5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
In the breeding season, stony hills with *Eucalyptus tintinnans* woodlands. In the non-breeding season, access to a diverse suite of native grasses including early-seeding perennial species such as cockatoo grass.

Ecology
Gouldian Finches occupy two different regions of the landscape on an annual cycle. In the early to mid dry season, they nest in tree hollows in hilly woodlands (in the Kakadu area, dominated by Salmon Gum *Eucalyptus tintinnans*). During this period they feed upon native sorghum and find water at small rocky waterholes that remain within the hills until the next wet. In the late dry and wet season, Gouldian Finches move from the hills into lowland drainages to feed upon perennial grasses that begin to seed in mid December.

These grasses include soft spinifex, cockatoo grass and golden beard grass.

Clutch size averages 5.2 and fledging rate is 1.5 young per pair (Tidemann *et al*. 1999). Pairs may raise several clutches per year.

Impacts of fire
How fire affects the species Fire has a complex range of short-term and longer-term impacts. Over the longer-term, extensive and high intensity fires in the breeding habitat probably reduce the abundance of old trees and suitable hollows (Brazill-Boast *et al*. 2011, 2013). A high fire frequency probably also leads to longer-term changes in the grass species composition, probably to the detriment of perennial grasses that provide pivotal food resources during the wet season. Some key food resources (such as some spinifexes) may require at least 3 years without fire before producing seed. In the short term, some fire may be required in the early-mid dry season to clear the dense grass layer and allow the finches access to fallen seed on the ground; however high intensity fires at this time may destroy a high proportion of that fallen seed resource (Woinarski 1990).
Preferred fire regime Fine-scale patchy fire, at low intensity.

Impacts of feral animals
Feral pigs selectively dig up and consume a pivotal food resource, cockatoo grass (Crowley 2008).

High densities of livestock (or feral horses, donkeys, cattle, buffalo) may reduce habitat quality and food resources (Tidemann 1990).

Impacts of weeds
Invasive pasture grasses will exacerbate fire impacts, and replace native grasses that may provide key food resources.

Impacts of other threatening processes
Disease Some populations have a high incidence of air-sac mite, with possible reduction in health (Tidemann *et al*. 1992; Bell 1996).
Climate change Not known or likely
Exploitation Formerly extensively trapped; now unlikely.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
None

Extent of current targeted management in Kakadu
No targeted management in Kakadu

Options/needs for ex situ breeding and/or assisted re-introduction
No particular need.

Feasibility of applying preferred management
Feasible, but challenging.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
Bell, P.J. (1996). Survey of the nasal mite fauna (Rhinonyssidae and Kytoditidae) of the Gouldian Finch, *Erythrura gouldiae*, and some co-occurring birds in the Northern Territory. *Wildlife Research* **23**, 675-686.
Brazill-Boast, J., Pryke, S. R., and Griffith, S. C. (2011). Selection of breeding habitat by endangered Gouldian finch (*Erythrura gouldiae*) at two spatial scales. *Emu* **111**, 304-311.
Brazill-Boast, J., Pryke, S.R., and Griffith, S.C. (2013). Provisioning habitat with custom-designed nest-boxes increases reproductive success in an endangered finch. *Austral Ecology* **38**, 405-412.
Crowley, G. (2008). Cockatoo grass *Alloteropsis semialata* as a keystone species in northern Australia. *Northern Territory Naturalist* **20**, 58-63.

O'Malley, C. (2006a). *National Recovery Plan for the Gouldian Finch* (*Erythrura gouldiae*). (WWF-Australia, Sydney.)

Tidemann, S.C. (1990). The relationship between finches and pastoral practices in northern Australia. In *Granivorous Birds and Agriculture* (Eds. J. Pinowski and J.D. Summers-Smith.) pp. 305-315. (PWPN – Polish Scientific Publishers, Warsaw.)

Tidemann, S.C., Lawson, C., Elvish, R., Boyden, J., and Elvish, J. (1999). Breeding biology of the gouldian finch *Erythrura gouldiae,* an endangered finch of northern Australia. *Emu* **99**, 191-199.

Tidemann, S.C., McOrist, S., Woinarski, J.C.Z., and Freeland, W.J. (1992). Parasitism of wild Gouldian Finches *Erythrura gouldiae* by the air sac mite *Sternostoma tracheacolum*. *Journal of Wildlife Diseases* **20**, 80-84.

Woinarski, J. C. Z. (1990). Effects of fire on bird communities of tropical woodlands and open forests in northern Australia. *Australian Journal of Ecology* **15**, 1-22.

NORTHERN QUOLL
Dasyurus hallucatus

Conservation status
AUSTRALIA: Endangered
NORTHERN TERRITORY: Critically Endangered
IUCN Red List: Endangered

Target for 2025:
1. Abundance stable or increasing over three consecutive monitoring episodes.
2. Feral cats and wild dogs are subject to intensive control or exclusion in at least one area with a significant population of this species.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. Maintain or enhance experimental release of toad-trained quolls.
2. Reduce abundance of wild dogs and feral cats at locations with significant quoll populations.
3. Reduce incidence and extent of fires in lowland woodlands and stone country.
4. Stabilise incidence, extent and abundance of invasive pasture grasses, across the extent of lowland woodlands.

Key research needed to enhance management effectiveness:
1. Assess capability and cost-effectiveness of, and need for, longer-term and broader-scale application of toad aversion training.
2. Assess relative impacts of wild dogs and feral cats as a cause of mortality.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics in lowland woodlands and Stone Country.
2. Monitoring of abundance of feral cats and wild dogs in areas subject to intensive control.

Direct monitoring parameter(s)
1. Annual assessment of changes in abundance of toad-trained quolls and their descendants.
2. Assessment of abundance in fire-plot monitoring program (at 5-year intervals)

Is there an existing management standard operating plan or protocol?
No targeted management plan in Kakadu; however a national Recovery Plan provides a broad framework (Hill and Ward 2010).

Is there an existing monitoring standard operating protocol?
Standard protocol for sampling in fire plots (Woinarski *et al*. 2010); protocol for monitoring persistence of toad-trained quolls (Webb *et al*. 2012).

Distribution
Total range The Northern Quoll occurs across much of northern Australia, from southeastern Queensland to the southwest Kimberley, with a disjunct population in the Pilbara. It has declined across much of this range (Braithwaite and Griffiths 1994).
Kakadu Prior to the arrival of Cane Toads, Northern Quolls were generally abundant and widespread in Kakadu, although there was some evidence of at least local declines (Woinarski *et al*. 2001). Subsequent to the arrival of Cane Toads, the population in Kakadu (and elsewhere) crashed, and it is now known to have persistent populations in Kakadu only near the East Alligator ranger station, although occasional sightings are also still reported more broadly.
% Kakadu <5%

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Northern Quolls den in tree hollows, hollow logs and rock crevices.

Ecology
The Northern Quoll is a generalist predator, consuming a wide range of invertebrates and small vertebrate prey. It dens in hollow logs, rock crevices and caves, and in tree hollows. Most foraging is on the ground. It occurs in a wide range of habitats, but the most suitable habitats appear to be rocky areas.

Northern Quolls typically have an annual life cycle, with almost all males living for only one year (Oakwood 2000; Oakwood *et al*. 2001). Young are born in the mid dry season (June), and attain independence in the early wet season (November) (Begg 1981). During the non-breeding season, home ranges are about 35 ha, but this increases to about 100 ha for males in the breeding season (Oakwood 2002).

Impacts of fire
How fire affects the species High intensity fire reduces habitat suitability (Begg *et al*. 1981) (possibly through reduction in available den sites); very long periods without fire may also be detrimental (Woinarski *et al*. 2004). Extensive fires may increase predation risks (Oakwood 2000).
Preferred fire regime Probably fine-scale patchy fires, with average return times of 3-5 years.

Impacts of feral animals
The recent severe decline of Northern Quolls in Kakadu is principally due to poisoning by Cane Toads when quolls try to consume them (Oakwood 2004). It is possible that there may be some natural gradual recovery, with post-invasion decline in the abundance of toads, and some general learnt avoidance of toads by quolls.
Predation by feral cats and wild dogs has been demonstrated (Oakwood 2000), and may have major population-level impacts.

Impacts of weeds
Invasive pasture grasses probably have some detrimental impacts mostly through exacerbating impacts of fire. Dense stands of pasture grasses may also constrain quoll's ability to hunt and disperse on the ground.

Impacts of other threatening processes
Disease Not known, but some diseases (mostly toxoplasmosis) reported in quolls elsewhere.
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
Not known, but probably now <1000.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known
(Note that the population may have reached a nadir over this period, with some possible limited and gradual recovery).

Current monitoring programs
(i) Broad-scale monitoring of abundance in fire plots at 5-year intervals, with the most recent reported sampling (2007-09) reporting quolls from 29 quadrats (Woinarski *et al*. 2010). (ii) Localised sampling of abundance and genetic relatedness of toad-trained (and 'wild') quolls around East Alligator area (e.g. Webb *et al*. 2012).

Extent of current targeted management in Kakadu
Current experimental release of toad-trained quolls (O'Donnell *et al*. 2010; Webb *et al*. 2012).

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding for taste-aversion training and then experimental reintroduction is now being undertaken (Webb *et al*. 2012). It may be feasible to introduce individuals from populations that have persisted in toad-invaded areas in Queensland.

Feasibility of applying preferred management
For broad-scale toad-training, feasibility is currently being examined.

Preferred fire management is feasible; management to reduce abundance of wild dogs and feral cats will be challenging.

Likelihood that such management may benefit other threatened species
Enhanced management of fire and control of feral cats and wild dogs will benefit other species.

Likelihood that such management may be detrimental to other threatened species
Low.

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NORTHERN BRUSH-TAILED PHASCOGALE *Phascogale pirata*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Endangered
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates stable or increasing abundance over at least 3 successive monitoring periods.
2. The status and ecology of, and threats to, this species in Kakadu are well understood.
3. Feral cats are subject to intensive control or exclusion in at least one area with a significant population of this species.
4. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. In lowland woodlands, reduce fire frequency, intensity and extent.
2. Control (reduce, stabilise or prevent further incursions of) invasive pasture grasses that would inhibit appropriate fire management.
3. Reduce the abundance of feral cats in at least one or more sites that hold significant populations of this species

Key research needed to enhance management effectiveness:
1. Undertake detailed study to assess status and ecology, and the relative impacts of different threat factors and management responses on population viability.
2. Investigate management options to achieve increase in older-growth woodlands.
3. Investigate management options to achieve reduction in feral cat abundance.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics in lowland woodlands.
2. Monitoring of cat abundance in areas subject to intensive control.

Direct monitoring parameter(s)
Annual assessment of abundance in a series of lowland woodland plots (sampled with cage traps and remote cameras).

Is there an existing management standard operating plan or protocol?
No existing management plan.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol.

Distribution
Total range The Northern Brush-tailed Phascogale has a distribution restricted to the mainland Top End of the Northern Territory and some nearby islands.
Kakadu The distribution of this species in Kakadu is not well known, but it is likely to occur (or have occurred) across the Park's lowland woodlands. Most records are from the Cooinda and Jabiru areas in tall eucalypt woodlands.
% Kakadu c. 20% (difficult to assess given limited knowledge of range, and shrinking population size; but Kakadu is one stronghold)

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements Not well known, but requires large trees with tree hollows (for denning).

Ecology
Most of the few records of this species are from lowland eucalypt forests and woodland, particularly those dominated by *Eucalyptus miniata* and/or *E. tetrodonta*. Based on the ecology of other phascogale species, Northern Brush-tailed Phascogales shelter during the day in tree hollows, and forage in trees and on the ground. The diet comprises larger invertebrates and small vertebrates. They have large home ranges (females 20-40 ha; males >100 ha), are solitary and sparsely distributed within favourable habitat. Males have an annual life-cycle with mating occurring within a short (1-2

week) annual breeding season, after which all adult males in the population die (Rhind 1998).

Impacts of fire
How fire affects the species Not well known, but high intensity fires will reduce the availability of large trees and hollows. In the absence of fire, a dense grass understorey may inhibit ground movement.
Preferred fire regime Probably a mosaic of fine-scale patchy and low intensity fires, with substantial areas >5 years unburnt.

Impacts of feral animals
Predation by feral cats may be a major threat.

Honey bees may usurp tree hollows.

Impacts of weeds
Invasive pasture grasses will exacerbate detrimental impacts of fire, and may also make it harder for this species to travel across unburnt ground.

Impacts of other threatening processes
Disease Not known
Climate change Not known and not likely.
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
The only current monitoring is through the fire-plot monitoring program, but recent rounds of sampling have reported it from only two quadrats (Woinarski *et al*. 2010).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Moderate need for captive breeding, based on presumed rapid and severe decline across Top End (and in Kakadu), and limited knowledge of major threats and the extent to which they may be effectively managed (Woinarski *et al*. 2014).

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

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FAWN ANTECHINUS
Antechinus bellus

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Endangered

Target for 2025:
1. A robust monitoring program demonstrates stable or increasing abundance over at least 3 successive monitoring periods.
2. Feral cats are subject to intensive control or exclusion in at least one area with a significant population of this species.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. In lowland woodlands, reduce fire frequency, intensity and extent.
2. Control (reduce, stabilise or prevent further incursions of) invasive pasture grasses that would inhibit appropriate fire management.
3. Reduce the abundance of feral cats in at least one or more sites that hold significant populations of this species

Key research needed to enhance management effectiveness:
1. Investigate management options to achieve increase in older-growth woodlands.
2. Investigate management options to achieve reduction in feral cat abundance.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics in lowland woodlands.
2. Monitoring of cat abundance in areas subject to intensive control.

Direct monitoring parameter(s)
1. Annual monitoring of abundance at a set of lowland woodland sites, to assess short-term responses to management of fire and cats.
2. Ongoing monitoring (at c. 5 yr intervals) of abundance in fire-plot monitoring program.

Is there an existing management standard operating plan or protocol?
No.

Is there an existing monitoring standard operating protocol?
Existing standard protocol for fire-plot sampling (described in Woinarski *et al*. 2010).

Distribution
Total range The Fawn Antechinus is restricted to the Top End of the Northern Territory, within which it has a patchy distribution (Woinarski *et al*. 2014).
Kakadu The Fawn Antechinus has been reported across much of the lowland woodlands, but particularly in taller woodlands in the north of the park.
% Kakadu c. 10%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements No known specific requirements.

Ecology
The Fawn Antechinus is a nocturnal, generalist predator of invertebrates and small vertebrates. It is partly arboreal. It occurs mostly in open forests and woodlands dominated by *Eucalyptus miniata* and/or *E. tetrodonta*, particularly where these forests have a relatively dense shrubby understorey (Friend 1985; Friend and Taylor 1985). Breeding is seasonal, with young born in September and October; typically, litter size is ten (Friend 1985).

Impacts of fire
How fire affects the species Frequent, high intensity and extensive fires may reduce the abundance of denning sites and the preferred shrubby understorey.
Preferred fire regime The Fawn Antechinus declines in areas with frequent intense fire (Corbett *et al*. 2003); however, it is not especially common in areas from which fire has been excluded for long periods (>20 years) (Woinarski *et al*. 2004a). Preferred fire regime is probably fine-scale patchy fires of low intensity and relatively low frequency.

Impacts of feral animals
Predation by feral cats may be the primary factor driving current decline.

Impacts of weeds
Invasive pasture grasses exacerbate impacts of fire, and may make travel on the ground in unburnt areas more difficult.

Impacts of other threatening processes
Disease Not known
Climate change Not known or likely
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
Included within fire-plot monitoring, with most recent published round of monitoring (2007-09) reporting it from 16 quadrats).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
No current need.

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

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GOLDEN BANDICOOT
Isoodon auratus

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Endangered
IUCN Red List: Vulnerable

Target for 2025:
If cost-effective and likelihood of success is adequate, implement a staged reintroduction.

Key management prescriptions:
1. If reintroduction is sought, establish appropriate site in which threats can be controlled (e.g. cat-proof exclosure)
2. If reintroduction is sought, engage with relevant agencies and landholders from which animals could be sourced.

Key research needed to enhance management effectiveness:
Assess cost-benefit of captive breeding and reintroduction.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
n/a

Direct monitoring parameter(s)
To be considered only if reintroduced.

Is there an existing management standard operating plan or protocol?
No. However, a national recovery plan provides a series of management actions and objectives (Palmer *et al*. 2003).

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range
The Golden Bandicoot formerly occurred across most of northern, central and western Australia, extending to south-western NSW, and across a very broad variety of habitats. However, it declined precipitously within decades of European settlement, and disappeared from the central deserts between the 1940s and 1960s. There have been very few specimen records from the Territory mainland north of the Tanami, but these have included the Roper River area (in 1911) and South Alligator River (around 1900) (Parker 1973). There are also more recent records (1950s to 1980s) from mainland north-eastern Arnhem Land that are probably referable to this species (Lyne and Mort 1981; I. Morris *unpubl*.). Golden Bandicoots are now known only from Marchinbar Island (in the Wessel group off north-eastern Arnhem Land) with translocated populations from this on nearby Raragala and Guluwuru Islands; from a small area of the north Kimberley mainland and the nearby Augustus Island, and from Barrow and the nearby Middle Island off the Pilbara coast (Woinarski *et al*. 2014).
Kakadu The only records of this species from the Kakadu area are of three specimens collected in 1902-03 at 'South Alligator River' (Thomas 1904) and one specimen at Goodparla, collected in 1967. It has not been recorded from any of the extensive wildlife surveys of the Park conducted since then, suggesting that it is very uncommon and/or highly localised. However, it is possible that animals caught over that period were misidentified as juveniles of the morphologically similar but far more common Northern Brown Bandicoot *I. macrourus*. The specific identity of the 1967 specimen should be confirmed by more detailed scrutiny of its hair and/or genetic analysis.
% Kakadu 0

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Across its former broad range, the Golden Bandicoot used a wide range of habitats, and no specific habitat features appear to be critical.

Ecology
There is little available information on ecology. On Marchinbar Island, it occurs mainly in heathland and shrubland on sandstone or sandsheets, and avoids vegetation with greater tree cover. Individuals maintain overlapping home ranges of from 12-35 ha (Southgate *et al*. 1996). The diet comprises a broad range of invertebrates.

Impacts of fire
How fire affects the species Responses to fire regimes are poorly known. It is likely to be disadvantaged by frequent high intensity fires (which would reduce shelter and increase risks of predation), but may also benefit from fine scale patchy burning (Southgate *et al*. 1996).

Preferred fire regime Probably fine scale patchy burning that creates a local mosaic of burnt and unburnt patches.

Impacts of feral animals
Predation by feral cats is most likely the major factor that has caused the historic and current decline across northern Australia.

Impacts of weeds
No substantial known impact in the Stone Country.

Impacts of other threatening processes
Disease No evidence for or against.
Climate change No known impact
Exploitation Nil

Estimate of population size in Kakadu
Zero

Population trends in Kakadu (post 2005)
Not applicable, as no records over this period.

Current monitoring programs
Nil

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Medium. A captive breeding program would help provide some security for the small known population persisting in the Northern Territory. Any staged reintroduction to Kakadu would require sustained and intensive control of feral cats at the release site.

Feasibility of applying preferred management
Reintroduction to a cat exclosure would be feasible.

Likelihood that such management may benefit other threatened species
Some other threatened mammal and bird species would benefit from establishment of cat exclosures or intensive control of feral cats.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
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NABARLEK
Petrogale concinna

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population stability or increase over at least 3 successive monitoring episodes.
2. Threats and appropriate management responses well resolved.

Key management prescriptions:
Management requirements are currently poorly resolved, but most likely:
1. In at least one site with a significant population, reduce abundance of feral cats.
2. Reduce incidence of extensive and high intensity fire.

Key research needed to enhance management effectiveness:
1. Targeted survey to better define distribution and identify significant populations.
2. Model responses to a range of possible fire regimes, and define thresholds of fire tolerance.
3. Assess impacts of other potential threats (predation by feral cats, disease).
4. Confirm techniques using DNA or other approaches to unambiguously identify species from scats.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics for Stone Country.

Direct monitoring parameter(s)
1. Annual monitoring of at least one significant subpopulation (preferably >5 subpopulations), using scat counts or other relevant index.

Is there an existing management standard operating plan or protocol?
No specific management plan or protocol. However, some relevant management actions are included in the Stone Country fire management plan (Petty 2007). Also, a national recovery plan for this species (and some other rock-wallaby species) provides a broad management framework (Pearson 2012). Roache (2011) provides another set of management actions across its range.

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range The Nabarlek is restricted to higher rainfall areas of north-western Australia, with scattered subpopulations from the north-west Kimberley, Western Australia, to Murwangie, Arnhem Land, Northern Territory (Woinarski *et al*. 2014).
Kakadu The distribution of the Nabarlek in Kakadu is not well defined (Press 1988), partly because it may be challenging to differentiate in the field from Short-eared Rock-wallabies *P. brachyotis*.
% Kakadu c. 10%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
The Nabarlek is restricted to the Stone Country, but no specific habitat requirements are known.

Ecology
Nabarleks inhabit rugged rocky areas, typically dominated by sandstones but occasionally by granites (Churchill 1997; Telfer *et al*. 2008). They shelter in caves in cliffs and rockpiles during the day, emerging at night to feed, although they can be partly diurnal during cooler months. The diet includes a variety of grasses, sedges, ferns and forbs (Sanson *et al*. 1985; Telfer and Bowman 2006).

In the Northern Territory, breeding probably occurs throughout the year, but pouch young have mostly been observed in the wet season than in the dry season (Nelson and Goldstone 1986).

Impacts of fire
How fire affects the species Extensive high intensity fires probably reduce food availability and increase predation risks; some patchy low-intensity fires may be beneficial in increasing diversity of available resources, and abundance of some preferred food plants.
Preferred fire regime Not well known, but probably fine-scale patchy fires.

