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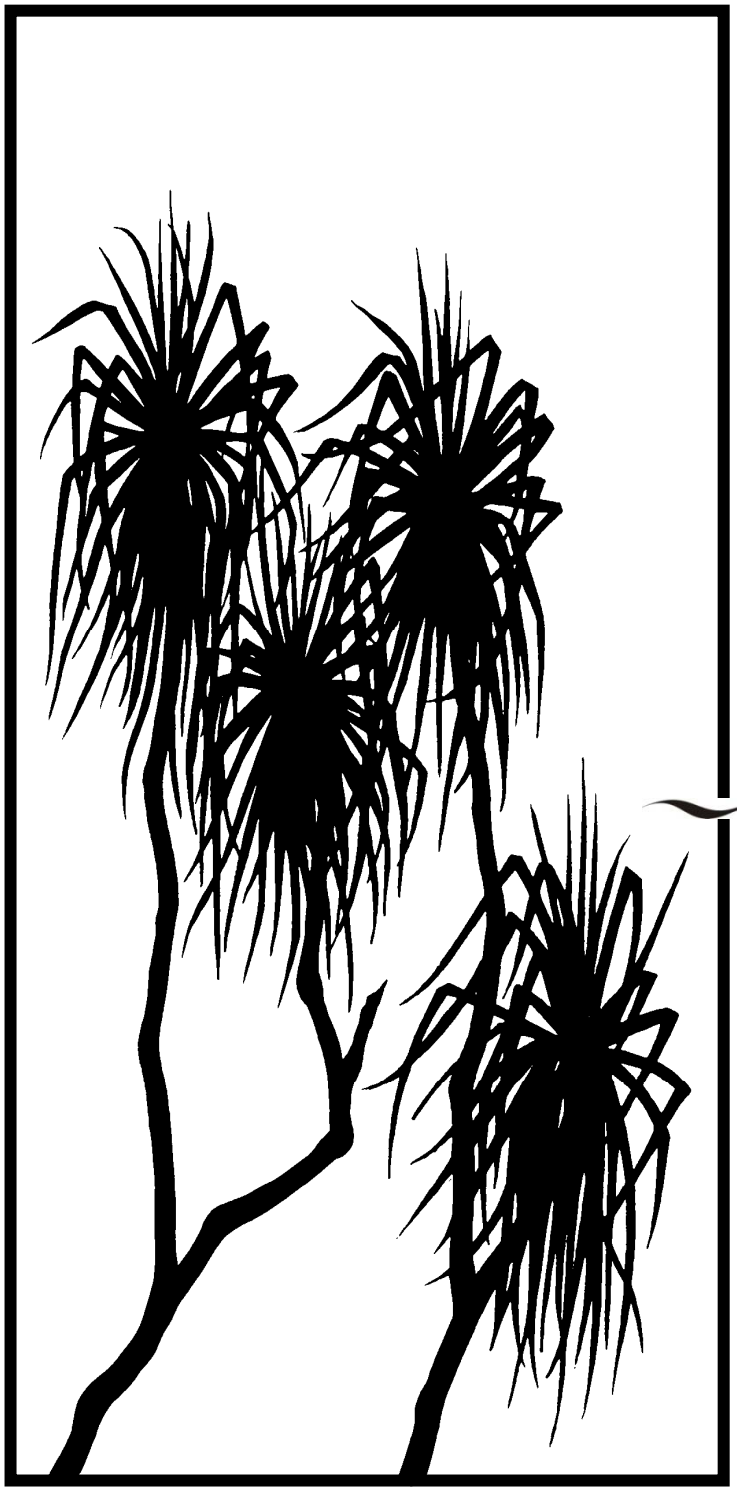

Kakadu National Park Symposia Series

Symposium 7: Conservation of threatened species, 26–27 March 2013, Bowali Visitor Centre, Kakadu National Park

S Winderlich & J Woinarski

(eds)

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Symposium 7: Conservation of threatened species, 26-27 March 2013, Bowali Visitor Centre, Kakadu National Park

Edited by S Winderlich[1] & J Woinarski[2]

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Contents

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The workshop received significant contributions from the Parks Australia and the National Environmental Research Program North Australia Hub under the direction of Michael Douglas of CDU: without this support the forum would not have been possible.