Impacts of feral animals
Predation by feral cats may be a major factor affecting population viability, but there is no compelling evidence.

Impacts of weeds
No substantial known impacts.

Impacts of other threatening processes
Disease Not known
Climate change Not likely
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
There is no current monitoring in Kakadu, but some limited baseline sampling is reported in Churchill (1997), with one brief repeat sampling by D. Pearson (unpublished).

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Probably no current need; but should be reviewed in c. 5 years.

Feasibility of applying preferred management
Fire management should be achievable; management of feral cats may be challenging.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

Key references
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Woinarski, J.C.Z., Burbidge, A.A., and Harrison, P. (2014). *The Action Plan for Australian mammals, 2012*. (CSIRO Publishing, Melbourne.)

GHOST BAT
Macroderma gigas

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Near Threatened
IUCN Red List: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates population stability or increase over at least 3 successive monitoring episodes.
2. Threats and appropriate management responses well resolved.

Key management prescriptions:
Management requirements are currently poorly resolved, and the probable main threat (poisoning by cane toads) may not be amenable to management.

1. Constrain human visitation or other disturbance to important roost sites, especially maternity sites, with such constraint designed not to detrimentally affect this species (e.g. by inappropriate gating).
2. Where possible and required, decontaminate important roost sites.

Key research needed to enhance management effectiveness:
1. Assess impacts of threats, particularly impacts of cane toads.
2. Targeted survey to better define distribution and identify significant roost sites.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Nil.

Direct monitoring parameter(s)
1. Population counts at main roost sites at 2-3 year intervals, using a standardised procedure.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No, but irregular roost site counts have been undertaken at some other Northern Territory sites, with most precision coming from thermal tracking software (e.g. Grant *et al*. 2010). Note that Ghost Bats are easily disturbed when roosting, and young may be dislodged by adults in rapid take-offs: so monitoring activity needs to be undertaken carefully.

A more broad-scale monitoring program (for a range of threatened bat species) using an array of bat detectors may be possible, but this species has a relatively low detectability in most such systems (e.g. McKenzie and Bullen 2009).

Distribution
Total range The Ghost Bat now occurs discontinuously across northern Australia, including the Pilbara; it no longer occurs across its formerly extensive central Australian range (Woinarski *et al*. 2014).
Kakadu The distribution of the Ghost Bat in Kakadu is not well defined, but it is, or was, probably widespread in the stone country and some lowland areas. Important roost sites are known at Nawurlandja and Ngarradj (White 2014).
% Kakadu c. 10%

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
This species requires caves (or adits) for roosting: preferred sites are generally deep natural caves or disused mines with a relatively stable temperature of 23°-28°C and moderate to high relative humidity of 50-100% (Pettigrew *et al*. 1986; Churchill and Helman 1990; Churchill 1991; Armstrong and Anstee 2000).

Ecology
The Ghost Bat is a large carnivorous bat. Its diet comprises a wide range of birds, lizards, mammals and invertebrates, but frogs (and hence cane toads) are also consumed.

Impacts of fire
How fire affects the species Not known: extensive fire may increase hunting efficiency for some prey types, but may also reduce prey abundance..
Preferred fire regime Not well know.

Impacts of feral animals
Across several sites in Queensland, the Ghost Bat has exhibited a dramatic decline soon after the arrival of cane toads (White and Madani 2014), and such a pattern may also be being exhibited at Kakadu (White 2014).

Impacts of weeds
No substantial known impacts.

Impacts of other threatening processes
Disease Not known
Climate change Not likely
Exploitation The Ghost Bat may have been detrimentally affected by some mining activities preceding the park's establishment; but some mining may also have created roost sites.

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
There is no current monitoring in Kakadu, but White (2014) has recently sampled some roost sites for which some information was available on former abundance.

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Probably no current need; but should be reviewed in c. 5 years.

Feasibility of applying preferred management
There is no feasible management to reduce cane toad abundance over large areas.

Likelihood that such management may benefit other threatened species
If toads could be reduced, this action would benefit a range of other native species.

Likelihood that such management may be detrimental to other threatened species
Low

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ARNHEM LEAF-NOSED BAT *Hipposideros inornatus*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Vulnerable

Target for 2025:
1. Determine status, habitat requirements, and distribution (notably including significant roost sites).
2. Establish a robust monitoring program.
3. Abundance stable or increasing over three consecutive monitoring episodes.

Key management prescriptions:
1. Manage known roosts to constrain human visitation, and (for abandoned mines) to reduce chemical contamination, while maintaining access by and suitability for this species.

Key research needed to enhance management effectiveness:
1. Survey to establish status, habitat use and significant roost sites.
2. Study to establish relative impacts of threatening factors, and of management responses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Nil

Direct monitoring parameter(s)
1. Annual counts at known roost sites, where possible using non-disturbing protocols.

Is there an existing management standard operating plan or protocol?
No existing management protocols.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocols, but roost-based counts are well-established for other bat species.

Distribution
Total range The Arnhem Leaf-nosed bat was first collected as recently as 1969 (McKean 1970) and has been recorded only from a few locations in the western Arnhem Land sandstone massif (Deaf Adder Gorge and upper South Alligator River area) and from one site (Tolmer Falls) in Litchfield National Park (McKean and Hertog 1979).
Kakadu Known only from the Stone Country, with largest known subpopulation at Deaf Adder Gorge.
% Kakadu c. 80-100% (formerly also occurred at Litchfield National Park, and probably also present in the sandstone massif to the east of Kakadu).

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Preferred characteristics of roost sites (particularly communal maternity roost sites) are not well known.

Ecology
The Arnhem Leaf-nosed Bat roosts in caves or abandoned mine adits in cool draughty areas, close to water (Churchill 1998; Corbett and Richards 2002). Little is known of its foraging habitat or diet, but it has been reported foraging in riparian areas and in eucalypt tall open forests. Its main diet is large invertebrates.

Impacts of fire
How fire affects the species Not known; extensive, frequent and high intensity fire may reduce suitability of foraging habitat (Woinarski *et al*. 2014)
Preferred fire regime Not well known, but probably infrequent and low intensity fire.

Impacts of feral animals
No known impacts; feral cats may prey on roosting individuals.

Impacts of weeds
No known or likely impacts.

Impacts of other threatening processes
Disease Not known.
Climate change Not known or likely
Exploitation No exploitation, but disturbance by human visitation at roost sites may have caused loss of the Litchfield subpopulation (Corbett and Richards 2002).

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring, but some records from call recordings at fire-plot monitoring. Some counts from the roost sites (Corbett and Richards 2002).

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed at present.

Feasibility of applying preferred management
High

Likelihood that such management may benefit other threatened species
Medium-high

Likelihood that such management may be detrimental to other threatened species
Low

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NORTHERN LEAF-NOSED BAT *Hipposideros stenotis*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Determine status, habitat requirements, and distribution (notably including significant roost sites).
2. Establish a robust monitoring program.
3. Abundance stable or increasing over three consecutive monitoring episodes.

Key management prescriptions:
1. Manage known roosts to constrain human visitation, and (for abandoned mines) to reduce chemical contamination, while maintaining access by and suitability for this species.

Key research needed to enhance management effectiveness:
1. Survey to establish status, habitat use and significant roost sites.
2. Study to establish relative impacts of threatening factors, and of management responses.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Nil

Direct monitoring parameter(s)
1. Annual counts at known roost sites, where possible using non-disturbing protocols.

Is there an existing management standard operating plan or protocol?
No existing management protocols.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocols, but roost-based counts are well-established for other bat species. More extensive monitoring may be possible with call recordings.

Distribution
Total range The Northern Leaf-nosed Bat is distributed widely in northern Australia, from the Mt Isa area of north-western Queensland to the Kimberley (Thomson and McKenzie 2008). Within this extensive range it is very patchily distributed (Milne and Hall 2008).
Kakadu The distribution in Kakadu is poorly known, but it has been reported from several caves, crevices, rock piles and mines (e.g. Palmer and Churchill 2000)
% Kakadu c. 5%

Habitat
☒ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
Preferred characteristics of roost sites (particularly maternity roost sites) are not well known.

Ecology
The Northern Leaf-nosed Bat typically occurs in rugged rocky areas. During the day it roosts solitarily or in small groups in caves, mines, boulder piles and culverts, and also in tight overhangs or semi-shaded sites along cliff lines (Schulz and Menkhorst 1984; Churchill 2008). It forages in a range of vegetation types, including eucalypt open forests and woodlands and grasslands (Churchill 2008), but typically where these are close to escarpments and other rocky areas (Milne *et al*. 2006; Milne ad Pavey 2011). The diet comprises small insects, including beetles and moths (Churchill 2008).

Impacts of fire
How fire affects the species Not known; extensive, frequent and high intensity fire may reduce suitability of foraging habitat (Woinarski *et al*. 2014)
Preferred fire regime Not well known, but probably infrequent and low intensity fire.

Impacts of feral animals
No known impacts; feral cats may prey on roosting individuals.

Impacts of weeds
No known or likely impacts.

Impacts of other threatening processes
Disease Not known.
Climate change Not known or likely
Exploitation No exploitation, but disturbance by human visitation at roost sites may be detrimental.

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known
(Inferred from range-wide pattern of decline: Milne and Pavey 2011)

Current monitoring programs
No existing monitoring program; although some counts exist for a few sites (e.g. Palmer and Churchill 2000)

Extent of current targeted management in Kakadu
No targeted management

Options/needs for ex situ breeding and/or assisted re-introduction
Not needed at this stage

Feasibility of applying preferred management
Medium

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

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BARE-RUMPED SHEATHTAIL BAT *Saccoilamus saccoilamus*

Conservation status
AUSTRALIA: Critically Endangered (as the subspecies *S. s. nudicluniatus*)
NORTHERN TERRITORY: Near Threatened

Target for 2025:
1. Targeted comprehensive sampling establishes current status in Kakadu.
2. A robust monitoring program is established.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. Reduce fire frequency, extent and intensity in the lowland woodlands

Key research needed to enhance management effectiveness:
1. Survey to establish status.
2. Identification of factors affecting habitat suitability, and hence of thresholds of fire sensitivity.
3. Development of diagnostic call recording.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of longer-unburnt lowland woodlands

Direct monitoring parameter(s)
1. (If calls can be reliably diagnosed) annual monitoring of incidence at a series of permanent sites across lowland woodlands, based on bat detectors.

Is there an existing management standard operating plan or protocol?
Not specifically for this species in Kakadu. However, a national recovery plan describes a broad management framework (Schulz and Thomson 2007).

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range The Bare-rumped Sheathtail Bat occurs across northern Australia, from north-eastern Queensland to the eastern Kimberley, although its occurrence within that range is poorly defined (Milne *et al*. 2009; Woinarski *et al*. 2014). The species extends beyond Australia from India to the Solomon Islands; the subspecies *S. s. nudicluniatus* is restricted to Australia.
Kakadu It was first recorded in the Northern Territory from two specimens collected in 1979 and 1980 at Kapalga (McKean *et al*. 1981). There are no subsequent confirmed records from Kakadu (Milne *et al*. 2004, 2009).
% Kakadu <5%

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No known specific habitat requirements known, but most roosts have been in large eucalypts.

Ecology
This is a high-flying insectivorous bat. The Kakadu specimens were collected from open *Pandanus* woodland fringing the sedgelands of the South Alligator River (Friend and Braithwaite 1986). In the Northern Territory, it has also been recorded from eucalypt tall open forests (Churchill 1998; Milne *et al*. 2009). In Queensland, it is known mainly from coastal lowlands, including eucalypt woodlands and rainforests (Duncan *et al*. 1999). The few known roosts have been mostly in hollows of large trees (Duncan *et al*. 1999; Milne *et al*. 2009).

Impacts of fire
How fire affects the species
Not known. High intensity fires may cause deaths for individuals roosting in hollow trees, and reduce the abundance of large hollow-bearing trees. A high frequency of fire may also lead to reduced abundance of large trees.

Preferred fire regime
Not reliably known, but likely to be a regime with a low incidence of low intensity fire.

Impacts of feral animals
No known impacts.

Impacts of weeds
No known direct impacts, but spread of invasive pasture grasses is likely to exacerbate impacts of fire.

Impacts of other threatening processes
Disease No known impact
Climate change No known impact
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No monitoring

Extent of current targeted management in Kakadu
Nil.

Options/needs for ex situ breeding and/or assisted re-introduction
Nil

Feasibility of applying preferred management
Feasible, but will require committed and strategic attention to fire management.

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

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BRUSH-TAILED RABBIT-RAT *Conilurus penicillatus*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Endangered

Target for 2025:
1. At least two known subpopulations with stable or increasing population trends.
2. >30% of lowland forests and woodlands is >3 years since last fire.
3. At least some parts of Kakadu lowlands are intensively managed to effectively reduce abundance of feral cats.

Key management prescriptions:
1. (Assuming some extant subpopulation) reduce lowland fire extent, intensity and frequency.
2. (Assuming some extant subpopulation) manage the area of significant subpopulations to reduce abundance of feral cats.
3. Develop management guidelines and processes for reintroduction; liaise with agencies and landowners from which reintroduced stock could be taken; establish reintroduction sites that adequately control major threats (e.g. cat exclosures).

Key research needed to enhance management effectiveness:
1. Targeted survey to attempt to locate surviving subpopulations.
2. Cost-benefit study to assess options for staged reintroduction.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Annual monitoring of fire metrics across lowland woodlands.

Direct monitoring parameter(s)
Currently n/a. Monitoring protocols would need to be developed for any reintroduction.

Is there an existing management standard operating plan or protocol?
No, but a national Recovery Plan is due for release in 2014 (Woinarski *et al*. 2014b).

Is there an existing monitoring standard operating protocol?
Not for current monitoring. Firth (2010) described protocols used for monitoring the species at Mardugal in 2000 and 2001.

Distribution
Total range In the Northern Territory, this species has been recorded from near-coastal areas from near the mouth of the Victoria River in the west to the Pellew Islands in the east, and including Bathurst, Melville, Inglis and Centre Islands and Groote Eylandt (Parker 1973; Kemper and Schmitt 1992; Woinarski 2000). There are no recent records from much of this historically recorded range, and it is currently known to persist in the Northern Territory only on Cobourg Peninsula, Bathurst, Melville and Inglis Islands, Groote Eylandt, and a small area within Kakadu. Beyond the Northern Territory, the species also occurs from higher rainfall, near-coastal areas of the north Kimberley, Bentinck Island (Queensland) and a small area of southern New Guinea.
Kakadu The Brush-tailed Rabbit-rat was at least locally common in Kakadu lowlands at the turn of the twentieth century (Dahl 1897; Collett 1897; Thomas 1904). Its range appears to have contracted markedly since. The Alligator Rivers Fact-finding study of the early 1970s recorded it as 'a reasonably common species in the region' (Calaby 1973). It was subsequently recorded, rarely, at only three of the 30 sites sampled over the period 1980-84 in the CSIRO fauna surveys of Stages I and II (Braithwaite 1985) and recorded with only a few individuals in the substantial set of ecological studies undertaken at Kapalga over the period 1986-1993 (Braithwaite and Muller 1997); then it was not recorded at all in the intensive and extensive fauna sampling of Stage III of the park (Mary River District) between 1988 and 1990 (Woinarski and Braithwaite 1991), nor in re-sampling of Kapalga sites in 1999 (Woinarski *et al*. 2001). The last known subpopulation in Kakadu was abundant and persisted in woodlands around Mardugal campground until at least 2002, but has since disappeared (Firth 2010). Occasional unconfirmed sightings have been reported in Kakadu in recent years.
% Kakadu <5%

Habitat

☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements Woodlands with adequate tree hollows and hollow logs; diverse understorey, preferably including Cockatoo Grass *Alloteropsis semialata*.

Ecology

Preferred habitat is eucalypt tall open forest, generally with a relatively dense tall shrubby understorey (PWCNT 2001; Firth *et al*. 2006a). However, at least on Cobourg Peninsula, it also occurs on coastal grasslands (with scattered large *Casuarina equisetifolia* trees, beaches, and stunted eucalypt woodlands on stony slopes.

Brush-tailed Rabbit-rats shelter in tree hollows (particularly of rough-barked species, and in larger trees), hollow logs (Firth *et al*. 2006b) and, less frequently, in the crowns of pandanus or sand-palms (Dahl 1897). Most foraging is on the ground, but it is also partly arboreal. The diet comprises mainly seeds (especially of grasses), with some fruits, invertebrates and leaves and grass.

The Brush-tailed Rabbit-rat mostly eats seeds, particularly of grass species (Morton 1992; Firth *et al*. 2005). Seeds of Cockatoo Grass may be particularly preferred (Firth *et al*. 2005). This grass species may be particularly sensitive to fire regimes and impacts of introduced herbivores (Crowley and Garnett 2001; Crowley 2008). Other dietary items include grass, termites, fruits and foliage (Morton 1992; Firth *et al*. 2005). It primarily forages on the ground, but, less so, also in trees (Kitchener *et al*. 1981; Friend *et al*. 1992).

Brush-tailed Rabbit-rats breed during the dry season. Females may give birth to at least two sets of young; average litter size is two to three (Taylor and Horner 1971; Firth 2007; Kemper and Firth 2008).

Impacts of fire

How fire affects the species This species is severely affected by frequent and/or high intensity fires (Firth *et al*. 2010). Fire may cause some immediate mortality, reduces available shelter, increases risks of predation, and may reduce in short and longer term the availability of food resources.
Preferred fire regime Low intensity patchy fires at infrequent intervals.

Impacts of feral animals

1. Predation by feral cats is likely to be a major factor driving the current decline (e.g. Woinarski *et al*. 2011).

2. Feral pigs select and destroy a pivotal food plant, Cockatoo Grass (Crowley 2008).

Impacts of weeds

Invasive pasture grasses are likely to be severely detrimental through exacerbating impacts of fire.

Impacts of other threatening processes

Disease Not known
Climate change. Kutt *et al*. (2009) predicted a 90% decline due to climate change for the period 2009-2030.
Exploitation Nil

Estimate of population size in Kakadu

Not known, but likely to be between 0 and 1000 individuals.

Population trends in Kakadu (post 2005)

☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs

No current monitoring

Extent of current targeted management in Kakadu

No targeted management in Kakadu.

Options/needs for ex situ breeding and/or assisted re-introduction

High. A captive breeding population was formerly retained at the Territory Wildlife Park, and it should be feasible to develop a reintroduction program to sites at which threats have been intensively managed.

Feasibility of applying preferred management

Enhanced fire management in lowlands, and feral cat control, will be challenging.

Reintroduction to intensively managed sites should be feasible, although this species may climb through or over cat exclosure fencing.

Likelihood that such management may benefit other threatened species

Enhanced fire management in the lowlands, and feral cat control will benefit many other threatened species.

Likelihood that such management may be detrimental to other threatened species

Nil.

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BLACK-FOOTED TREE-RAT *Mesembriomys gouldii*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. A robust monitoring program demonstrates stable or increasing abundance over at least 3 successive monitoring periods.
2. Feral cats are subject to intensive control or exclusion in at least one area with a significant population of this species.
3. >10% of lowland forests and woodlands is >10 years since last fire; >30% of lowland forests and woodlands is >3 years since last fire.

Key management prescriptions:
1. In lowland woodlands, reduce fire frequency, intensity and extent, in order to increase development or abundance of woody understorey, large trees and hollows.
2. Control (reduce, stabilise or prevent further incursions of) invasive pasture grasses that would inhibit appropriate fire management.
3. Reduce the abundance of feral cats in at least one or more sites that hold significant populations of this species

Key research needed to enhance management effectiveness:
1. Assess relative impacts of different threat factors and management responses on population viability.
2. Investigate management options to achieve increase in older-growth woodlands.
3. Investigate management options to achieve reduction in feral cat abundance.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Annual assessment of fire metrics in lowland woodlands.
2. Establishment of a series of transects to monitor woody shrub composition, size and fruit production in areas exposed to different fire regimes.
3. Monitoring of cat abundance in areas subject to intensive control.

Direct monitoring parameter(s)
Annual assessment of abundance in a series of lowland woodland plots (sampled with cage traps and remote cameras).

Is there an existing management standard operating plan or protocol?
No existing management plan.

Is there an existing monitoring standard operating protocol?
No existing monitoring protocol. (This species is included in fire-plot monitoring, with standard protocol.)

Distribution
Total range The Black-footed Tree-rat occurs across northern Australia from north-eastern Queensland to the Kimberley, and including Melville Island, however it is rare and localised in Queensland and Western Australia (Woinarski *et al*. 2014).
Kakadu The Black-footed Tree-rat is widely distributed in lowland woodlands across Kakadu, particularly where there are large trees and well-developed shrub understorey.
% Kakadu c. 10% (although widely distributed across northern Australia, it is sparse and localised in most of that range; Kakadu probably holds an important population)

Habitat
☐ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements Black-footed Tree-rats den mostly in large hollows in large trees (or sometimes hollow logs) (Pittman 2003; Rankmore 2006; Rankmore and Friend 2008). Their diet includes a reasonably high proportion of fleshy fruits, mostly from shrub species (Morton 1992), so habitat quality depends in part on a well-developed understorey, mostly associated with relatively long unburnt areas (Friend and Taylor 1985; Friend 1987; Woinarski *et al*. 2004).

Ecology
The Black-footed Tree-rat is a nocturnal rodent that dens mostly in tree hollows, but occasionally in dense foliage (notably of *Pandanus*), and occasionally in buildings. It forages on the ground and in trees, and individuals may make movements of at least 500 m from roost sites to foraging areas (Friend *et al*. 1992).The diet comprises mostly fruits (including of *Pandanus spiralis*) and seeds, but also includes some invertebrates, flowers and grass (Morton 1992; Rankmore 2006; Rankmore and Friend 2008). It occurs mostly in lowland open forests and woodlands dominated by *Eucalyptus miniata* and/or *E. tetrodonta*, particularly where these forests have a relatively dense shrubby understorey (Friend and Taylor 1985; Friend 1987). Breeding may occur throughout the year, but peaks in August-September (Friend 1987; Rankmore 2006). Litter size is small (1-3 young).

Impacts of fire
How fire affects the species Fire has multiple effects: (i) frequent fires will reduce the abundance and productivity of shrubby understorey, eroding the food resource base; (ii) high intensity fires will reduce the abundance of large hollow-producing trees and hollow logs; (iii) extensive fires are likely to increase predation risks; (iv) some fire may be beneficial to open out dense grassy understorey, allowing more ready movement on the ground.
Preferred fire regime Fire exclusion or fine-scale cool fire of limited extent.

Impacts of feral animals
Predation by feral cats (and possibly wild dogs) may reduce population viability.

Honey bees may usurp preferred tree hollows.

Impacts of weeds
Invasive pasture grasses will exacerbate detrimental impacts of fire, and may also make it harder for this species to travel across unburnt ground.

Impacts of other threatening processes
Disease Not known
Climate change Not known and not likely.
Exploitation Nil

Estimate of population size in Kakadu
Unknown

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
This species is included in part in the fire-plot monitoring program (Woinarski *et al*. 2010), although at the most recent reported sampling (2007-09), it was recorded from only one quadrat, which makes this program an inadequate base for monitoring.

Extent of current targeted management in Kakadu
No targeted management.

Options/needs for ex situ breeding and/or assisted re-introduction
Not necessary at this stage, but may need review in 2-3 years if population continues to decline rapidly.

Feasibility of applying preferred management
Feasible, but challenging

Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Low

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GOLDEN-BACKED TREE-RAT *Mesembriomys macrurus*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Critically Endangered

Target for 2025:
If cost-effective and likelihood of success is adequate, implement a staged reintroduction.

Key management prescriptions:
1. If reintroduction is sought, establish appropriate site in which threats can be controlled (e.g. cat-proof exclosure)
2. If reintroduction is sought, engage with relevant agencies and landholders from which animals could be sourced.

Key research needed to enhance management effectiveness:
1. Assess cost-benefit of captive breeding and reintroduction.
2. Follow up with intensive sampling any unconfirmed records.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s) n/a

Direct monitoring parameter(s) To be considered only if reintroduced.

Is there an existing management standard operating plan or protocol?
No. However, a national recovery plan provides a series of management actions and objectives (Palmer *et al*. 2003).

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range This species has declined from much of its former distribution in the Northern Territory and northern Western Australia (Dahl 1897; McKenzie 1981), with no confirmed records in the Northern Territory subsequent to 1969 (Woinarski 2000). It remains patchily common in the north Kimberley and some offshore islands (Abbott and Burbidge 1995).

Kakadu This species is not known to currently occur in Kakadu. However there are two relevant historic records, in 1903 (four specimens) from Nellie Creek (Thomas 1904), and in 1969 from Deaf Adder Gorge. There are a few subsequent unconfirmed records from within (e.g. Fisher *et al*. 1993) and near Kakadu (Ziembicki *et al*. 2013). The status of this species in Kakadu, and the Northern Territory generally, is puzzling. If it still persists, it is clearly very uncommon and/or highly localised. It has not been recorded in any of the extensive fauna surveys undertaken over the last 30 years in Kakadu, despite sampling in apparently suitable habitat and use of suitable traps.
% Kakadu 0%

Habitat
☒ Stone Country
☒ lowland woodlands
☒ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements This species dens in tree hollows and hollow trees, and may be associated with rainforests, riverside vegetation or rainforest-woodland boundaries.

Ecology
The only information from the Northern Territory is that all three records were from riverine vegetation. In the Kimberley, it has been recorded from a broad range of vegetation types, including eucalypt open forests with tussock grass understorey, rainforest patches on a variety of landforms and soils, eucalypt woodlands with hummock grass understorey, rugged sandstone screes, beaches, and blacksoil plains with pandanus. It roosts in tree hollows or, less commonly, in loosely woven nests under the spiky crown of pandanus. Its diet includes seeds, fruits, invertebrates, grass and leaves, and it forages both on the ground and in trees.

Impacts of fire
How fire affects the species Extensive, frequent and/or high intensity fires probably reduce habitat suitability by (i) reducing the size, cover and productivity of shrubs that produce fleshy fruits, (ii) reducing rainforest extent, (iii)

reducing the availability of shelters (such as hollow logs) and (iv) increasing exposure to predators.
Preferred fire regime Unresolved, but probably low incidence of patchy fire. (As with some other mammals, some fire may be required because dense grassy understories may impair movement.)

Impacts of feral animals
It is highly likely that predation by feral Cats is the primary factor responsible for the species' decline.

Impacts of weeds
Invasive grass species may be detrimental through their exacerbation of fire impacts.

Impacts of other threatening processes
Disease No direct evidence for or against.
Climate change Unlikely to be a major threat over 2-3 decades.
Exploitation Nil

Estimate of population size in Kakadu
Zero

Population trends in Kakadu (post 2005)
Not applicable, as no records over this period.

Current monitoring programs
Description Nil
Adequacy n/a
Feasibility of more adequate monitoring n/a

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Medium-high

Feasibility of applying preferred management
Captive breeding is likely to be feasible; but reintroduction would require some intensive control of feral Cats and other threats.
Likelihood that such management may benefit other threatened species
High

Likelihood that such management may be detrimental to other threatened species
Nil

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NORTHERN HOPPING-MOUSE *Notomys aquilo*

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable
IUCN Red List: Endangered

Target for 2025:
Options and cost-benefits of captive breeding and reintroduction evaluated.

Key management prescriptions:
1. Liaise with landholders and relevant agencies in areas that support extant populations to assess interest in supplying founder stock for possible reintroduction.
2. Liaise with captive breeding facility to assess interest in collaboration, or establish a captive breeding facility on site.
3. If reintroduction is considered appropriate, establish a predator-proof exclosure.

Key research needed to enhance management effectiveness:
1. Based on habitat of extant populations, identify any suitable habitat for reintroduction.
2. Assess costs and benefits for reintroduction.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Not relevant unless reintroduction proceeds.

Direct monitoring parameter(s)
Not relevant unless reintroduction proceeds.

Is there an existing management standard operating plan or protocol?
No specific management plan for Kakadu; however a national recovery plan (Woinarski 2004) provides a broad management framework.

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range The Northern Hopping-mouse is now known only from Groote Eylandt and small areas of mainland north-eastern Arnhem Land (Woinarski *et al*. 2014). There is a record from the Cadell River (c. 100 km east of Kakadu) in 1973 (Woinarski *et al*. 1999).
Kakadu The only record(s) from Kakadu are recent subfossil specimens from Angbangbang shelter (Foley 1985).
% Kakadu 0: probably no longer extant in Kakadu.

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements Known records are from sandy substrates.

Ecology
The Northern Hopping-mouse is a nocturnal rodent, with diet comprising mostly seeds. It occurs in a range of environments (including eucalypt open forests, heathlands and dunefields), with sandy substrates (Woinarski *et al*. 1999). It shelters in complex burrow systems.

Impacts of fire
How fire affects the species Not well known, but many of the shrubs providing the seeds that are key food sources probably require fire-free intervals of at least 3-5 years. Extensive fires may also increase rates of predation.

Preferred fire regime Not well known, but probably prefers vegetation at least 3 years post-fire.

Impacts of feral animals
Predation by feral cats may reduce population viability.

Impacts of weeds
No known impact.

Impacts of other threatening processes
Disease No known impact.
Climate change No impact
Exploitation Nil

Estimate of population size in Kakadu
Probably zero.

Population trends in Kakadu (post 2005)
Not applicable as no records over this period.

Current monitoring programs
No current monitoring.

Extent of current targeted management in Kakadu
No targeted management in Kakadu.

Options/needs for ex situ breeding and/or assisted re-introduction
Potentially suitable for staged reintroduction.

Feasibility of applying preferred management
Feasible, but challenging.

Likelihood that such management may benefit other threatened species
Limited

Likelihood that such management may be detrimental to other threatened species
Nil.

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KAKADU PEBBLE-MOUSE *Pseudomys calabyi*

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Near Threatened
IUCN Red List: Vulnerable

Target for 2025:
1. Population trends stable or increasing over three successive monitoring episodes.
2. >10% of habitat is >10 years since last fire; >30% is >3 years since last fire.

Key management prescriptions:
1. Establish a fine-scale patchy fire regime in stony woodland habitats.
2. Reduce the abundance of feral cats in stony woodland habitats.

Key research needed to enhance management effectiveness:
Little is known about the ecology, distribution or abundance of this species, or of its management requirements

1. Targeted survey to better define distribution and identify significant populations.
2. Assessment of diet and responses of preferred food plants to fire regimes.
3. Model responses to a range of possible fire regimes, and define thresholds of fire tolerance.
4. Assess impacts of other potential threats (notably predation by feral cats).
5. Develop an effective sampling and monitoring protocol.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of late dry season fires across range.

Direct monitoring parameter(s)
1. Abundance at a set of sites sampled consistently, with monitoring at 2-5 year intervals. Note that this species may be more likely to be detected by pitfall trapping than by Elliott trapping.

Is there an existing management standard operating plan or protocol?
No.

Is there an existing monitoring standard operating protocol?
No. This species is included in the current fire plot monitoring program, but its incidence in that program is too low to be useful for monitoring (Woinarski *et al*. 2010).

Distribution
Total range The distribution of the Kakadu Pebble-mouse is poorly known, but it is currently known only from foothill woodlands in Kakadu, Litchfield and nearby areas. Within that range it is probably highly fragmented, with relatively specialised habitat requirements (Woinarski *et al*. 2014).
Kakadu The distribution of the Kakadu Pebble-mouse in Kakadu is poorly known: most records are from the southern third of the park.
% Kakadu c. 50%: most records are from the Kakadu area..

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements The Kakadu Pebble-mouse occurs mostly in stony hills (rather than the more rugged Stone Country) (Woinarski 1992).

Ecology
The Kakadu Pebble-mouse is a nocturnal terrestrial rodent. Its diet probably mostly comprises seeds, particularly of grass species. It constructs burrows, sealed and surrounded by a small heap of pebbles.

Impacts of fire
How fire affects the species Not well known, but fire may expose this species to higher risks of predation and consume part of the seed resource. Some fire regimes may cause change in the understorey species composition, potentially to the detriment of plant species favoured as food resources.

Preferred fire regime Not well known, but probably fine-scale fire mosaics, or small fires at intervals of 3-5 years.

Impacts of feral animals
Predation by feral cats may reduce population viability.

Impacts of weeds
No known impact, but it is likely that high desnities of invasive pasture grasses may lead to unfavourable fire regimes.

Impacts of other threatening processes
Disease No known impact.
Climate change No impact
Exploitation Nil

Estimate of population size in Kakadu
Unknown.

Population trends in Kakadu (post 2005)
Limited evidence, but this suggests decline (Woinarski *et al*. 2010).

Current monitoring programs
Low incidence in fire-plot monitoring program.

Extent of current targeted management in Kakadu
No targeted management in Kakadu. The habitat of this species is not really included in the current Stone Country fire program.

Options/needs for ex situ breeding and/or assisted re-introduction
No current priority for captive breeding or re-introduction, although a captive population could provide some information on diet and ecology.

Feasibility of applying preferred management
Feasible.

Likelihood that such management may benefit other threatened species
Enhanced fire management for stony woodlands will also benefit Kakadu Dunnart and Gouldian Finch.

Likelihood that such management may be detrimental to other threatened species
Nil.

Key references
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Woinarski, J.C.Z., Burbidge, A.A., and Harrison, P. (2014). *The Action Plan for Australian mammals, 2012*. (CSIRO Publishing, Melbourne.)

ARNHEM ROCK-RAT
Zyzomys maini

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Population trends stable or increasing over three successive monitoring episodes.
2. >10% of Stone Country is >10 years since last fire; >30% is >3 years since last fire.

Key management prescriptions:
1. Manage fire in the Stone Country to ensure protection of rainforest and thicket patches in rocky areas, through a combination of cool burns around perimeter, broader-scale patchy early fires, and suppression.

Key research needed to enhance management effectiveness:
1. Targeted survey to better define distribution and identify significant populations.
2. Model responses to a range of possible fire regimes, and define thresholds of fire tolerance.
3. Assess impacts of other potential threats (predation by feral cats, disease).

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Extent of late dry season fires across range;
2. Extent and condition of sandstone rainforest and thicket habitat.

Direct monitoring parameter(s)
1. Relative abundance at a set of at least 10 sites, monitored annually.

Is there an existing management standard operating plan or protocol?
The Arnhemland Plateau Draft Fire Management Plan (Petty 2007) provides a general approach to the management of fire in that portion of this species' range in Kakadu, but does not provide a specific management focus for this species.

Is there an existing monitoring standard operating protocol?
This species is included in the fire plot monitoring program, for which a standard sampling protocol is used (Woinarski *et al*. 2010).

Previous sampling at Nawurlandja (Begg 1981; Begg *et al*. 1981), Jabiluka (Kerle and Burgman 1984) and 'Stage III' (Woinarski *et al*. 2002) provides some additional baselines on which longer-term monitoring could be established (with some re-sampling of these baseline studies reported by Woinarski *et al*. (2002) and Watson and Woinarski (2003)).

Distribution
Total range The Arnhem Rock-rat is known only from the sandstone massif of western Arnhem Land. Its extent of occurrence is c. 8000 km^2 (Woinarski *et al*. 2014), but it only occupies a small proportion of this area.
Kakadu The Arnhem Rock-rat is very patchily distributed in suitable rugged areas in Kakadu, but many potential sites have not been sampled, and there is little information available to delineate significant populations.
% Kakadu c. 30%

Habitat
☒ Stone Country
☐ lowland woodlands
☒ rainforest
☐ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
This species is closely associated with very rugged rocky areas, especially where these support rainforest/thicket vegetation, or areas with such vegetation abutting spinifex.

Ecology
The ecology of the Arnhem Rock-rat is relatively well known from a series of studies at Nawurlandja in Kakadu National Park (Begg and Dunlop 1980, 1985; Begg 1981; Begg *et al*. 1981). It is an entirely terrestrial, nocturnal species, restricted to areas with large sandstone boulders or escarpment with fissures and cracks. It occurs in these areas very patchily, being restricted mostly to monsoon rainforest patches and thickets, notably in

gullies and along creeklines, or in fire-protected refugia. This is a much narrower habitat range than that occupied by the Common Rock-rat. The Arnhem Rock-rat's diet comprises mainly seeds, fruit and some other vegetable matter. The seeds eaten include those from many species of rainforest tree. Large seeds may be cached, or at least moved to be eaten at relatively safe sites, resulting in distinctive piles of chewed hard seeds in rock fissures or under large overhangs.

Breeding may occur throughout the year, but the incidence of pregnant females peaks in March-May (Begg 1981). Litter size is small (two young reported from two litters: Watts and Aslin 1981).

Impacts of fire
How fire affects the species On the basis of its response to a single large fire, the Arnhem Rock-rat appears to be unusually fire-sensitive, with substantial decline for at least 1-2 years post-fire (Begg *et al*. 1981). A high frequency of fire will result in diminution of its preferred sandstone monsoon rainforests (Russell-Smith *et al*. 1993, 1998).
Preferred fire regime Little or no fire.

Impacts of feral animals Predation by feral cats may be having detrimental impacts, although the very rugged nature of its preferred habitat may somewhat limit cat abundance and hunting efficiency.

Impacts of weeds Not known and not likely

Impacts of other threatening processes
Disease Not known
Climate change Not known and not likely over the next 2-3 decades
Exploitation Nil

Estimate of population size in Kakadu
Not known

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☒ decreasing
☐ severely decreasing
☐ not known

Current monitoring programs
This species is included in the fire plot monitoring program, but at the most recent reported sampling (over the period 2007-09) it was recorded from only 12 quadrats (which may give inadequate statistical power), and the period between repeat sampling (5 years) may not allow for rapid management response.

Extent of current targeted management in Kakadu
There is no specific targeted management for this species.

Options/needs for ex situ breeding and/or assisted re-introduction
No substantial need for such activity at this stage.

Feasibility of applying preferred management
The existing Stone Country fire management plan has been applied successfully to date. Protection of defined significant populations of this species should be feasible within an enhanced Stone Country fire plan.

Likelihood that such management may benefit other threatened species
Fire management targeting this species will be beneficial for a wide range of other Stone Country threatened species.

Likelihood that such management may be detrimental to other threatened species
Nil

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Begg, R.J. (1981). The small mammals of Little Nourlangie Rock, N.T. IV. Ecology of *Zyzomys woodwardi*, the large rock-rat, and *Z. argurus*, the common rock-rat (Rodentia: Muridae). *Australian Wildlife Research* **8**, 73-85.

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WATER MOUSE
Xeromys myoides

Conservation status
AUSTRALIA: Vulnerable
NORTHERN TERRITORY: Data Deficient
IUCN Red List: Vulnerable

Target for 2025:
1. Targeted comprehensive sampling establishes current status in Kakadu.
2. (If detected) a robust monitoring program is established.

Key management prescriptions:
Too little is known of the occurrence and ecology of this species in Kakadu to guide any management.
.

Key research needed to enhance management effectiveness:
1. Targeted survey to establish distribution, abundance, and habitat requirements.
2. Ecological study to assess relative impacts of threats, and to define management priorities.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Assessment of changes in area and condition of suitable habitat in lowland coastal and wetland areas.

Direct monitoring parameter(s)
To be determined if any population is located.

Is there an existing management standard operating plan or protocol?
No. However, a national Recovery Plan (DERM 2010) provides broad management guidelines.

Is there an existing monitoring standard operating protocol?
No, although relevant protocols may be transferrable from monitoring in Queensland (DERM 2010).

Distribution
Total range As currently defined (but subject to possible taxonomic revision), the Water Mouse has a very discontinuous known distribution in coastal eastern Queensland and the Northern Territory (including Melville Island), and New Guinea.
Kakadu The only confirmed record from the Kakadu area is from 'the coastal plain and tidal section of the South Alligator' in 1903 (Parker 1973).
% Kakadu <5%.

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☒ floodplain
☒ marine and estuaries

Particular habitat requirements
The Water Mouse occurs in mangrove forests, freshwater swamps and floodplain saline grasslands (Woinarski *et al*. 2000).

Ecology
The Water Mouse is a nocturnal predator eating mainly marine and freshwater invertebrates, especially including crabs, pulmonates and molluscs. It forages entirely on the ground, and is an adept swimmer. It builds and shelters in either burrows or substantial earthen mounds. Habitat includes mangrove forests, near coastal freshwater swamps and saline grasslands (Redhead and McKean 1975; Magnusson *et al*. 1976; Woinarski *et al*. 2000).

Impacts of fire
How fire affects the species
Unknown. Fire is probably not a factor in core mangrove habitat, but may affect suitability in saline grasslands and wetlands.

Preferred fire regime
Unknown.

Impacts of feral animals
Unknown. Buffalo and pigs may reduce habitat quality; predation by feral cats may have some detrimental impacts.

Impacts of weeds
Unknown.

Impacts of other threatening processes
Disease Not known and not likely.
Climate change Sea level rise and consequential reductions in habitat suitability and area is considered to be a major threat in north-eastern Australia (Traill *et al*. 2011), but may be less detrimental in Kakadu area.
Exploitation Nil.

Estimate of population size in Kakadu
Not known; may be zero.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
No current monitoring

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Captive breeding may provide a useful insurance population, but at this stage no demonstrated need.

Feasibility of applying preferred management
Not known

Likelihood that such management may benefit other threatened species
Not known

Likelihood that such management may be detrimental to other threatened species
Not known

Key references
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Parker, S.A. (1973). An annotated checklist of the native land mammals of the Northern Territory. *Records of the South Australian Museum* **16**, 1-57.

Redhead, T.D., and McKean, J.L. (1975). A new record of the false water-rat, *Xeromys myoides*, from the Northern Territory of Australia. *Australian Mammalogy* **1**, 347-354.

Traill, L. W., Perhans, K., Lovelock, C. E., Prohaska, A., McFallan, S., Rhodes, J. R., and Wilson, K. A. (2011). Managing for change: wetland transitions under sea-level rise and outcomes for threatened species. *Diversity and Distributions* **17**, 1225-1233.

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PALE FIELD-RAT
Rattus tunneyi

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: Vulnerable

Target for 2025:
1. Abundance at least stabilised over 3 successive monitoring episodes.
2. Causes of decline well understood, and mechanisms to control causes implemented.

Key management prescriptions:
1. In at least some lowland areas with populations of this species, significantly reduce the abundance of feral cats to levels at which they have no significant impact.
2. In at least some lowland areas with populations of this species, significantly reduce fire frequency, extent and intensity to levels at which fire has no significant impact.
3. In at least some lowland areas with populations of this species, reduce abundance of feral pigs to levels at which they have no significant impact on the abundance of *Alloteropsis*.

Key research needed to enhance management effectiveness:
1. Assess relative impacts of threats (particularly feral cats).
2. Assess options for the feasible control of primary threats.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Abundance of key food plants (notably *Alloteropsis*)
2. Abundance of feral cats
3. Abundance of feral pigs
4. Fire history

Direct monitoring parameter(s) {and frequency}
1. Maintain existing fireplot monitoring (at 5 yr intervals).
2. Establish c. 20-50 additional monitoring sites with site selection designed to assess efficacy of management, with sites sampled annually.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
For fireplot monitoring, yes.

Distribution
Total range The Pale Field-rat has a broad range in northern Australia, but has disappeared from much of its former range in central and southern Australia.
Kakadu The Pale Field-rat was formerly abundant and widespread across lowland woodlands and Stone Country, but has patchily disappeared from many areas. Its current distribution is not well-defined.
% Kakadu <5%.

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☒ rivers, wetlands
☐ floodplain
☐ marine and estuaries

Particular habitat requirements
No known specific habitat requirements. Braithwaite and Griffiths (1996) noted a preference for riparian areas, but it occurs over a broad habitat range.

Ecology The Pale Field-rat is a terrestrial rodent, that feeds mostly on grass stems and seeds, but also consumes fungi and root material (Braithwaite and Griffiths 1996). It often occurs semi-colonially, with local high population density. It shelters mostly in shallow but complex and extensive burrow systems. Breeding is mostly in the wet season, but may occur throughout the year (Braithwaite and Griffiths 1996).

Impacts of fire
How fire affects the species Over the short term, fire may reduce shelter availability, increase risks of predation and reduce availability of food resources (seeds and grass stems). Over the longer term, fire regimes may modify habitat suitability through changes in understorey plant species composition and structure.

Preferred fire regime Not well established, but likely to be disadvantaged by high intensity fires (Legge *et al*. 2008), and by long periods (>10 years of fire exclusion (Woinarski *et al*. 2004). Preferred regime is probably patchy low intensity fires every 3-5 years.

Impacts of feral animals
1. Predation by feral cats may be the major cause of population decline.
2. Feral pigs preferentially dig up and destroy Cockatoo Grass *Alloteropsis semialata*, a staple food for Pale Field-rats (Braithwaite and Griffiths 1996).
3. High densities of feral cattle, buffalo and horses reduce cover and food availability, and trample and destroy burrows (Legge *et al*. 2011)

Impacts of weeds
Gamba grass and mission grasses fuel higher intensity fires that are likely to reduce habitat quality and food availability.

Impacts of other threatening processes
Disease Not known
Climate change Not known and not likely
Exploitation Not known and not likely

Estimate of population size in Kakadu
Not known.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☒ severely decreasing
☐ not known

Current monitoring programs
Currently sampled within existing fireplot sampling: the most recent reported sampling (for 2007-09) recorded it from 22 of 136 sampled plots (Woinarski *et al*. 2010.

Extent of current targeted management in Kakadu
No substantial existing targeted management for this species.

Options/needs for ex situ breeding and/or assisted re-introduction
No immediate priority, but option should be considered if population continues to decline.

Feasibility of applying preferred management
Low for broad-scale control of feral cats, but may increase for targeted intensive local-scale control.

Low for broad-scale control of feral pigs, but may increase for targeted intensive local-scale control.

Medium for broad-scale improvement in lowlands fire regime.

Likelihood that such management may benefit other threatened species
High – many threatened mammal (and possibly some bird and reptile species) would benefit from reduction in the abundance of feral cats; some would benefit from reduction in feral pigs; some would benefit from reduced fire frequency and extent.

Likelihood that such management may be detrimental to other threatened species
Nil

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Woinarski, J.C.Z., Burbidge, A.A., and Harrison, P. (2014). *The Action Plan for Australian mammals, 2012*. (CSIRO Publishing, Melbourne.)

DUGONG
Dugong dugon

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. Abundance at least stable over 3 successive monitoring episodes.

Key management prescriptions:
1. Maintain or enhance prescriptions on fish netting in Kakadu marine waters.

Key research needed to enhance management effectiveness:
1. Assess relative abundance, distribution and threats in Kakadu waters.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
1. Incidence of illegal fishing activities, and of bycatch in fisheries operations in Kakadu and nearby areas

Direct monitoring parameter(s) {and frequency}
1. Incidence of reporting (recorded by cyber-tracker or similar devices) in logged Parks marine activities.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range Dugongs have a very large and fragmented Indo-West Pacific range encompassing about 860 000 km^2 of shallow marine habitat across 128 000 km of coastline in 38-44 nations and territories (Marsh *et al*. 2011). Their range extends between about 26-27° north and south of the equator, and includes parts of East Africa, Red Sea and Gulf of Aden, Arabian/Persian Gulf, India and Sri Lanka, Andaman and Nicobar Island, East and South-east Asia and coastal islands and major archipelagos, Australia, and tropical and subtropical islands in the Western Pacific region east to Vanuatu (Marsh *et al*. 2002).
Kakadu The Dugong is 'regularly seen' in Kakadu's coastal waters (Morris 1996).
% Kakadu <1%.

Habitat
☐ Stone Country
☐ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☐ floodplain
☒ marine and estuaries

Particular habitat requirements
Dugongs are often associated with sea-grass beds.

Ecology Dugongs are entirely marine, herbivorous mammals. They feed primarily on seagrasses in shallow marine coastal waters less than 10 m deep and mostly above 3 m depth, but they are also known to eat algae, mangrove leaves and invertebrates (Marsh *et al*. 2011), and use estuaries (Lawler *et al*. 2002).

Relatively large numbers occur in wide shallow bays and mangrove channels, or in the lee of large inshore islands where substantial seagrass beds develop. Dugongs also occur in deeper water shelf habitats offshore, feeding on deepwater seagrass down to 33 m depth (Marsh *et al*. 2002).

Impacts of fire
How fire affects the species Nil
Preferred fire regime Not relevant

Impacts of feral animals
Nil

Impacts of weeds
Nil

Impacts of other threatening processes
Disease Not known
Climate change Impacts of climate change are not well resolved. More frequent or intense cyclones may lead to losses of seagrass habitat.
Exploitation There is substantial Indigenous take of dugongs in parts of range, which may

be unsustainable (Heinsohn *et al*. 2004), but little such take in Kakadu waters.

Estimate of population size in Kakadu
Not known, but probably <200 individuals.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
Nil.

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Nil

Feasibility of applying preferred management
Feasible to maintain exclusions of commercial fisheries and constraints on other fishing activity.

Likelihood that such management may benefit other threatened species
High. Such fisheries constraints will benefit coastal dolphins and threatened sharks and sawfish.

Likelihood that such management may be detrimental to other threatened species
Nil

Key references
Heinsohn, R., Lacey, R. C., Lindenmayer, D. B., Marsh, H., Kwan, D., and Lawler, I. R. (2004). Unsustainable harvest of dugongs in Torres Strait and Cape York (Australia) waters: two case studies using population viability analysis. *Animal Conservation* **7**, 1-9.

Lawler, I., Marsh, H., McDonald, B., and Stokes, T. (2002). Current state of knowledge: dugongs in the Great Barrier Reef. CRC Reef Research Centre, Townsville.

Marsh, H., Penrose, H., Eros, C., and Hugues, J. (2002). Dugong status report and action plans for countries and territories. Early warning and assessment reports. United Nations Environment Programme, Nairobi.

Marsh, H., O'Shea, T. J., and Reynolds J. E. (2011). 'Ecology and conservation of the Sirenia: dugongs and manatees.' (Cambridge University Press: Cambridge).

DINGO
Canis dingo

NOTE: A recent taxonomic study (Crowther *et al*. 2014) has proposed that the Dingo is an Australian endemic species *Canis dingo*, rather than a subspecies of the far more widespread *Canis lupus*.

Conservation status
AUSTRALIA: not listed
NORTHERN TERRITORY: not listed
IUCN Red List: Vulnerable

Target for 2025:
1. Abundance at least stable over 3 successive monitoring episodes.

Key management prescriptions:
No specific management prescriptions; but need to consider possible impacts on dingo of any proposed baiting programs (e.g. for feral cats or pigs).

Key research needed to enhance management effectiveness:
1. Assess abundance (and where possible, compare with previous information on abundance).
2. Assess genetic composition and risks associated with introgression with camp dogs.

Recommended monitoring to chart management effectiveness:
Indirect monitoring parameter(s)
Nil

Direct monitoring parameter(s) {and frequency}
1. Assess genetic 'purity' status, and compare with broader Australian sampling (e.g. Daniels and Corbett 2003; Stephens 2011), and monitor this at decadal scale.
2. (If any broad-scale baiting programs undertaken), monitor extent of impacts on dingoes.
3. Monitor incidence and impacts of disease.

Is there an existing management standard operating plan or protocol?
No

Is there an existing monitoring standard operating protocol?
No

Distribution
Total range Dingoes are widespread in mainland Australia, and occur also in Thailand and less so in Cambodia, China, India, Indonesia, Lao Peoples Democratic Republic, Malaysia, Myanmar, Papua New Guinea, Philippines and Vietnam (Corbett 1995, 2008)
Kakadu Dingoes are widespread and abundant across Kakadu.
% Kakadu <1%.

Habitat
☒ Stone Country
☒ lowland woodlands
☐ rainforest
☐ rivers, wetlands
☒ floodplain
☐ marine and estuaries

Particular habitat requirements
Nil.

Ecology
Dingoes are generalist predators. In Kakadu, they have a very broad diet, with dietary composition differing across habitats (e.g. Dingoes in floodplain areas consume a high proportion of waterfowl and Dusky Rats) (Corbett 1989).

Impacts of fire
How fire affects the species Extensive fire may make hunting more effective, but may also lead to long-term reduction in some prey species.
Preferred fire regime Not known

Impacts of feral animals
Across much of their Australian range, the genetic 'purity' of dingoes is degraded by introgression with wild dogs (originating since Euroepan settlement of Australia). Wild dogs may also spread disease.

Dingoes may take considerable numbers of some feral stock (as carrion or by direct kill). Feral cats may reduce some prey availability.

Impacts of weeds
Dense cover of some invasive pasture grasses may reduce hunting efficiency.

Impacts of other threatening processes
Disease Heartworm 'virtually eliminated dingoes at Kapalga … in the 1980s (Corbett 1995; Corbett *et al*. 2001).
Climate change Not known, but probable indirect impacts if sea-level rise reduces productivity of floodplain environments (particularly of waterfowl and dusky rats).
Exploitation Nil.

Estimate of population size in Kakadu
Not known, but probably >1000 individuals.

Population trends in Kakadu (post 2005)
☐ strongly increasing
☐ increasing
☐ stable
☐ decreasing
☐ severely decreasing
☒ not known

Current monitoring programs
This species is recorded, but with very low incidence, in fire plot monitoring: that program is not particularly applicable for this species.

Extent of current targeted management in Kakadu
Nil

Options/needs for ex situ breeding and/or assisted re-introduction
Nil

Feasibility of applying preferred management
No current management required.

Likelihood that such management may benefit other threatened species
Not applicable.

Likelihood that such management may be detrimental to other threatened species
Not applicable

Key references

Corbett, L.K. (1989). Assessing the diet of dingoes from feces: a comparison of 3 methods. *Journal of Wildlife Management* **53**, 343-346.

Corbett, L. K. (1995). 'The dingo in Australia and Asia.' (University of New South Wales Press: Sydney.)

Corbett, L. K. (2008). *Canis lupus* ssp. *dingo*. In 'IUCN red list of threatened species.' Version 2012.1. <www.iucnredlist.org>. Accessed 7 July 2012.

Corbett, L., Fleming, P., Harden, R., and Thomson, P. (2001). *Managing the impacts of dingoes and other wild dogs*. (Bureau of Rural Sciences, Canberra.)

Crowther, M.S., Fillios, M., Colman, N., and Letnic, M. (2014). An updated description of the Australian dingo (*Canis dingo* Meyer, 1793). *Journal of Zoology* **293**, 192-203.

Daniels M. J., and Corbett, L. (2003). Redefining introgressed protected mammals: when is a wildcat a wild cat and a dingo a wild dog? *Wildlife Research* **30**, 213-218.

Stephens, D. (2011). The molecular ecology of Australian wild dogs: hybridisation, gene flow and genetic structure at multiple geographic scales. Ph.D. Thesis, The University of Western Australia, Nedlands.

Appendix 2 - List of Data Deficient and Near Threatened species reported from Kakadu

This list includes those species found in Kakadu that are considered Near Threatened (NT) or Data Deficient (DD) or in the Northern Territory, uder the *Territory Parks and Wildlife Conservation Act*, and are not listed as threatened under the EPBC Act.

Common name	Scientific name	Status
Plants		
	Acacia amanda	NT
	Acacia armitii	DD
	Acacia proiantha	NT
	Acacia rigescens	NT
	Acacia sp. Dinner Creek	DD
	Acacia sp. Gimbat	DD
	Acacia sp. Jim Jim Falls	DD
	Acanthus ebracteatus subsp. *ebarbatus*	DD
	Amyema conspicua subsp. *obscurinervis*	DD
	Amyema sp. Alligator	DD
	Aphyllodium stylosanthoides	DD
	Arytera bifoliolata	NT
	Atalaya salicifolia	NT
	Austrodolichos errabundus var. *variabilis*	DD
	Avicennia integra	NT
	Boronia decumbens	DD
	Boronia grandisepala subsp. *acanthophida*	NT
	Boronia laxa	NT
	Boronia prolixa	NT
	Boronia rupicola	NT
	Boronia suberosa	NT
	Boronia verecunda	NT
	Boronia xanthastrum	NT
	Borya jabirabela	NT
	Bulbostylis densa	DD
	Bulbostylis sp. Koongarra	DD
	Bursaria incana	NT
	Butomopsis latifolia	DD
	Caesia setifera	DD
	Caldesia acanthocarpa	NT
	Calochilus caesius	DD
	Calochilus holtzei	DD
	Calochilus imperiosus	DD
	Calytrix inopinata	NT
	Calytrix rupestris	NT
	Calytrix surdiviperana	NT
	Cenchrus elymoides	DD

Common name	Scientific name	Status
	Centranthera tranquebarica	DD
	Centrolepis sp. carinate	DD
	Chamaecrista nomame var. *grandiflora*	DD
	Citrus gracilis	NT
	Cleome bundeica	DD
	Cleome tetrandra var. *pentata*	DD
	Cleome tetrandra var. *tetrandra*	DD
	Corchorus obclavatus	DD
	Crateva religiosa	DD
	Crepidium fontinale	DD
	Crotalaria quinquefolia	NT
	Cynanchum brachystelmoides	DD
	Cyperus cracens	DD
	Cyperus tenuiculmis	DD
	Dendrobium paludicola	DD
	Dentella arnhemensis	DD
	Desmodium rhytidophyllum	NT
	Dichapetalum timoriense	NT
	Digitaria benthamiana	DD
	Digitaria leucostachya	DD
	Dipteracanthus bracteatus	NT
	Dopatrium junceum	DD
	Drummondita calida	NT
	Dubouzetia australiensis	NT
	Ectrosia lasioclada	DD
	Emmenosperma cunninghamii	NT
	Eragrostis concinna	DD
	Eragrostis petraea	DD
	Eriachne axillaris	DD
	Eriachne pauciflora	DD
	Eriachne vesiculosa	DD
	Eriocaulon tricornum	DD
	Eucalyptus koolpinensis	NT
	Fatoua villosa	NT
	Fimbristylis bisumbellata	DD
	Fimbristylis dunlopii	DD
	Fimbristylis sp. Deaf Adder Gorge	DD
	Fimbristylis velata	DD
	Finlaysonia obovata	DD
	Gardenia jabiluka	DD
	Gleichenia dicarpa	NT
	Glinus sessiliflorus	DD
	Gonocarpus implexus	DD
	Goodenia elaiosoma	DD

Common name	Scientific name	Status
	Goodenia kakadu	DD
	Gossypium cunninghamii	NT
	Grevillea dunlopii	DD
	Habenaria elongata	DD
	Habenaria hymenophylla	DD
	Heliotropium arenitense	DD
	Heterostemma magnificum	NT
	Hibbertia auriculiflora subsp. *auriculiflora*	NT
	Hibbertia echiifolia subsp. *rotata*	DD
	Hibbertia extrorsa	NT
	Hibbertia fractiflexa subsp. *filicaulis*	DD
	Hibbertia guttata	NT
	Hibbertia incompta	DD
	Hibbertia incurvata	DD
	Hibbertia ligulata	DD
	Hibbertia marrawalina	DD
	Hibbertia solanifolia	NT
	Hibbertia sp. Mount Howship	NT
	Hibbertia tridentata	DD
	Hibiscus aneuthe	DD
	Hibiscus inimicus	NT
	Hibiscus riceae	DD
	Hibiscus symonii	NT
	Hildegardia australiensis	NT
	Histiopteris incisa	NT
	Indigofera adenotricha	DD
	Indigofera sp. Ja Ja	DD
	Indigofera sp. Marrawal	DD
	Isolepis sp. Nourlangie	DD
	Lemna tenera	DD
	Lindernia sp. Hann River	DD
	Lindernia sp. Narridj Creek	DD
	Lindernia sp. robust branched	DD
	Lindernia sp. Robyns showy anthers	DD
	Lindernia sp. small whitish corolla	DD
	Lindernia tectanthera	DD
	Lipocarpha chinensis	DD
	Micraira compacta	NT
	Micraira inserta	DD
	Micraira spinifera	DD
	Micraira viscidula	NT
	Microchloa indica	DD
	Microcorys elliptica	DD
	Microlepia speluncae	NT

Common name	Scientific name	Status
	Mitrasacme brachystemonea	DD
	Mitrasacme geniculosa	DD
	Mitrasacme troglodytica	DD
	Murdannia cryptantha	DD
	Najas pseudograminea	DD
	Neobyrnesia suberosa	NT
	Nephrolepis acutifolia	NT
	Nervilia crociformis	DD
	Nesaea striatiflora	DD
	Nymphoides planosperma	NT
	Nymphoides subacuta	NT
	Oldenlandia intonsa	DD
	Omegandra kanisii	NT
	Pachystoma pubescens	DD
	Pavetta speciosa	DD
	Pavetta tenella	DD
	Pentapetes phoenicea	NT
	Phoringopsis byrnesii	DD
	Phyllanthus cauticola	DD
	Pityrodia byrnesii	DD
	Plagiocarpus arnhemicus	DD
	Portulaca sp. Nitmiluk	DD
	Psychotria loniceroides	NT
	Ptilotus comatus	DD
	Ptilotus lophotrichus	DD
	Ptilotus rotundatus	DD
	Remusatia vivipara	DD
	Sarcostemma esculentum	DD
	Sauropus sp. Jabiru	DD
	Schizachyrium perplexum	DD
	Scleria biflora subsp. *biflora*	DD
	Scleria sp. Jabiru	NT
	Shonia territorialis	DD
	Solanum sejunctum	DD
	Sonneratia lanceolata	NT
	Sorghum grande	DD
	Spermacoce brevidens	DD
	Spermacoce cardiophora	DD
	Stylidium accedens	DD
	Stylidium divergens	DD
	Stylidium notabile	NT
	Stylidium prophyllum	DD
	Symplectrodia gracilis	DD
	Syzygium arenitense	DD

Common name	Scientific name	Status
	Syzygium forte subsp. *forte*	DD
	Tephrosia humifusa	NT
	Tephrosia sp. crows foot	DD
	Terminalia sp. Black Point	NT
	Ternstroemia cherryi	NT
	Thoracostachyum sumatranum	DD
	Tiliacora australiana	NT
	Trachymene umbratica	DD
	Tragia arnhemica	DD
	Triodia aristiglumis	DD
	Triodia contorta	NT
	Triodia radonensis	DD
	Triodia uniaristata	NT
	Trithuria cowieana	DD
	Typhonium russell-smithii	DD
	Utricularia cheiranthos	NT
	Utricularia foveolata	DD
	Utricularia hamiltonii	NT
	Utricularia holtzei	NT
	Utricularia rhododactylos	NT
	Utricularia subulata	NT
	Utricularia tubulata	DD
	Vallisneria triptera	NT
	Vigna vexillata var. *youngiana*	DD
	Viscum whitei subsp. *flexicaule*	DD
	Whiteochloa multiciliata	DD
	Xanthostemon sp. Obiri Rock	DD
	Ximenia americana	NT
	Zornia muriculata subsp. *muriculata*	DD
Invertebrates		
Freshwater snail	*Austropeplea lessoni*	DD[1]
Leichhardt's Grasshopper	*Petasida ephippigera*	NT
Monarch	*Danaus plexippus*	DD
Kakadu Fourbarred Swordtail	*Protographium leosthenes geimbia*	DD
Rock Grass-dart	*Taractrocera ilia ilia*	DD
Frogs		
Giant Frog	*Litoria australis*	DD
Northern Dwarf Tree-frog	*Litoria bicolor*	DD
Ornate Burrowing Frog	*Platyplectrum ornatus*	DD
Reptiles		
Pig-nosed Turtle	*Carettochelys insculpta*	NT
Sandstone Long-necked Turtle	*Chelodina burrungandjii*	DD
Arnhemland Ctenotus	*Ctenotus arnhemensis*	DD
Alligator Rivers Ctenotus	*Ctenotus kurnbudj*	DD

Common name	Scientific name	Status
Kakadu Ctenotus	*Ctenotus gagadju*	DD
Point Stuart Ctenotus	*Ctenotus stuarti*	DD
Common Blue-tongued Lizard	*Tiliqua scincoides*	DD
Chameleon Dragon	*Chelosania brunnea*	NT
Black-spotted Ridge-tailed Monitor	*Varanus baritji*	DD
Kimberley Rock Monitor	*Varanus glauerti*	DD
Long-tailed Rock Monitor	*Varanus glebopalma*	DD
Mangrove Monitor	*Varanus indicus*	NT
Northern Ridge-tailed Monitor	*Varanus primordius*	NT
Spotted Tree Monitor	*Varanus scalaris*	DD
Green Tree Snake	*Dendrelaphis punctulata*	DD
Olive Whip Snake	*Demansia olivacea*	DD
King Brown Snake	*Pseudechis australis*	NT
Taipan	*Oxyuranus scutellatus*	DD
Narrow-banded Northern Bandy-bandy	*Vermicella multifasciata*	DD
Birds		
Emu	*Dromaius novaehollandiae*	NT
Freckled Duck	*Stictonetta naevosa*	NT
Flock Bronzewing	*Phaps histrionica*	NT
Chestnut-quilled Rock-pigeon	*Petrophassa rufipennis*	NT
Banded Fruit-dove	*Ptilonopus cinctus*	NT
Great Frigatebird	*Fregata minor*	DD
Australian Little Bittern	*Ixobrychus dubius*	DD
Letter-winged Kite	*Elanus scriptus*	NT
Square-tailed Kite	*Lophoictinia isura*	NT
Baillon's Crake	*Porzana pusilla*	DD
Australian Spotted Crake	*Porzana fluminea*	DD
Spotless Crake	*Porzana tabuensis*	DD
Pale-vented Bush-hen	*Amaurornis moluccana*	NT
Australian Bustard	*Ardeotis australis*	NT
Bush Stone-curlew	*Burhinus grallarius*	NT
Grey Plover	*Pluvialis squatarola*	NT
Latham's Snipe	*Gallinago hardwickii*	DD
Pin-tailed Snipe	*Gallinago stenura*	DD
Swinhoe's Snipe	*Gallinago megala*	DD
Black-tailed Godwit	*Limosa limosa*	NT
Whimbrel	*Numenius phaeopus*	NT
Grey-tailed Tattler	*Tringa brevipes*	NT
Ruddy Turnstone	*Arenaria interpres*	NT
Pectoral Sandpiper	*Calidris melanotus*	DD
Chestnut-backed Button-quail	*Turnix castanotus*	DD
Hooded Parrot	*Psephotus dissimilis*	NT
Eastern Grass Owl	*Tyto longimembris*	NT
White-lined Honeyeater	*Meliphaga albilineata*	NT

Common name	Scientific name	Status
Buff-sided Robin	*Poecilodryas cerviniventris*	NT
Australian Reed-warbler	*Acrocephala australis*	NT
Star Finch	*Noechmia ruficauda*	NT
Yellow-rumped Mannikin	*Lonchura flaviprymna*	NT
Pictorella Mannikin	*Heteromunia pectoralis*	NT
Mammals		
Kakadu Dunnart	*Sminthopsis bindi*	DD
Red-cheekd Dunnart	*Sminthopsis viriginiae*	DD
Northern Brown Bandicoot	*Isoodon macrourus*	NT
Northern Brushtail Possum	*Trichosurus vulpecula arnhemensis*	NT
Spectacled Hare-wallaby	*Lagorchestes conspicillatus*	NT
Northern Nailtail Wallaby	*Onychogalea unguifera*	NT
Black Wallaroo	*Macropus bernardus*	DD
Ghost Bat	*Macroderma gigas*	NT
Orange Leaf-nosed Bat	*Rhinonicteris aurantia*	NT
Arnhem Sheath-tailed Bat	*Taphozous kapalgensis*	NT
Kakadu Pebble-mouse	*Pseudomys calabyi*	NT
Western Chestnut Mouse	*Pseudomys nanus*	NT
Dugong	*Dugong dugon*	NT
Australian Snubfin Dolphin	*Orcaella heinsohni*	DD
Indo-Pacific Humpback Dolphin	*Sousa chinensis*	DD

Notes: 1 Although classified as DD in the most recent (2012-13) review of the Northern Territory threatened species listing, Richard Willan (Northern Territory Museums and Art Galleries) notes (*pers. comm.*) that 'it is common in every billabong and pond throughout the coastal part of the Northern Territory'.

Appendix 3 - A listing of threatened species found in areas adjacent to Kakadu but not yet reported from Kakadu

Taxonomic group	Scientific name	Conservation status			Occurrence
		EPBC Act	TPWC Act	IUCN	
Plants					
	Boronia quadrilata	VU	VU		Magela Creek
	Boronia viridifilora	VU	VU		Nabarlek
	Cephalomanes obscurum		EN		Magela Creek
	Hibbertia sp. South Magela		VU		Magela Creek
	Toechima sp. East Alligator	EN	EN		E. Alligator gorge
Invertebrates					
	Leptopalaemon gudjangah			VU	near Oenpelli

Appendix 4 - Summary of existing conservation actions in Kakadu for threatened species

Kakadu National Park was established serially from 1979. Since that period – and indeed prior to that establishment – research, monitoring and management actions and programs have been designed and implemented to enhance the conservation of threatened species, and biodiversity generally, in Kakadu. There has never been a comprehensive review of these actions, or of their effectiveness, although an internal audit was conducted on the conservation outcomes of the most recent Plan of Management and reviews of threatened species management requirements and some activities were compiled in 2014 (Winderlich and Woinarski 2014). A recent assessment concluded that threatened species were, on average, faring better in Kakadu (and other nearby conservation reserves in the Top End of the Northern Territory) than in comparable lands of other tenure or land use in that region (Woinarski *et al.* 2013).

There has been a long history of biodiversity inventory in Kakadu, with a robust foundation established with the Alligator Rivers Region Environmental Fact-finding Study from 1972 to 1977 (e.g. Calaby (1973)), substantial surveys of terrestrial (particularly vertebrate) fauna by CSIRO and others from 1981 to 1990 (Braithwaite 1985; Woinarski and Braithwaite 1991), of aquatic fauna mostly by eriss (O'Connor *et al.* 1997b), plant surveys by numerous botanists (Brennan 1996; Cowie and Liddle 2014), and more recently some surveys of estuarine and marine animal groups (Larson 2002; Palmer 2011; Kyne 2014). Many surveys have focused specifically on threatened species, seeking to document their distribution and abundance in Kakadu (Kerrigan 2003; Armstrong 2004; Kerrigan 2004; Mahney *et al.* 2011; Kyne 2014).

In part this substantial survey effort reflects and is a response to the high species richness and very high rates of endemism in the Stone Country (Bruce 1993; Ingwersen 1995; Woinarski *et al.* 2006; Woinarski *et al.* 2009; Short *et al.* 2013). Nonetheless, some groups, particularly many invertebrate orders, are notably under-sampled, and the conservation status of species in these groups is largely unknown.

Some surveys and inventories have focused on the knowledge held by traditional owners (Press 1986; Winderlich and O'Dea 2014). A recent series of 'hotspot' surveys undertaken collaboratively by Parks staff, staff from the Northern Territory environment agency and traditional owners has sought to sample for particular threatened species and report on traditional knowledge of those species.

Many of these inventory studies have provided information relevant to the assessment of conservation status and of population trends for individual species, and hence have helped to justify threatened species categorisations. Historical accounts, notably the collecting expeditions in the area by Knut Dahl in the 1890s and J.T. Tunney in 1902-03 (Collett 1897; Dahl 1897; Thomas 1904; Dahl 1926), provide a valuable baseline, and marked differences in the abundance of some (mostly mammal) species between those early accounts and more recent sampling attest to severe decline (and probable extirpation) for some species at some period between those historical and recent sampling episodes. Decadal-scale changes in abundance for some mammal and plant species have also been documented from Indigenous knowledge (Russell-Smith *et al.* 1997; Ziembicki *et al.* 2013). Historical imagery has been used to record landscape-scale vegetation change, particularly of rainforest extent and of the abundance of some fire-sensitive tree species, most notably *Callitris intratropica* and *Allosyncarpia ternata* (Banfai and Bowman 2006; Bowman and Dingle 2006; Banfai and Bowman 2007). More recent changes in abundance have been documented based on comparison of results from successive periods of inventory and other studies, with a particularly acute description of decline in the mammal fauna in the Kakadu lowlands between studies in the late 1980s and repeat sampling in 1999 (Woinarski *et al.* 2001). A more substantial, specifically planned and systematic monitoring programs

was established in 1995 to document vegetation change associated with fire regimes (Edwards *et al.* 2003; Russell-Smith *et al.* 2009; Russell-Smith *et al.* 2014), with vertebrate fauna added to this sampling from 1996. This monitoring program has been instrumental in documenting trends for very many plant and animal species in Kakadu, and relating those trends to fire management. It has provided further corroboration of recent and severe decline for many mammal species (including threatened species) (Woinarski *et al.* 2010), but – because it was not established particularly to sample trends for threatened species – provides little or no information on trends for most other threatened species (Edwards *et al.* 2003; Woinarski *et al.* 2012), and is becoming less useful for even threatened mammal species as their numbers have declined to a point that the program now lacks statistical power to discern trends for them. More narrowly-focused monitoring programs have been established for some individual threatened species. The most notable of these has been a program that has monitored nesting activity for flatback turtles *Natator depressus* at Field Island, intermittently from about 1990 (Winderlich 1998; Schäuble *et al.* 2006). One other monitoring program established specifically to report on trends of the brush-tailed rabbit-rat *Conilurus penicillatus* at the site of its last known stronghold in Kakadu charted the apparent extirpation of this subpopulation (Firth 2010). Other monitoring programs have been established specifically for some highly localised threatened plant species, but most of these have not been subject to ongoing re-sampling (Kerrigan 2003, 2004; Cowie and Liddle 2014). There has been substantial biodiversity monitoring (particularly of aquatic animals) in Kakadu associated with assessments of the impacts of mining activities in the Kakadu area (O'Connor *et al.* 1997a), however this has not involved sampling of threatened species.

There has been much ecological research in Kakadu, with much of this research effort coordinated through the Kakadu Research Advisory Committee in an attempt to prioritise research to address perceived management needs. This research has included many studies on the ecology of many individual plant and animal species, including many threatened species, with particular focus on the response of species to fire (Begg *et al.* 1981; Friend 1985; Friend and Taylor 1985; Friend 1987; Russell-Smith *et al.* 1998; Russell-Smith *et al.* 2002; Andersen *et al.* 2003; Fraser *et al.* 2003; Russell-Smith 2006). This provides a robust foundation for fire management for many threatened species (Andersen *et al.* 2012). However, for many other threatened species, there is still very little knowledge of ecology or of their responses to fire and other threats, and hence little information available to guide management. With some exceptions (such as the impact upon northern quoll *Dasyurus hallucatus* of cane toads *Rhinella marina*), there has been little research in Kakadu on the response of threatened species to other threats, such as invasive grasses, predation by feral cats, or of other introduced animals, although such response can be inferred to some degree from more broadly-focused studies of these factors in Kakadu or elsewhere.

Information on threatened species in Kakadu has been compiled in several reviews (Roeger and Russell-Smith 1995; Woinarski 2004; Winderlich and Woinarski 2014), and recently in a 'ready reckoner' identification guide for rangers, TOs and tourists. There is no specific live consolidated database for distributional records of threatened species in Kakadu, although many records are collated in the Park's GIS database; nor is there an integrated monitoring database, although a database for the fireplot monitoring program is maintained jointly with the relevant Northern Territory agency.

There have been some specific management actions in Kakadu directed towards individual threatened species and much more management action and programs directed at biodiversity conservation more generally. The bulk of this activity has involved the management of fire, some feral animals and some weeds.

The active management of fire in Kakadu comprises much of the resource investment of staff time, and also involves substantial inputs from Kakadu's traditional owners. Fire is managed in Kakadu for diverse purposes – including asset protection, cultural reasons and conservation – and with varying levels of success in meeting multiple and potentially divergent objectives (Atkins and Winderlich 2010). Concern about declining trends for many Stone Country plants, including threatened plant

species, was instrumental in developing and implementing a Stone Country fire strategy that sought to reduce the incidence and extent of late dry season fires, and (thereby) increase the fire-free interval at sites known to be important for some fire-sensitive threatened plant species and a smaller number of fire-sensitive threatened animal species (e.g. white-throated grass-wren *Amytornis woodwardi* (Petty *et al.* 2007). This program has largely been successful in meeting those objectives in most years (Murphy 2013; Edwards and Russell-Smith 2014). As yet, there is no comparable strategic program, that focuses substantially on the requirements of threatened species, for fire management in the lowlands. Nonetheless, current fire management in the lowlands probably provides some benefit for some threatened species by reducing the incidence of extensive late dry season fires, and in protecting some rainforest patches. However, under the current fire regime, the extent of longer-unburnt habitat (required or favoured by some threatened species) in the lowlands is very small and becoming smaller, and the patchiness of fires is probably coarser than that preferred by some other threatened species (i.e. larger patches of burnt and of unburnt areas than ideal).

Sustained programs for the management of weeds in Kakadu have provided some notable conservation outcomes (Winderlich 2010). Some weed management activities, notably the control of gamba grass *Andropogon gayanus*, provide direct benefits to biodiversity generally, but also provide more substantial indirect benefits by serving to reduce the risks of increasingly detrimental fire regimes. Substantial and sustained investments in control of mimosa *Mimosa pigra* have also resulted in substantial environmental benefits, in maintaining the structure, integrity and diversity of floodplain environments generally. Other weed management activities have eliminated local incursions of some potentially high impact weeds, and contained or reduced the abundance of other more entrenched weeds. Although these weed management actions typically are not designed specifically to benefit threatened species, they do provide substantial benefits to biodiversity generally and at least some threatened species would likely to be detrimentally affected by these weeds if not managed.

There has been a long history in Kakadu of management of some pest species in order to reduce their environmental impacts (Jambrecina 2010). Probably the most notable of the management benefits has been in the sustained reduction in numbers of water buffalo *Bubalus bubalis*, particularly in floodplain areas where their previous impacts had been devastating (Skeat *et al.* 1996). There is substantial management investment in the ongoing periodic control of buffalo, and feral pig *Sus scrofa*, cattle *Bos* spp., horse *Equus caballus* and donkey *E. asinus*, with these programs designed mostly to reduce the general environmental detriment produced by these feral species. Many threatened species may benefit from this management, but the programs are typically not generally designed specifically for the benefit of any particular threatened species, and there has been no monitoring of the response of any threatened species to management activities directed at the control of these feral animals.

Although large feral mammals have occupied much of the attention of management in Kakadu, there are many other pest species. One exceptional management action was the eradication from Kakadu of an infestation of the introduced big-headed ants *Pheidole megacephala*, a species which potentially could have caused substantial detriment to some native fauna, possibly including some threatened species (Hoffmann and O'Connor 2004). Another recent management project sought to locate infestations of the introduced black rat *Rattus rattus*, and investigate whether this species was acting as a vector for novel diseases that may spread to and have detrimental impact upon native mammals, particularly threatened species (Jackson *et al.* 2010). Two other pest species, feral cats *Felis catus* and cane toad *Rhinella marina*, with demonstrable detrimental impacts upon threatened species, have generally not been the subject of sustained management programs in Kakadu, on the basis that there are currently no cost-effective control options. However, two notable management responses, that seek to ameliorate their impacts upon threatened species, have been established recently. Two 800 m x 800 m cat-exclosures were established in a lowland area in Kakadu in November 2013, with the objective of documenting the impacts upon native mammals of cat predation, and seeking to establish whether exclosures could be used to increase the population size of some threatened mammal species. Another manipulative management action has involved the aversion training and experimental

reintroduction of northern quolls *Dasyurus hallucatus*, a threatened species particularly affected by cane toads. Early results from this project indicate some potential for seeding the recovery, from recent near-extirpation, of this species in Kakadu (O'Donnell *et al.* 2010). Some northern quolls from Kakadu were also used in a translocation project to toad-free islands off north-eastern Arnhem Land, providing some insurance population over the course of the mainland crash of this species arising from the spread of toads (Rankmore *et al.* 2008).

Some *ex situ* conservation, including the maintenance of seed collections, has also been initiated for a small number of Kakadu's threatened plant species (Cowie and Liddle 2014). A current proposal to establish a captive breeding population of the threatened Oenpelli python *Morelia oenpelliensis* may also have some conservation benefit.

Much of Kakadu's management allocation involves tourism. Some information on threatened species in Kakadu is included in interpretational material, and some constraints on tourism access may have some benefit to some threatened species. Regulation of fishing activities (particularly some closures of river stretches) in Kakadu provides some benefit to a set of threatened fish species.

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Appendix 5 - Values attributed to Kakadu threatened species

Species are arranged in order of decreasing total value, with total value being the sum of values for threatened score, taxonomic distinctiveness, cultural value, ecological value and the significance of Kakadu to the species (i.e. proportion of total range or population occurring in Kakadu).

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Allosyncarpia ternata				0	3	3	3	4	13.0
Northern River Shark	EN	EN	CR	3	2	1	2	4	12.0
Dwarf Sawfish	VU	VU	EN	2	2	2	2	3	11.0
Speartooth Shark	CR	VU	EN	3	2	1	2	3	11.0
Partridge Pigeon	VU	VU	VU	2	2	3	1	3	11.0
Oenpelli Python		VU		1	1	3	2	4	11.0
Magpie Goose				0	3	3	3	2	11.0
Arnhem Land Skink	EN	VU		2.5	3	1	0	4	10.5
Emu		NT		0.5	3	3	3	1	10.5
Flatback Turtle	VU	NT		1.5	3	3	1	2	10.5
Pig-nosed Turtle		NT	VU	0.5	3	3	1	3	10.5
Loggerhead Turtle	EN	VU	EN	2.5	3	3	1	1	10.5
Olive Ridley	EN	NT	VU	2	3	3	1	1	10.0
Hawksbill Turtle	VU	VU	CR	2	3	3	1	1	10.0
Brush-tailed Rabbit-rat	VU	EN		2.5	2	1	1	3	9.5
Northern Brush-tailed Phascogale	VU	EN	VU	2.5	2	1	1	3	9.5
Leichhardt's Grasshopper		NT		0.5	3	3	0	3	9.5
Largetooth Sawfish	VU	VU	CR	2	2	2	2	1	9.0
Arnhem Rock-rat	VU	VU		2	2	0	1	4	9.0
Acacia equisetifolia	CR	CR		4	0	0	0	5	9.0
Green Turtle	VU		EN	1	3	3	1	1	9.0
Northern Quoll	EN	CR	EN	3.5	1	1	2	1	8.5
Plains Death Adder	EN	VU		2.5	1	1	1	3	8.5
Ghost Bat		NT	VU	0.5	3	2	1	2	8.5
Narrow Sawfish		NT	EN	0.5	3	2	2	1	8.5
Dugong		NT	VU	0.5	3	3	1	1	8.5
Australian Bustard		NT		0.5	2	3	2	1	8.5
Neobyrnesia suberosa		NT		0.5	3	0	1	4	8.5

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Golden-backed Tree-rat	VU	CR		3	2	1	1	1	8.0
Yellow Chat (Alligator R.)	EN	EN		3	1	0	0	4	8.0
Black Wallaroo				0	0	3	1	4	8.0
Echidna				0	3	2	2	1	8.0
Hibiscus brennanii	VU	VU		2	0	0	1	5	8.0
Arafura File Snake				0	2	3	1	2	8.0
Barramundi				0	1	3	3	1	8.0
Golden Bandicoot	VU	EN	VU	2.5	2	1	1	1	7.5
Gouldian Finch	EN	VU		2.5	2	1	0	2	7.5
Northern Brushtail Possum		NT		0.5	2	2	1	2	7.5
Chestnut-quilled Rock-pigeon		NT		0.5	2	1	0	4	7.5
Nymphoides planosperma		NT		0.5	0	1	1	5	7.5
Black-footed Tree-rat		VU		1	2	1	1	2	7.0
Smooth Kakadu-shrimp			CR	0	2	0	0	5	7.0
Mitchell's Water Monitor		VU		1	0	2	2	2	7.0
Yellow-spotted Monitor		VU		1	0	2	2	2	7.0
Merten's Water Monitor		VU		1	0	2	2	2	7.0
Humped Kakadu-shrimp			VU	0	2	0	0	5	7.0
Magela Shrimp			VU	0	2	0	0	5	7.0
Monochoria hastata		VU		1	2	1	1	2	7.0
Frillneck lizard				0	3	2	1	1	7.0
Masked Owl (northern)	VU	VU		2	1	1	1	2	7.0
Rock Narrow-wing			VU	0	3	0	0	4	7.0
Freycinetia excelsa		VU		1	2	1	1	2	7.0
Red Goshawk	VU	VU		2	2	1	1	1	7.0
Freshwater Crocodile				0	0	3	3	1	7.0
Callitris intratropica				0	1	3	2	1	7.0
Saltwater Crocodile				0	0	3	3	1	7.0

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Dingo			VU	0	0	3	3	1	7.0
Water Mouse	VU	NT	VU	1.5	3	0	1	1	6.5
Spectacled Hare-wallaby		NT		0.5	2	2	1	1	6.5
Yellow-snouted Gecko	EN	VU		2.5	0	0	0	4	6.5
Northern Brown Bandicoot		NT		0.5	2	2	1	1	6.5
Northern Nailtail Wallaby		NT		0.5	2	2	1	1	6.5
Orange Leaf-nosed Bat		NT		0.5	3	1	1	1	6.5
Bush Stone-curlew		NT		0.5	2	2	1	1	6.5
Eucalyptus koolpinensis		NT		0.5	0	0	1	5	6.5
Hildegardia australiensis		NT		0.5	0	1	1	4	6.5
Dienia montana		VU		1	2	1	0	2	6.0
Nabarlek		VU		1	0	2	1	2	6.0
Arnhem Leaf-nosed Bat		VU	VU	1	0	0	1	4	6.0
White-throated Grass-wren		VU	VU	1	0	1	0	4	6.0
Bar-tailed Godwit		VU		1	2	1	1	1	6.0
Hibbertia pancerea		VU		1	0	0	0	5	6.0
Hibbertia tricornis		VU		1	0	0	0	5	6.0
Jacksonia divisa		VU		1	0	0	0	5	6.0
Crested Shrike-tit (northern)	VU			1	2	0	1	2	6.0
Top End Dragon			VU	0	2	0	0	4	6.0
Antilopine Wallaroo				0	1	3	1	1	6.0
King Brown Snake		NT		0.5	1	1	2	1	5.5
Freckled Duck		NT		0.5	3	1	1	0	5.5
Fawn Antechinus		EN		1.5	0	0	1	3	5.5
Mangrove Monitor		NT		0.5	0	2	2	1	5.5
Melaleuca stipitata		NT		0.5	0	0	0	5	5.5
Australian Painted Snipe	EN	VU	EN	2.5	2	0	1	0	5.5
Calytrix inopinata		NT		0.5	0	0	0	5	5.5

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Banded Fruit-dove		NT		0.5	0	0	2	3	5.5
Hibbertia auriculiflora subsp. *auriculiflora*		NT		0.5	0	0	0	5	5.5
Hibbertia extrorsa		NT		0.5	0	0	0	5	5.5
Microlepia speluncae		NT		0.5	0	0	0	5	5.5
Boronia verecunda		NT		0.5	0	0	0	5	5.5
Omegandra kanisii		NT		0.5	3	0	0	2	5.5
Avicennia integra		NT	VU	0.5	1	0	1	3	5.5
Triodia uniaristata		NT		0.5	0	0	1	4	5.5
Boronia grandisepala subsp. *acanthophida*		NT		0.5	0	0	0	5	5.5
Emmenosperma cunninghamii		NT		0.5	2	0	1	2	5.5
Citrus gracilis		NT		0.5	0	1	1	3	5.5
Hibiscus symonii		NT		0.5	0	0	1	4	5.5
Stylidium notabile		NT		0.5	0	0	0	5	5.5
Micraira compacta		NT		0.5	0	1	0	4	5.5
Micraira viscidula		NT		0.5	0	1	0	4	5.5
Ximenia americana		NT		0.5	2	1	1	1	5.5
Bare-rumped Sheath-tailed Bat	EN	NT		2	1	0	1	1	5.0
Eastern Curlew		VU	VU	1	1	1	1	1	5.0
Hibbertia brennanii		VU		1	0	0	0	4	5.0
Hibbertia sp. South Magela		VU		1	0	0	0	4	5.0
Kakadu Vicetail			VU	0	1	0	0	4	5.0
Cycas armstrongii		VU	VU	1	0	2	1	1	5.0
Lithomyrtus linariifolia		VU		1	0	0	0	4	5.0
Northern Ridge-tailed Monitor		NT		0.5	0	1	1	2	4.5
Kakadu Pebble-Mouse		NT	VU	0.5	0	0	1	3	4.5

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Chameleon Dragon		NT		0.5	3	0	0	1	4.5
Whimbrel		NT		0.5	1	1	1	1	4.5
Black-tailed Godwit		NT		0.5	1	1	1	1	4.5
Ruddy Turnstone		NT		0.5	2	0	1	1	4.5
Eastern Grass Owl		NT		0.5	1	1	1	1	4.5
Arnhem Sheath-tailed Bat		NT		0.5	1	0	1	2	4.5
Hooded Parrot		NT		0.5	1	1	1	1	4.5
Square-tailed Kite		NT		0.5	2	1	1	0	4.5
Drummondita calida		NT		0.5	1	0	0	3	4.5
Calytrix rupestris		NT		0.5	0	0	0	4	4.5
Calytrix surdiviperana		NT		0.5	0	0	0	4	4.5
Vallisneria triptera		NT		0.5	1	0	1	2	4.5
Hibbertia solanifolia		NT		0.5	0	0	0	4	4.5
Boronia rupicola		NT		0.5	0	0	0	4	4.5
Boronia suberosa		NT		0.5	0	0	0	4	4.5
Hibiscus inimicus		NT		0.5	0	0	1	3	4.5
Triodia contorta		NT		0.5	0	0	1	3	4.5
Boronia laxa		NT		0.5	0	0	0	4	4.5
Acacia amanda		NT		0.5	0	0	0	4	4.5
Boronia xanthastrum		NT		0.5	0	0	0	4	4.5
Boronia prolixa		NT		0.5	0	0	0	4	4.5
Hibbertia sp. Mount Howship		NT		0.5	0	0	0	4	4.5
White-lined Honeyeater		NT		0.5	0	0	1	3	4.5
Scleria sp. Jabiru		NT		0.5	0	0	0	4	4.5
Utricularia cheiranthos		NT		0.5	0	0	0	4	4.5
Utricularia rhododactylos		NT		0.5	0	0	0	4	4.5
Tiliacora australiana		NT		0.5	0	1	1	2	4.5
Acacia proiantha		NT		0.5	0	0	0	4	4.5

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Sauropus filicinus		NT		0.5	0	0	0	4	4.5
Acacia rigescens		NT		0.5	0	0	0	4	4.5
Northern Hopping-mouse	VU	VU	EN	2	0	0	1	1	4.0
Northern Leaf-nosed Bat		VU		1	0	0	1	2	4.0
Common Blue-tongued Lizard				0	2	1	0	1	4.0
Centralian Blue-tongued Lizard				0	2	1	0	1	4.0
Asian Dowitcher		VU		1	2	0	1	0	4.0
Pale-vented Bush-hen		NT		0.5	2	0	1	0	3.5
Pictorella Mannikin		NT		0.5	3	0	0	0	3.5
Grey-tailed Tattler		NT		0.5	1	0	1	1	3.5
Hibbertia guttata		NT		0.5	0	0	0	3	3.5
Caldesia acanthocarpa		NT		0.5	2	0	0	1	3.5
Nymphoides subacuta		NT		0.5	0	1	1	1	3.5
Terminalia sp. Black Point		NT		0.5	0	0	0	3	3.5
Arytera bifoliolata		NT		0.5	0	0	0	3	3.5
Gossypium cunninghamii		NT		0.5	0	1	0	2	3.5
Dubouzetia australiensis		NT		0.5	0	0	0	3	3.5
Borya jabirabela		NT		0.5	0	0	0	3	3.5
Buff-sided Robin		NT		0.5	2	0	0	1	3.5
Utricularia hamiltonii		NT		0.5	0	0	0	3	3.5
Utricularia holtzei		NT		0.5	0	0	0	3	3.5
Tephrosia humifusa		NT		0.5	0	0	0	3	3.5
Dipteracanthus bracteatus		NT		0.5	0	0	1	2	3.5
Pale Field-rat		VU		1	0	0	1	1	3.0
Bolbitis quoyana		VU		1	0	0	0	2	3.0
Utricularia dunstaniae		VU		1	0	0	0	2	3.0

Species	EPBCA	TPWCA	IUCN	Threatened score	Taxonomic distinct.	Cultural value	Ecological value	Kakadu significance	Sum value
Greater Sand Plover (Mongolian)		VU		1	0	0	1	1	3.0
Lesser Sand Plover		VU		1	0	0	1	1	3.0
Red Knot		VU		1	0	0	1	1	3.0
Great Knot		VU	VU	1	0	0	1	1	3.0
Curlew Sandpiper		VU		1	0	0	1	1	3.0
Western Chestnut Mouse		NT		0.5	0	0	1	1	2.5
Letter-winged Kite		NT		0.5	1	0	1	0	2.5
Australian Reed-warbler		NT		0.5	1	0	0	1	2.5
Grey Plover		NT		0.5	0	0	1	1	2.5
Heterostemma magnificum		NT		0.5	0	0	0	2	2.5
Sonneratia lanceolata		NT		0.5	0	0	1	1	2.5
Psychotria loniceroides		NT		0.5	0	0	1	1	2.5
Atalaya salicifolia		NT		0.5	0	0	0	2	2.5
Utricularia subulata		NT		0.5	0	0	0	2	2.5
Fatoua villosa		NT		0.5	1	0	0	1	2.5
Ternstroemia cherryi		NT		0.5	0	0	1	1	2.5
Grey Falcon		VU	VU	1	0	0	1	0	2.0
Flock Bronzewing		NT		0.5	1	0	0	0	1.5
Yellow-rumped Mannikin		NT		0.5	1	0	0	0	1.5
Star Finch		NT		0.5	1	0	0	0	1.5
Gleichenia dicarpa		NT		0.5	0	0	0	1	1.5
Bursaria incana		NT		0.5	0	0	0	1	1.5
Pentapetes phoenicea		NT		0.5	0	0	0	1	1.5
Dichapetalum timoriense		NT		0.5	0	0	0	1	1.5
Nephrolepis acutifolia		NT		0.5	0	0	0	1	1.5
Histiopteris incisa		NT		0.5	0	0	0	1	1.5
Crotalaria quinquefolia		NT		0.5	0	0	0	1	1.5
Desmodium rhytidophyllum		NT		0.5	0	0	0	1	1.5

Scoring systems for individual variables: **Threatened score** is the mean score from EPBCA and TPWCA conservation status, where 4=CR, 3=EN, 2=VU, 1=NT. **Taxonomic distinct.** Taxonomic distinctiveness, where 3=monospecific genus, 2=2-5 species in genus (or a subspecies of a species in a monospecific genus), 1=6-10 species in genus (or subspecies of a species in a genus with 2-5 species); 0=>10 species in genus. **Cultural value**: 3=important food or spiritual significance; 2=some food or spiritual significance; 1=little known cultural significance; 0=no known cultural value. **Ecological value**: 3=The species makes an essential contribution to ecosystem function and its removal may cause ecosystem collapse; 2=The species makes an important contribution to ecosystem function and its removal may have substantial consequences for other species; 1=minor impacts on other species; empty=no likely consequences of loss to any other species. **Kakadu significance**: 5=endemic to Kakadu; 4=30-99% of range or population in Kakadu; 3=10-30%; 2=5-10%, 1=<5%.

Appendix 6 - Threats to threatened species in Kakadu

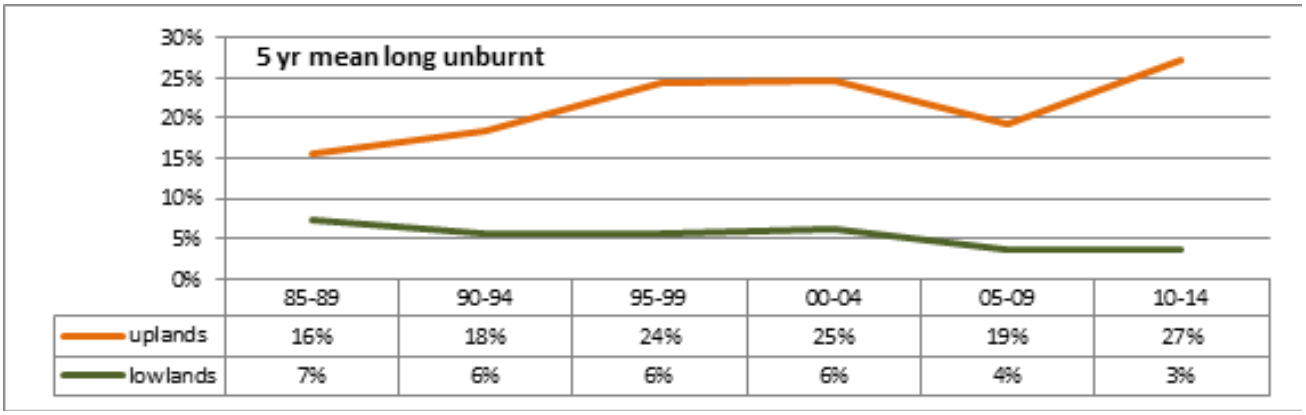
The many threatened species in diverse habitats of Kakadu are exposed to a range of threatening factors. In this section, the main threats are described briefly, along with, where available, some evidence of the impacts of those threats on threatened species.

Fire

Fire is the most complex of the threats affecting threatened species in Kakadu, because any fire regime affects individual threatened species differently, because fire interacts with other threats, because fire has short and longer-term impacts, and because fire is managed in Kakadu for many reasons in addition to the conservation of threatened species (Atkins and Winderlich 2010). For some threatened species, responses to fire (and preferred fire regime) are relatively well defined. Examples include: many heathland plant species of the Stone Country, which require fire-free intervals of at least 3-5 years in order to mature and set seed (Russell-Smith *et al.* 2002; Murphy 2013; Edwards and Russell-Smith 2014); the White-throated Grass-wren, which probably likewise prefers fire-free intervals of more than 3-5 years (Woinarski *et al.* 2009); the Partridge Pigeon, which prefers mixes of burnt and unburnt areas within its home range, and hence is favoured by a very fine-scale fire mosaic (Fraser *et al.* 2003); and several mammal species occurring in lowland woodlands that prefer habitat characteristics associated with longer-unburnt (e.g. >5 years) areas (Friend and Taylor 1985; Friend 1987). Furthermore, monitoring and modelling studies have demonstrated or projected severe decline of some threatened species under current fire regimes (Pardon *et al.* 2003; Firth 2010; Woinarski *et al.* 2010; Griffiths 2013). However, for other threatened species in Kakadu, a preferred fire regime, or extent of fire regime tolerance, is little known.

Fire interacts with many other threatening factors. In recent studies in the Kimberley, a far greater impact of cat predation upon native mammals has been reported from extensively burnt areas than from unburnt or very patchily burnt areas (Leahy 2013; McGregor *et al.* in press). Invasive grass species tend to increase the severity of fire regimes (Setterfield *et al.* 2010), and probably hence on some threatened species.

There is substantial investment in fire management in Kakadu. Based in large part on a strategic plan that considers the fire requirements of threatened and some other plant species (Petty *et al.* 2007), the fire regimes in the Stone Country are now more benign for these species (Murphy 2013; Edwards and Russell-Smith 2014). However, fire regimes in the lowland woodlands are largely unfavourable for those threatened species that prefer or require relatively long periods without fire, with only 3% of such woodlands now more than five years unburnt (Fig. A6.1). For this set of threatened species (including Common Brushtail Possum, Black-footed Tree-rat, Northern Brush-tailed Phascogale), there is a clear management priority to manage fire strategically to substantially increase the representation of longer unburnt woodlands (Friend and Taylor 1985; Kerle 1985; Friend 1987; Andersen *et al.* 2012).



	85-89	90-94	95-99	00-04	05-09	10-14
uplands	16%	18%	24%	25%	19%	27%
lowlands	7%	6%	6%	6%	4%	3%

Figure A6.1. (Percentage) of vegetation that is more than five years unburnt for the Stone Country (orange) and lowland woodlands (green). [from Edwards and Russell-Smith (2014)]

Predation by feral cats

Predation by feral cats is recognised to have been the principal cause of extinction of many Australian mammal species, and is considered to be the factor causing decline of more threatened mammal species than any other threat (Woinarski *et al.* 2014). It is likely to be also contributing to decline in some ground-dwelling bird species (e.g. Partridge Pigeon) and probably some terrestrial reptile species (e.g. Yellow-snouted Gecko), although there is no direct evidence relating to the extent of any such impact. The evidence for population-level impacts of cat predation upon Australian mammals is very substantial, with documented rapid decline of many native mammals on the mainland and islands soon after the arrival of feral cats; demonstration of recovery of some native mammals on islands from which cats have been exterminated; demonstration of recovery of native mammals from experimental and other studies where cats have been excluded (by fences) or effectively controlled (by baiting); dietary studies showing that feral cats have high rates of consumption of mammals; and radio-tracking studies that have shown that cat predation is a major cause of mortality for many native mammal species (Kutt 2011; Woinarski *et al.* 2011; Kutt 2012; Frank *et al.* in press; Leahy *et al.* in review).

Recent studies have demonstrated that cat impacts are especially severe in areas that are extensively burnt, because such areas provide little shelter and because they may offer few food resources for native mammals, such that they have to forage for longer or in more risky sites (Leahy 2013). Cat impacts may also be more pronounced in heavily grazed sites, because these may also offer less shelter from predators (McGregor *et al.* in press). It may also be more substantial in areas in which wild dogs (or dingoes) are controlled, although the evidence for this interaction in northern Australia is limited.

Threatened species likely to be particularly affected by feral cats in Kakadu include Brush-tailed Rabbit-rat, Pale Field-rat, Black-footed Tree-rat, Northern Brush-tailed Phascogale, Nabarlek, Common Brushtailed Possum, Partridge Pigeon and Yellow-snouted Gecko. The abundance of feral cats in Kakadu is not known, although current research is considering this (Woinarski and Ward 2010). There is no current management of feral cats in Kakadu, however an experimental cat-proof exclosure has recently been established.

Predation by wild dogs/dingoes

Dingoes and wild dogs prey on a range of threatened species, although the population-level impact of such predation is poorly known. In Kakadu, dingoes have been reported to eat at least two threatened species, Common Brushtail Possum and Northern Quoll (Corbett 1989), and several studies have indicated that they may be a significant cause of mortality for Northern Quoll (Oakwood 2000; Webb *et al.* 2012).

There is no current management of dingoes/wild dogs in Kakadu. As noted above (for predation by feral cats), any management of dingoes may need to consider their interactions with feral cats.

Poisoning by Cane Toads

The spread of the Cane Toad across northern Australia, including through Kakadu, has been accompanied by severe decline of many predator species that are susceptible to its poison. The most dramatic of these declines has been for the Northern Quoll, but severe declines have also been reported for most monitor (goanna) species, some other lizard species (including blue-tongued lizards *Tiliqua* spp. and Frilled Lizard) and some snakes. Many of these species were formerly common in Kakadu but are now close to extirpated. It is likely, but not certain, that at least some of these species may eventually recover, as toad-avoiding individuals may persist and re-populate, and especially so if toad numbers decline. It is unlikely that any effective management response to control toads can be implemented in the short-term, however there has been some preliminary success with training one toad-susceptible species, the Northern Quoll, to avoid toads.

The deconstruction, due to toads, of the previous predator regime due to toads may have led to indirect impacts on many other threatened species. For example, it is possible that reduction in the abundance of goannas and some snakes may have led to increase in the abundance of cats and hence greater overall predation pressure on some native species. Conversely, decrease in the abundance of goannas, due to toads, may have led to increased nesting success for the Flatback and Pig-nosed Turtles.

Competition with, or predation by, Cane Toads

There is little information available on the impacts in Kakadu of predation by or competition with Cane Toads. Most native frogs appear to have remained relatively abundant, although the extent of monitoring has been limited. Concern about potential impacts of Cane Toad predation led to the listing as threatened by IUCN of three Kakadu endemic or near-endemic shrimp species (De Grave 2013a, 2013b, 2013c), but the actual extent of impact has not been reported. Many components of the invertebrate fauna of Kakadu are very poorly known, and major declines in some species may have occurred without record.

Competition with, or predation by, Black Rats

Black Rats have been linked directly to the extinction and decline of many island plant and animal species, world-wide (Thibault *et al.* 2002; Towns *et al.* 2006; Meyer and Butaud 2009), however their impacts on continental biodiversity are less well resolved. There is some evidence of a recent increase in the abundance and distribution of Black Rats across the Top End, even in areas remote from human infrastructure. Their distribution, population trends and impacts in Kakadu are poorly known, but they are locally abundant at some sites (for example, Black Jungle Springs) (Woinarski and Ward 2010).

Habitat degradation due to feral herbivores

Feral buffalo, cattle, horses and donkeys occur in Kakadu, and where and when abundant, these may cause considerable environmental degradation (Bradshaw *et al.* 2007). The most notable impacts include broad-scale disturbance of floodplains and of lowland and Stone Country springs and seeps by buffalo, with floodplain damage contributing to saltwater intrusion (Skeat *et al.* 1996). Such degradation is likely to reduce habitat suitability for some floodplain threatened species, including the plant *Monocharia hastata*, Yellow Chat and Water Mouse, and if sustained may lead to other floodplain species becoming threatened. Where degradation leads to increased erosion and siltation, this may also affect habitat quality for some aquatic species, such as Pig-nosed Turtles and sawfish species.

These feral herbivore species are subject to ongoing periodic control in some parts of Kakadu (Jambrecina 2010).

Feral pigs

At high densities, feral pigs cause habitat degradation in wetlands and rainforest environments through soil disturbance. But feral pigs also have more specific impacts on threatened species, through consumption of eggs (with impacts particularly severe for marine turtles, but probably also for Pig-nosed Turtle and some goanna species) and of the fruits, bulbs or corms of some threatened plant species (probably such as the orchid *Dienia montana*). Studies in Arnhem Land have indicated that pig predation on aestivating turtles and their eggs lead to severe impacts on local population viability of some freshwater turtle species, and such species may become threatened with ongoing levels of predation by pigs (Fordham *et al.* 2006; Fordham *et al.* 2008).

Feral pigs are absent from Field Island, and this absence is probably an important factor in the breeding success of Flatback Turtles there. As for feral herbivores, there is some episodic control of pigs in some parts of Kakadu (Jambrecina 2010).

Disease, parasites and pathogens

With notable exceptions such as the Devil Facial Tumour, the role of disease, if any, in the decline and extinction of Australian biodiversity is very poorly resolved. There is some strong circumstantial evidence of historical decline of many mammal species following the undocumented introduction of an unspecified disease in Western Australia in the late nineteenth century (Abbott 2006), but there is no comparable record from the Top End.

A novel disease, trypanosomosis, spread by Black Rats is known to have caused the extinction of two endemic rodent species on Christmas Island (Wyatt *et al.* 2008). However, a recent assessment of the disease status of Black Rats in Kakadu and around Darwin revealed no diseases of particular concern to native wildlife (Jackson *et al.* 2010). Toxoplasmosis, possibly spread by feral cats, may be implicated in the decline of some native Australian mammals, although the evidence may be contested or not definitive (Fancourt and Jackson 2014): a limited sample of Northern Quolls in Kakadu found little or no incidence of toxoplasmosis (Oakwood and Pritchard 1999). The population of Dingoes in Kapalga was 'virtually eliminated' in the 1980s due to heartworm (Corbett 1995).

To date, there has been no record of pathogens in plants in Kakadu, although it is likely that myrtle rust may spread to the Top End, and Kakadu, within the next 20 years, and may have detrimental impacts upon at least some of the many species (including many Kakadu-endemic species) in the family Myrtaceae.

Weeds

As with most areas in the Top End, Kakadu hosts a large number of weed species (Cowie and Werner 1993; Winderlich 2010a). Some of these may have direct impacts upon threatened species, and some are known to have significant detrimental indirect impacts. Weed species that occur at very high densities and biomass (such as some invasive pasture grasses and *Mimosa pigra*) transform habitat structure and may reduce habitat suitability for some threatened species. For example, high densities of invasive pasture grasses in woodlands probably constrain the movement of medium-sized mammal species (such as Common Brushtail Possum) and perhaps reduce foraging efficiency for Partridge Pigeons, and some aquatic weeds, at dense cover, may outcompete the threatened wetland plant *Monocharia hastata*. If left unmanaged, some weed species (such as Gamba Grass or *Mimosa pigra*) are likely to lead to broad-scale habitat transformation, and reduction in soil fertility (Rossiter-Rachor *et al.* 2009), and such changes may well cause some currently unlisted native species to become threatened.

However, the most severe current and potential impact of weeds on threatened species is indirect, and operates through their capability to exacerbate fire severity. This is the case particularly for Gamba Grass and mission grasses in lowland woodlands (Rossiter *et al.* 2003; Setterfield *et al.* 2010; Setterfield *et al.* 2013), and regimes of more intense, frequent and extensive fire, due to invasive grasses, detrimentally affect very many woodland threatened species.

Kakadu managers have invested substantially in weed management, with particularly notable control of *Mimosa pigra* and Gamba Grass, and more localised success with some other weed species (Winderlich 2010a).

Climate change (including saltwater intrusion)

Likely climate changes in Kakadu over the next few decades are not well resolved. The most substantial risk to biodiversity generally and threatened species specifically associated with climate change is for sea level rise leading to increased saltwater intrusion on lowland aquatic systems, especially floodplain environments (Winderlich 2010b). Such change is likely to reduce habitat suitability for the threatened aquatic plant *Monocharia hastata*, and may have detrimental impacts on other lowland species including Yellow Chat and Water Mouse, and possibly also on many shorebirds. Such substantial habitat change may also cause many currently non-threatened species to become threatened.

Projected changes in temperature and rainfall have also been modelled to have catastrophic impacts within a few decades for some threatened species. Of eight mammal species recorded from Kakadu considered in modelling for impacts of climate change, the distribution of Brush-tailed Rabbit-rat, Black Wallaroo, Northern Brush-tailed Phascogale and Arnhem Rock-rat was predicted to decline by 90% by 2030, that of Tropical Short-tailed Mouse, Black-footed Tree-rat, by 60%, Common Planigale by 30% and Pale Field-rat by 20% (Kutt *et al.* 2009).

Changes in atmospheric CO_2, associated with, and driving, climate change have been considered to be contributing to changes in the relative extent of some habitat types (possibly including expansion of some rainforests) in Kakadu and elsewhere in northern Australia (Banfai and Bowman 2006; Bowman and Dingle 2006; Bowman *et al.* 2010), but it is not clear that any such changes will have a direct impact on any threatened species.

Climate change may have some impacts on a set of reptile species with eggs that have temperature-dependent sex determination, such as marine turtles and the Pig-nosed Turtle, but the rate of this change, and the extent to which it can be moderated by maternal behavioural flexibility, are unresolved.

Climate change is also likely to lead to changes in the fire regime, with likely increase in fire extent and severity, although the magnitude of this impact is not yet well resolved (Williams *et al.* 2009).

Harvest, fishing

All threatened species in Kakadu are protected from commercial or recreational take. However, some threatened fish species are captured incidentally or through identification error in some Kakadu waters by recreational fishers (Kyne 2014). There is some traditional harvest of a small number of threatened species (such as Pig-nosed Turtle and Flatback Turtle, and some goanna species) but the extent and sustainability of such harvest is little documented (Kyne 2014).

Pollution

There are some localised sites in Kakadu that have been exposed to contamination from historical mining activities, and some ongoing risks of pollution associated with current mining. The threatened species most at risk from such pollution are bats that roost in abandoned mines, however these impacts are likely to be very minor (Palmer and Churchill 2000).

As elsewhere in marine environments, the coastal waters of Kakadu have some marine debris, including abandoned fisheries netting, and these may have some minor impacts on coastal threatened species.

Disturbance, tourism

Kakadu is a very large reserve, and most disturbance impacts are likely to be small and diluted relative to the range of most threatened species. However, some threatened species have very restricted ranges and any impacts in these areas may have substantial consequences. The most acute of these cases may be for colonial bat species that roost (and breed) in caves and abandoned mines. Some of these bat species, such as the Ghost Bat, are known to be highly susceptible to disturbance, with even few visits leading to site abandonment or decline in colony size (Woinarski *et al.* 2014). To some extent, this threat can be managed effectively by controls on visitation, including through the careful use of gating.

Distant factors

For some migratory (or other highly dispersive) threatened species occurring in Kakadu, decline is occurring not because of any factors operating in Kakadu but rather because of threats occurring elsewhere in their range. This the case particularly for migratory shorebirds (declining due to loss of habitat mostly in eastern Asia), marine turtles and some river sharks and sawfish (potentially declining due to targeted fishing or bycatch, or marine pollution, or other factors operating beyond Kakadu waters). For these species, broad-based collaborative conservation strategies are required.

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Appendix 7 - Key Threatening Processes listed under the EPBC Act

This table lists Key Threatening Processes that occur, or may occur, in Kakadu, along with major actions listed for them in their Threat Abatement Plans (TAP). Note that only relevant actions are included here, and that (for simplicity) some wording is abridged and modified.

Key Threatening Process	Threat Abatement Plan	Relevant actions
Infection of amphibians with chytrid fungus resulting in chytridiomycosis	Department of the Environment and Heritage (2006)	1.1.1. Regularly report on incidence
		1.1.2. Undertake coordinated national survey using standard sampling and diagnosis protocols
		1.1.3. Prepare risk-based analysis and response if detection reported in areas currently chytrid-free
		1.1.4. In the Northern Territory, develop and implement strategies to prevent accidental introduction
		1.3.3. Subject any amphibians that are accidentally translocated in agricultural produce or nursery material into chytridiomycosis-free areas to quarantine and/or destruction
		1.4.1. Use existing state protocols for quarantine and handling amphibians
		1.4.2. Implement field hygiene protocols that aim to prevent transmission
		1.4.3. Ensure licences and permits for wildlife or flora studies ... include conditions that require the use of appropriate disinfection strategies
		4.1.2. Educate the community to ensure support for, and compliance with, existing legislation and regulations
Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris	Department of the Environment Water Heritage and the Arts (2009)	1.2 State, territory and Australian governments and appropriate local bodies facilitate studies of boating hubs for the disposal of fishing gear
		2.1. Develop nationally consistent survey methods for reporting and mapping marine debris
		2.2. Support community groups involved in clean-up and monitoring
		2.3. Establish a national network of permanent monitoring sites
		3.1. Monitor and report on incidence of marine life affected by debris
		3.2. Implement marine turtle recovery plan actions relating to marine debris

Key Threatening Process	Threat Abatement Plan	Relevant actions
Invasion of northern Australia by Gamba Grass and other introduced grasses	Department of Sustainability Environment Water Population and Communities (2012)	1.1. Map the five listed grasses at a scale that allows for appropriate planning
		1.2. Develop a better understanding of spread pathways
		2.3. Develop hygiene protocols, focusing on high priority spread pathways
		2.4. Further develop prioritisation tools to identify high-priority areas for monitoring and management actions
		2.5. Include strategic management of the five listed grasses in management plans, giving priority to identified key assets
		2.6. Improve and promote understanding of invasive grass control and land rehabilitation methods
		2.7. Facilitate collaborative applied research that can be used to inform or support improved management of the five listed grasses
		3.1. Identify key assets for priority protection
		3.2. Identify areas at risk of invasion, prioritise for monitoring and determine appropriate management actions
		4.1. Develop and deliver communication strategies to raise awareness of the threats posed by the five listed grasses
		4.2. Better assist the capacity of Indigenous people to participate in the management of the five listed grasses
		5.1. Foster a coordinated partnership approach to the management of the five listed grasses
		5.2. Where feasible, implement immediate management actions in high-priority areas around key assets and spread pathways
		5.3. Where feasible, implement management actions in other infested areas to reduce the area and/or density of occupancy of the five listed grasses
		5.4. Where feasible, apply land rehabilitation methods to high priority areas as they are cleared of the five listed grasses
		6.1. Ensure that management plans for high-priority areas include recognition of the asset being protected as well as appropriate monitoring of managed sites. Encourage monitoring to enable the effectiveness of actions to be determined
		6.2. Report on progress and effectiveness of management programs against their goals

Key Threatening Process	Threat Abatement Plan	Relevant actions
Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	no TAP	
Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases	no TAP	
Novel biota and their impact on biodiversity	no TAP	
Predation by feral cats	Department of the Environment Water Heritage and the Arts (2008)	1.1. Collate data on islands, assess their conservation value and if there are cats present, and assess risks of cat invasion
		1.2. Collaboratively, minimise risks of cat incursions to cat-free areas
		1.3, 1.4. Develop and implement island management plans for biosecurity and response to cat invasion
		1.5. Where feasible, cost-effective and a conservation priority, eradicate cats from areas with high conservation values
		1.6. Monitor native prey species in areas from which cats have been eradicated
		2.1. Identify areas for feral cat control (based in part on significance of threatened species populations)
		2.2. Control or monitor regional feral cat control through new and existing programs in priority areas
		3.1. Develop simple cost-effective methods for monitoring the impacts of feral cats
		3.2. Investigate interactions between feral cats and native predators
		3.3. Determine the nature of interactions between feral cats, foxes and wild dogs to effectively integrate control activities
		3.4. Determine impacts of cat-borne diseases on native species
		3.5. Identify any unintended effects that feral cat control may cause
		4.2. Determine appropriate baiting strategies for various regions

Key Threatening Process	Threat Abatement Plan	Relevant actions
		4.3. Ensure that habitat rehabilitation and management of potential prey, competitors and predators of feral cats are considered in feral cat control programs
		4.4. Test and disseminate information on exclusion fence designs
		4.5. Promote codes of practice for the humane management of feral cats
		5.1. Promote the issues considered in this plan and the implementation of the plan
		5.2. Develop specific communications campaigns
Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs	Department of the Environment and Heritage (2005)	1.1. Identify areas with low eradicable numbers of pigs, and that are priority areas for nationally listed threatened species
		1.3. Develop and implement strategies including surveillance monitoring and contingency plans to remove pigs in such areas
		4.1. Identify areas where nationally threatened species are under threat from feral pigs
		4.2. Undertake research to assess such impacts
		5.1, 5.2. Assess options for managing feral pigs in priority areas for the protection of nationally listed threatened species
The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*)	Department of Sustainability Environment Water Population and Communities (2011)	1.1. Identify native species, ecological islands and off-shore islands currently known to be at high or moderate risk
		1.2. Identify the ways in which cane toads impact the native species and ecological communities listed in 1.1.
		1.3. Where impact is unknown but may be high, undertake research to assess impacts. Where appropriate, research ways to assist with the recovery of priority native species
		1.4. Develop a prioritisation tool to guide resource allocation for protection of native species
		2.1. Focus management of cane toad impacts on designated high priority native species and ecological communities
		2.2. Prepare guidelines for emergency responses and on-going management for high priority native species … Australian Government to prepare and implement management plans for designated high priority species on land managed by Australian Government agencies
		3.2. Encourage monitoring, evaluation and reporting on cane toad management actions

References

Department of Sustainability Environment Water Population and Communities (2011) 'Threat abatement plan for the biological effects, including lethal toxic ingestion, caused by cane toads.' Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Department of Sustainability Environment Water Population and Communities (2012) 'Threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses.' Department of Sustainability Environment Water Population and Communities, Canberra.

Department of the Environment and Heritage (2005) 'Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs.' Department of the Environment and Heritage, Canberra.

Department of the Environment and Heritage (2006) 'Threat Abatement Plan. Infection of amphibians with chytrid fungus resulting in chytridiomycosis.' Department of the Environment and Heritage, Canberra.

Department of the Environment Water Heritage and the Arts (2008) 'Threat abatement plan for predation by feral cats.' Department of the Environment, Water, Heritage and the Arts, Canberra.

Department of the Environment Water Heritage and the Arts (2009) 'Threat Abatement Plan for the impacts of marine debris on vertebrate marine life.' Department of the Environment Water Heritage and the Arts, Canberra.

Appendix 8 - Extent of current monitoring of threatened species in Kakadu

Y=Yes, the existing monitoring program meets the criterion, P=Partly meets, and N=Does not meet

Common name	Scientific name	Extent of current monitoring	Program meets monitoring criteria?										
			i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
Plants														
	Acacia equisetifolia	occasional	Y	N	P	Y	N	P	N	Y	P	P	N	Y
	Bolbitis quoyana	baseline established	Y	N	N	P	N	N	N	Y	N	N	Y	Y
	Cycas armstrongii	nil												
	Dienia montana	occasional	P	N	N	N	N	P	N	P	P	N	N	P
	Freycinetia excelsa	nil												
	Hibbertia brennanii	nil												
	Hibbertia pancerea	nil												
	Hibbertia sp. South Magela	baseline established	Y	N	P	P	N	P	N	Y	P	P	N	Y
	Hibbertia tricornis	baseline established	Y	N	P	P	N	P	N	Y	P	P	N	Y
	Hibiscus brennanii	baseline established	Y	N	P	P	N	P	N	Y	P	P	N	Y
	Jacksonia divisa	nil												
	Lithomyrtus linariifolia	baseline established	Y	N	P	P	N	P	N	Y	P	P	N	Y
	Monochoria hastata	occasional	P	P	P	N	N	P	N	P	P	P	N	Y
	Sauropus filicinus	baseline established	Y	N	P	P	N	P	N	Y	P	P	N	Y
	Utricularia dunstaniae	nil												
Invertebrates														
	Leptopalaemon gibbosus	nil												
	Leptopalaemon glabrus	nil												
	Leptopalaemon magelensis	nil												
Top End Dragon	*Antipodogomphus dentosus*	nil												
Kakadu Vicetail	*Hemigomphus magela*	nil												
Rock Narrow-wing	*Lithosticta macra*	nil												
Fish														
Northern River Shark	*Glyphis garricki*	nil*												
Speartooth Shark	*Glyphis glyphis*	nil*												
Dwarf Sawfish	*Pristis clavata*	nil*												
Largetooth Sawfish	*Pristis pristis*	nil*												
Narrow Sawfish	*Anoxypristis cuspidata*	nil*												

Common name	Scientific name	Extent of current monitoring	Program meets monitoring criteria?											
			i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
Reptiles														
Flatback Turtle	*Natator depressus*	regular breeding counts	Y	Y	P	P	Y	Y	N	Y	Y	P	P	P
Green Turtle	*Chelonia mydas*	nil												
Olive Ridley	*Lepidochelys olivacea*	nil												
Hawksbill Turtle	*Eretmochelys imbricata*	nil												
Loggerhead Turtle	*Caretta caretta*	nil												
Yellow-snouted Gecko	*Lucasium occultum*	nil												
Arnhem Land Skink	*Bellatorias obiri*	nil												
Merten's Water Monitor	*Varanus mertensi*	very limited info from fireplot monitoring	P	P	N	N	P	P	N	N	P	P	P	N
Mitchell's Water Monitor	*Varanus mitchelli*	very limited info from fireplot monitoring	P	P	N	N	P	P	N	N	P	P	P	N
Yellow-spotted Monitor	*Varanus panoptes*	very limited info from fireplot monitoring	P	P	N	N	P	P	N	N	P	P	P	N
Plains Death Adder	*Acanthophis hawkei*	nil												
Oenpelli Python	*Morelia oenpelliensis*	very limited info from fireplot monitoring	P	P	N	N	P	P	N	N	P	P	P	N
Birds														
Partridge Pigeon	*Geophaps smithii*	fireplot monitoring	Y	P	P	P	P	Y	N	P	P	P	P	P
Red Goshawk	*Erythrotriorchis radiatus*	nil												
Grey Falcon	*Falco hypoleucos*	nil												
Greater Sand Plover (Mongolian)	*Charadrius leschenaultii leschenaultii*	nil												
Lesser Sand Plover	*Charadrius mongolus*	nil												
Australian Painted Snipe	*Rostratula australis*	nil												
Bar-tailed Godwit	*Limosa lapponica baueri*	nil												
Eastern Curlew	*Numenius madagascariensis*	nil												

Common name	Scientific name	Extent of current monitoring	Program meets monitoring criteria?										
			i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
Asian Dowitcher	*Limnodromus semipalmatus*	nil												
Red Knot	*Calidris canutus*	nil												
Great Knot	*Calidris tenuirostris*	nil												
Curlew Sandpiper	*Calidris ferruginea*	nil												
Masked Owl (northern)	*Tyto novaehollandiae kimberli*	nil												
White-throated Grass-wren	*Amytornis woodwardi*	limited info from fireplot monitoring; more recent targeted sampling	P P	P P	P P	P P	P N	Y Y	N N	P Y	P Y	P P	P P	P P
Yellow Chat (Alligator R.)	*Epthianura crocea tunneyi*	baseline established	P	N	P	N	N	P	N	P	P	N	N	P
Crested Shrike-tit (northern)	*Falcunculus frontatus whitei*	nil												
Gouldian Finch	*Erythrura gouldiae*	nil												
Mammals														
Northern Quoll	*Dasyurus hallucatus*	fireplot monitoring; recent targeted monitoring	Y P	P Y	P Y	Y P	P P	Y P	N N	Y Y	P P	P P	P P	P Y
Northern Brush-tailed Phascogale	*Phascogale pirata*	very limited info from fireplot monitoring	P	P	N	N	P	Y	N	N	P	P	N	N
Fawn Antechinus	*Antechinus bellus*	fireplot monitoring	Y	P	P	P	P	Y	N	Y	P	P	P	Y
Golden Bandicoot	*Isoodon auratus*	nil (but probably extirpated)												
Nabarlek	*Petrogale concinna*	nil												
Ghost Bat	*Macroderma gigas*	nil												
Arnhem Leaf-nosed Bat	*Hipposideros inornatus*	nil												
Northern Leaf-nosed Bat	*Hipposideros stenotis*	nil												
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus nudicluniatus*	nil												

Common name	Scientific name	Extent of current monitoring	Program meets monitoring criteria?											
			i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	very limited info from fireplot monitoring; previous monitoring at one site from which it is now apparently absent (Firth 2010)	P	P	N	N	P	Y	N	Y	P	P	P	N
Black-footed Tree-rat	*Mesembriomys gouldii*	limited info from fireplot monitoring	P	P	N	N	P	Y	N	Y	P	P	P	N
Golden-backed Tree-rat	*Mesembriomys macrurus*	nil (but probably extirpated)												
Northern Hopping-mouse	*Notomys aquilo*	nil (but probably extirpated)												
Kakadu Pebble-Mouse	*Pseudomys calabyi*	limited info from fireplot monitoring	P	P	N	N	P	Y	N	Y	P	P	P	N
Arnhem Rock-rat	*Zyzomys maini*	fireplot monitoring	Y	P	P	P	P	Y	N	Y	P	P	P	Y
Water Mouse	*Xeromys myoides*	nil												
Pale Field-rat	*Rattus tunneyi*	fireplot monitoring	Y	P	P	P	P	Y	N	Y	P	P	P	Y
Dugong	*Dugong dugon*	nil												
Dingo	*Canis lupus dingo*	nil												
Ecological communities														
Arnhem Plateau Sandstone Shrubland Complex		fireplot monitoring	P	P	P	N	P	N	N	N	P	P	N	P

Monitoring criteria (see main text for more detailed explanation):

(i) extent and comprehensiveness of sampling

(ii) periodicity

(iii) capability to measure response to management actions

(iv) statistical power

(v) long-term commitment

(vi) consistency and description of monitoring protocols

(vii) targets, thresholds and triggers

(viii) design specificity.

(ix) collaborative sampling

(x) data management and access

(xi) reporting and consequentiality

(xii) cost-effectiveness

Reference

Firth RSC (2010) 'Population monitoring of a threatened species; the brush-tailed rabbit-rat *Conilurus penicillatus* in Kakadu National Park and Garig Gunak Barlu National Park (Cobourg Peninsula).' EWL Sciences Pty Ltd, Darwin.

Appendix 9 - A composite index for threatened species trends in Kakadu

For some purposes it may be desirable to collate monitoring information across species to derive a smaller set of composite indices of trends for Kakadu's threatened species. There are many possible approaches to this simplification. One is simply to tally the number of threatened species present, with refinement possible to include consideration of any changes in threatened status (e.g. if a species is uplisted from Vulnerable to Endangered). However, although widely used, this is a notably insensitive index as it is dependent mostly on the vagaries of the listing process rather than reflecting responses to management.

Information on population trends is far more relevant than simply occurrence information. However, trends can really only be detected through monitoring, and as noted in Appendix 6, there is no monitoring program for most threatened species in Kakadu. One index that may be important to track is this level of monitoring activity, and a simple monitoring index is the number of threatened species that are being monitored (or monitored adequately) in any given year. Figure A9.1 shows trends in this number since the establishment of Kakadu.

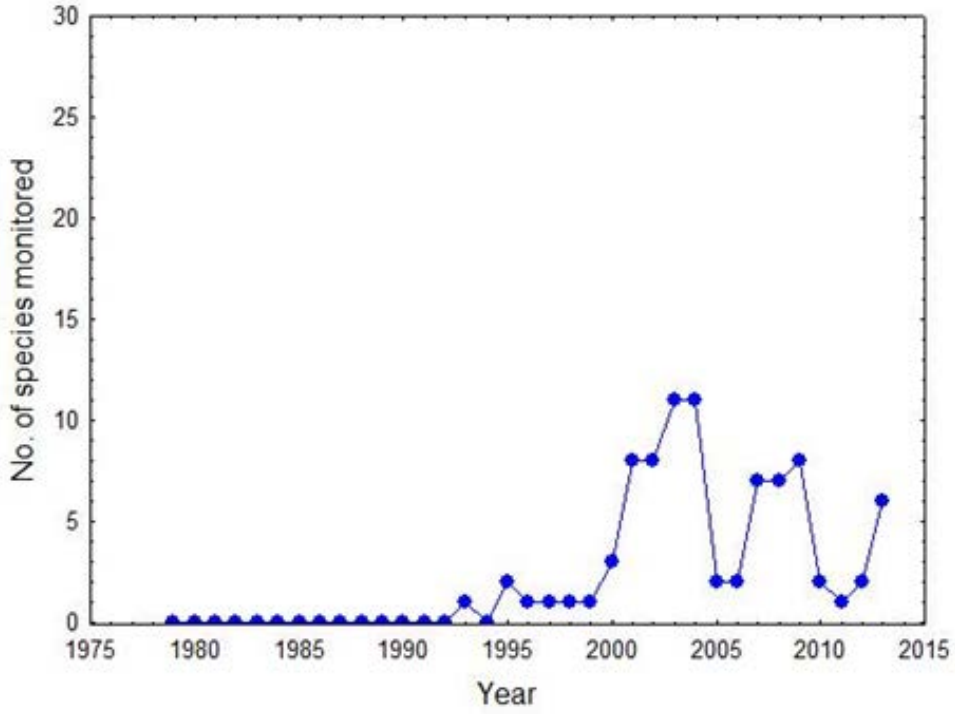

Figure A9.1. The number of threatened species for which monitoring activity is conducted in any year. Note that this includes only species for which the information obtained from monitoring is adequate to detect trends. The cyclical peaks relate mostly to inclusion of some threatened species in fire plot monitoring. The relatively high values in c. 2004-05 are due to baseline sampling for some threatened plant species, for most of which no subsequent sampling has occurred. Note that the tallies are small relative to the >70 threatened species present in Kakadu.

Changes in abundance from one monitoring period to the next provide the basis for trend data. Ideally the monitoring periods occur sufficiently frequently to reflect management investments, but with the notable exception of the annual monitoring for flatback turtles, most Kakadu monitoring periodicity is 5+ years. To simplify the derivation of composite indices, an assumption can be made that trends for any species are consistent across the period between monitoring events. With such assumption, it is possible to indicate for any species whether its population trend is increasing, stable, decreasing or unknown (with such categorisation capable of being nuanced further according to the extent of statistical significance of such changes). Based on interpretation of monitoring data, trends in this categorisation are presented in Figure A7.2.

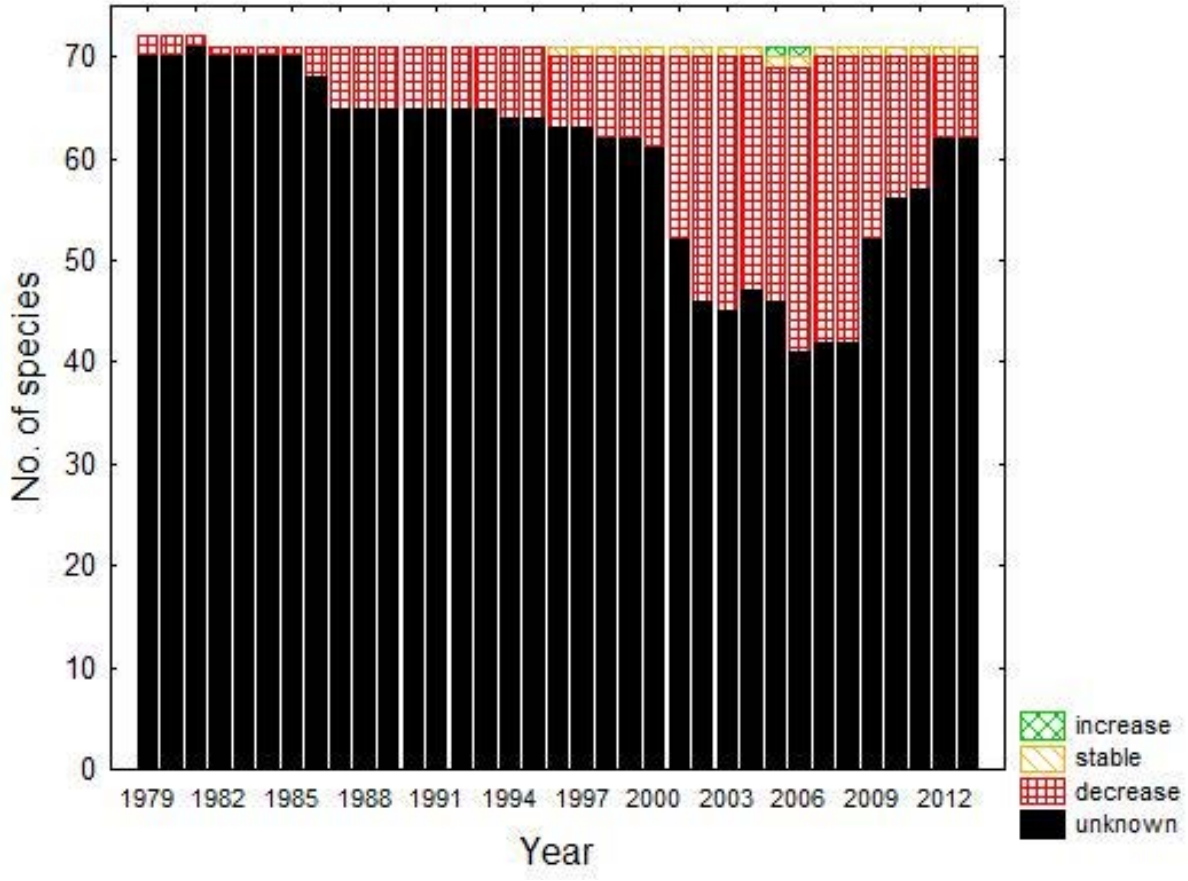

Figure A9.2. Chronology of threatened species trends in Kakadu, based on interpretation of available monitoring data. This Figure shows that trends are unknown for most threatened species; where they are known, the trends are mostly for decline. The recent rise in the number of threatened species with unknown trends is because the latest round of fire plot monitoring has not been fully sampled and analysed.

Such presentation lends itself readily to annual assessment against performance targets, with desired states being the reduction in the proportion of species with unknown trends, reduction in the proportion of species with decreasing trends, and increase in the proportion of species with stable or increasing abundance trends.

This information can be further simplified to a single composite trend index:

(no. increasers – no. decreasers) / (no. increasers + no. decreasers + no. stable)

where 'no. increasers' is the number of threatened species for which an increasing trend is demonstrated or interpolated for the given year, 'no. decreasers' is the tally of threatened species with decreasing population trends for that year, and 'no. stable' is the number of threatened species

with stable (i.e. no significant change) population trends for that year. Such an index varies from +1 (if all threatened species for which trend data are available are increasing) through 0 (if the number of threatened species with increasing population trends is the same as the number with decreasing trends, or if all species show stable population trends) to -1 (if all threatened species for which trend data are available are decreasing).

Based on interpretation of monitoring and other relevant data, chronological change in this index is presented in Figure A9.3.

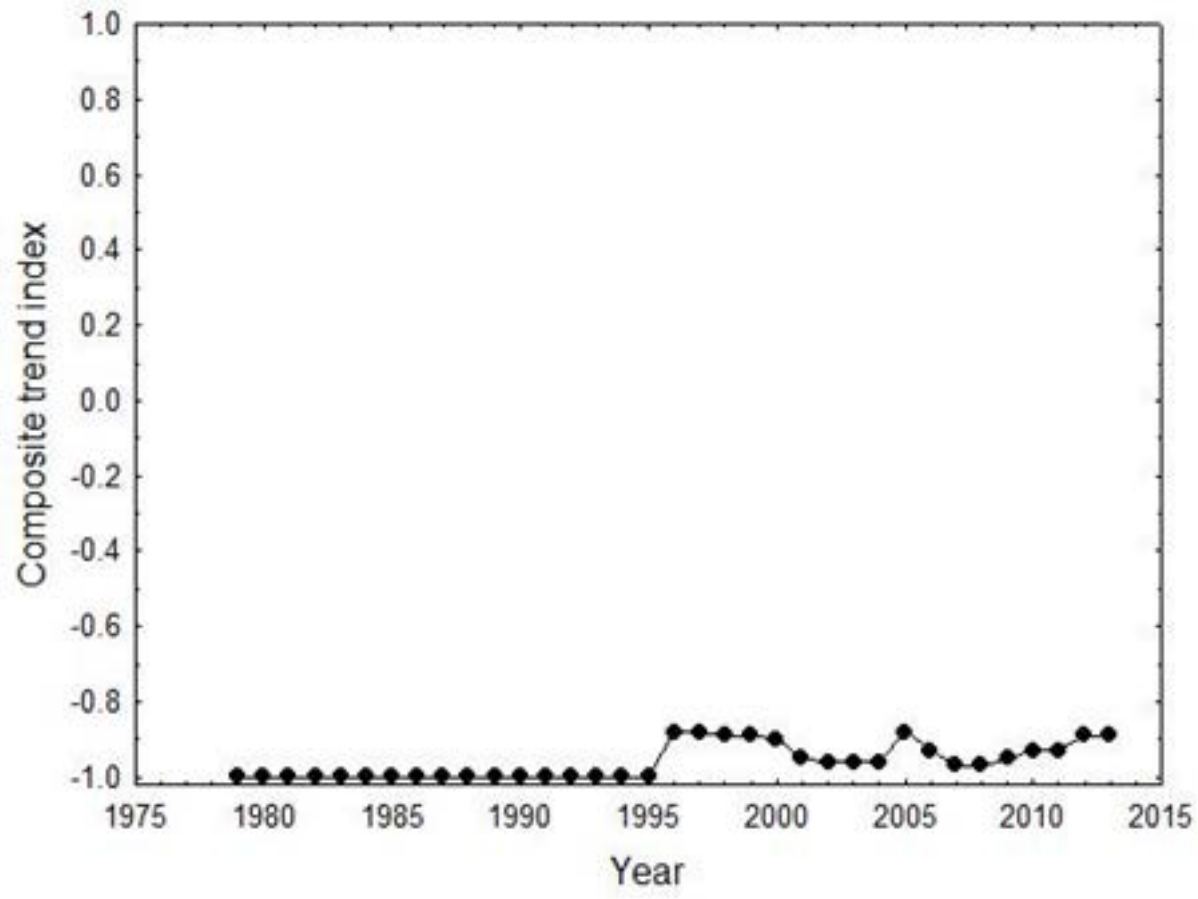

Figure A9.3. A composite trend index for threatened species in Kakadu, based on the relative number of species declining, stable and increasing. Note that sample sizes (i.e. the number of threatened species for which trends are unknown) is especially small in some years (particularly prior to c. 1996), and the index then is of lower reliability.

This index represents a distillation from Figure A9.2, and similarly can be readily used to track progress against targets, with preferred states being a positive value for the index (i.e. more species are increasing than decreasing). To date there has been little change in the index over the course of Kakadu's existence.

Appendix 10 - Standard Operating Procedures for a threatened species monitoring program

A consistent template for a monitoring program for any threatened species helps to ensure that sampling is undertaken uniformly across sampling periods, allows participants to have a clear conception of their role, ensures that managers can anticipate and factor in monitoring activity, provides managers and others with a clear understanding of the location and significance of monitoring sites, ensures well-regulated data entry, and provide the interpretation and basis necessary for reporting.

A draft template, with template settings marked in bold, is provided below, with indicative information for an imaginary plant species.

STANDARD OPERATING PROTOCOL FOR MONITORING PROGRAM FOR: *Kakadu Gum*

Purpose and context

Target: population trends increasing over at least 3 successive monitoring periods

Thresholds and triggers: review management if decline by 20%; establish ex situ population if decline by >30% over two monitoring periods.

Sampling

Location of sampling sites: Three 1 ha quadrats: 144.2735'S 18.5673'E (Q1), 144.2741'S 18.5666'E (Q2), 144.2812'S 18.6152'E (Q3).

Access: Q1 requires helicopter access (landing site at 144.2739'S 18.5619E), Q2 and Q3 are 100 m from Jim Jim Rd.

Park district: XX (contact: xx)

Landowner group: XX (contact: xx)

Sampling sites permanently marked?: Yes, star picket at SE and NW corners of each quadrat

Management inputs: Quadrats 1 and 2 to be protected from fire, Q3 exposed to ambient fire

Appropriate sampling time: March-April (when flowering)

Sampling resources required:

no. of people: 2. **equipment**: 50 m tape, callipers. **expected time taken**: 4 hrs per site

Estimated cost per sampling episode: $550 (helicopter time); 2 people-days; 4WD for 2 days

Sampling frequency: annual

Any issues with identification or detectability?: Species is readily identifiable by purple flowers: for picture see XX.

Sampling protocol: All trees of >10cm dbh in quadrat are tagged (Q1: 001 etc.). Count stems and measure dbh of each tagged tree across entire quadrat. Count individuals <10 cm dbh (and record their dbh and height) in 10 randomly sited 5 m x 5m quadrats across quadrat.

Additional information to be recorded at sampling sites: Record whether quadrat had been burnt since last sample

Data storage

All data on survival and growth of individual stems entered into excel file KNPmonitoring_KG_mature.xls; data on number so mature and individual stems entered into excel file KNPmonitoring_KG_stemcount.xls; within 30 days of sampling; with master file maintained at KNP.

Sampling history and reporting (updates):

Sampling commenced 2010, with repeat sampling in 2011 and 2013. Analysis in 2013 showed increase in abundance of 2% since 2010.

Checklist against monitoring criteria:

(i) ***extent and comprehensiveness of sampling*** Yes, sample sites include most of the known population.

(ii) ***periodicity*** Yes, annual.

(iii) ***capability to measure response to management actions*** Partial; information provided on response to fire.

(iv) ***statistical power*** Moderate, as most of the population is sampled.

(v) ***long-term commitment*** Yes, program confirmed until 2016

(vi) ***consistency and description of monitoring protocols***. Yes, this standard protocol implemented.

(vii) ***targets, thresholds and triggers***. Yes.

(viii) ***design specificity*** Yes.

(ix) ***collaborative sampling*** Yes, sampling should include at least one relevant ranger and TO.

(x) ***data management and access*** Yes, protocols established and implemented

Appendix 11 - Collation of priority actions

6.2.1. Survey for known roost sites (particularly maternity roosts) for Ghost Bats, and develop and implement a monitoring program based at these.

6.2.2. Participate in national monitoring programs for shorebirds.

6.2.3. Evaluate the options, costs, benefits, risks and requirements of reintroduction of mammal species for which there are no recent Kakadu records.

6.2.4. Develop and implement monitoring programs for all toad-affected vertebrate species to assess the extent of natural or assisted recovery.

6.2.5. Develop and implement an integrated monitoring program for sawfish and river shark species.

6.2.6. Maintain and review (analyse results and refine) existing monitoring program for Flatback Turtle.

6.2.7. Undertake a targeted survey program for three floodplain threatened species in order to define distribution (and important populations), assess abundance, and examine habitat requirements.

6.2.8. Design and implement monitoring programs for three floodplain threatened species.

6.2.9. Undertake targeted searches for further subpopulations in Kakadu, and more intensive survey at the sole known site for Dienia montana.

6.2.10. Control feral pigs at the sole subpopulation of Dienia montana.

6.2.11. Design and implement monitoring programs for both rainforest plant species, for the abundance of pigs (and pig impacts) at both sites, and of the responses to management intervention.

6.2.12. Undertake surveys that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened lowland species.

6.2.13. Refine knowledge of the preferred fire regime and thresholds of concern for all lowland threatened species.

6.2.14. Assess the relative impacts of cat predation vis-à-vis other threats for threatened lowland animal species, and options for controlling cats to densities at which their impact is inconsequential.

6.2.15. Change lowland fire management in a manner more analogous to the Stone Country Fire Management Plan, in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity.

6.2.16. Where cost-effective and/or at significant sites (holding important populations of threatened species), control (or exclude) feral cats.

6.2.17. Design and implement monitoring programs for currently unmonitored threatened lowland species, and maintain and enhance existing monitoring programs for those species currently subject to some monitoring.

6.2.18. Monitor fire regimes in relation to targets set for threatened lowland species.

6.2.19. Undertake surveys that refine knowledge of the distribution, abundance, habitat requirements and likely threats for poorly-known threatened Stone Country species.

6.2.20. Identify significant sites (i.e. those holding important populations) for threatened Stone Country species.

6.2.21. Refine knowledge of the preferred fire regime and thresholds of concern for all Stone Country threatened species.

6.2.22. Maintain and enhance Stone Country Fire Management Plan, in order to increase the extent of longer-unburnt habitat, reduce fire size and increase fire-mediated heterogeneity.

6.2.23. Design and implement monitoring programs for currently unmonitored threatened Stone Country species (and threatened ecological community), and maintain and enhance existing monitoring programs for those species currently subject to some monitoring.

6.2.24. Monitor fire regimes in relation to targets set for threatened Stone Country species.

6.3.1. Assess and report on the extent of current and ongoing compliance with these mandated Recovery Plan actions.

6.3.2. Develop and implement local-scale interpretations of some of the more generic actions in existing national Recovery Plans.

6.3.3. Collaborate with other agencies and individuals that are collectively involved in the implementation of these national Recovery Plans.

6.3.4. Contribute to the review of these current plans and development of subsequent iterations of them.

6.3.5. Incorporate into management planning and implementation any actions from relevant newly developed plans for additional species.

6.4.1. Geographically delineate important subpopulations for all spatially restricted threatened species in Kakadu.

6.4.2. Refine knowledge of the responses of many threatened species to fire regimes.

6.4.3. Refine knowledge of the population-level responses of some threatened animal species (particularly mammals) to feral cats.

6.4.4. Clarify the status (particularly population size), ecology and management requirements in Kakadu of some poorly-known threatened species.

6.4.5. Clarify the conservation status of all Data Deficient species occurring in Kakadu.

6.5.1. Assess the current abundance of feral cats and the costs and effectiveness of a range of control and mitigation measures to reduce their abundance and impacts.

6.5.2. Assess the costs, effectiveness and feasibility of options to enhance fire management, particularly for options to increase the extent of longer-unburnt lowland woodlands.

6.5.3. Assess the costs, effectiveness and feasibility of options to reduce the spread, incidence and cover of invasive grass species.

6.5.4. Assess the impacts of wild dogs on a set of threatened species, options for management, and interactions with feral cats.

6.6.1. Continue to refine and review management prioritisation at 2 to 3 year intervals.

6.6.2. Assess and report on the extent of current and ongoing compliance with relevant national Threat Abatement Plan actions.

6.6.3. Collaborate with other agencies and individuals that are collectively involved in the implementation of these national Threat Abatement Plans.

6.6.4. Ensure that all relevant objectives and priority actions in this strategy are explicitly included in and provide direction to Kakadu threat management plans and strategies.

6.7.1. Substantially enhance database management for biodiversity records in Kakadu.

6.7.2. Substantially enhance GIS management in Kakadu.

6.7.3. Develop and maintain comprehensive and integrated data bases that store all relevant monitoring information about threatened species and threatening factors.

6.7.4. Develop and regularly update appropriate guides (handbooks, posters or web products) that allow Park managers, traditional landowners, tourists and others to readily identify threatened species.

6.7.5. Consolidate compilation of traditional knowledge about threatened species, and ensure that such knowledge is appropriately considered in management guidelines.

6.7.6. Ensure researchers working on threatened species in Kakadu provide in timely manner explicit management advice arising from their work.

6.8.1. Establish realistic longer-term and shorter-term targets for every threatened species.

6.8.2. Where appropriate, describe thresholds that indicate that progress towards established targets is inadequate, and which trigger review of management.

6.8.3. Maintain and refine targets within the Stone Country Fire Management Plan, and set appropriate complementary thresholds of concern and targets for fire management in lowland woodlands.

6.8.4. Institute in annual reporting and performance review a clear accountability for progress towards these targets.

6.9.1. Design (with regard to stipulated monitoring program criteria) and implement monitoring programs for every threatened species in Kakadu.

6.9.2. Enhance existing, or design and implement new, monitoring programs that report on the incidence, extent and impacts of current and projected threats, and of management actions designed to address such threats.

6.9.3. Develop a comprehensive and integrated reporting process for all threatened species, a composite index for trends across all threatened species.

6.9.4. Develop a comprehensive monitoring data, display and interpretation program, that ensures that all monitoring data are rapidly and reliably entered, and readily accessible and interpretable to all park managers and the public generally.

6.9.5. Develop a consistent series of Standard Operating Procedures.

6.9.6. Commit to a regular review (at least annually) of all monitoring results.

6.9.7. Report monitoring trends (and management investments) for threatened species in Kakadu to appropriate external bodies (e.g. World Heritage committee, Ramsar, etc.) to demonstrate trends in the condition of values on which listing is based.

6.9.8. Maintain the existing fire plot monitoring program.

6.10.1. Maintain and enhance collaboration (and, where appropriate, training) amongst researchers, managers, Bininj, and, where appropriate, tourists and other volunteers.

6.10.2. Maintain and enhance collaborative linkages between research, monitoring and management programs for threatened species in Kakadu and comparable programs elsewhere in the region.

6.10.3. Where feasible and appropriate, seek to augment internally available resources with external funding and other resource support.

6.11.1. Develop appropriate protocols for assessment and implementation of captive breeding programs.

6.11.2. Assess likely options, costs and benefits for an integrated ex situ (and where appropriate, reintroduction) program for Kakadu threatened plant species.

6.11.3. Assess likely options, costs and benefits for the establishment of one or more cat-proof exclosures for the reintroduction of now extirpated mammal species.

6.12.1. Establish and maintain a Kakadu threatened species recovery and advisory group.

6.13.1. Develop and maintain an account and itemisation in Kakadu's budget that relates explicitly to investments made for the conservation of threatened species.

6.13.2. Dedicate a staff position to a Kakadu Threatened Species Conservation Officer with primary responsibility for the delivery of this strategy, and with dedicated budget.

6.13.3. Seek to maintain and enhance resource contributions from external sources.

National Environmental Research Program

NORTHERN AUSTRALIA HUB

Improving biodiversity conservation in northern Australia

kakadu NATIONAL PARK

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