Thanks also to all those who demonstrated a shared the commitment to improve the management of threatened species in Kakadu and the region and gave of their time to attend the forum. In particular, we acknowledge Alan Anderson, Peter Kyne, Ian Cowie, Graeme Gillespie and Dion Wedd who presented and were part of the Technical Working group that met the day after the workshop to consider the outcomes of the first day and start the process of producing a Threatened Species Strategy for the park. The role of the National Environment Research Program, Charles Darwin University, NT Department of Land Resource Management, CSIRO Ecosystem Sciences Darwin NT, Supervising Scientist, Territory Wildlife Park, and Kakadu National Park in supporting the involvement of their staff is gratefully acknowledged.

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1. Introduction: the conservation of threatened species of Kakadu National Park

S Winderlich[1] & J Woinarski[2]

The Threatened Species Symposium is the seventh in the series of symposia and workshops held by Kakadu National Park (KNP). The previous volumes have focused on landscape change (Walden & Nou 2008) and factors driving biodiversity change: weeds (Winderlich 2010a), fire (Atkins & Winderlich 2010), climate change (Winderlich 2010b), feral animals (Jambrecina 2010), and Cultural Heritage (S. Winderlich (ed) not yet published). Threatened species have been considered in these previous symposia, but have not been the primary focus.

This symposium was held at the Bowali Visitor Centre Training Room in Jabiru on 26–27 March 2013. Fifty one participants attended, from a wide range of stakeholders, including Traditional Owners, government agencies, academic institutions, neighbouring landholders, and non-government conservation organisations.

As with the previous symposia in this series, the aims of this symposium were (i) to have an effective two-way transfer of knowledge between KNP staff, researchers, the Kakadu Research Advisory Committee (KRAC) members, stakeholders and Traditional Owners on issues relating to the conservation and management of threatened plant and animal species and, less directly, on other species of biodiversity or cultural significance; and (ii) to ensure that the outcomes of this consideration are integrated in an appropriate and effective manner into Park management. In this case, the symposium timing is particularly opportune; as such considerations will contribute directly to the current development of the Park's 6th Plan of Management.

The format for the symposium included a series of status update presentations, followed by workshops focusing on key management and research questions and priorities. In most cases, presentations focused on the major taxonomic groupings of threatened species. Presenters and workshop facilitators were given a series of focus questions to assist in guiding the information presented and the subsequent discussions. These included:

- What species occurring (or formerly occurring) in Kakadu are listed as threatened under relevant Northern Territory or Australian legislation, or are included in international lists?
- What is the status and trends of each listed species in Kakadu?
- What are the main threats to the threatened taxa; and how can these threats be more effectively managed?
- What are the priorities for research and management?

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- The presentations catalysed discussion around these issues amongst workshop participants, and the presentations here are informed by those workshop deliberations.

There were three notable features of this symposium. Firstly, there was recognition amongst participants that trends for many threatened species were negative, with evidence demonstrating that many species are showing current decline. Workshop participants viewed this as an indication that current management was sub-optimal, and that there was a need to consider substantial and urgent change in prioritisation or manner of management. This symposium is an important landmark in such change. Secondly, participants recognised that the number and diversity of threatened species occurring in KNP makes for a formidable management challenge, further magnified because there is little information on distribution, status or management requirements for many of these species. Prioritisation between research and management actions amongst such a wide range of disparate species (and one threatened ecological community) is a difficult management challenge. Thirdly, notwithstanding such differences in management requirements amongst many and varied threatened species, most participants considered that there was scope for much management efficiency through focusing management by broad landscape unit – Stone Country, lowland woodlands and open forests, rainforests, and aquatic and marine systems.

The symposium proved to be a successful and stimulating forum, with a considerable amount of very useful new information contributed by presenters, and considerable insight and expertise contributed by all attendees. Much of this information is presented here, and much will also be used to develop the Park's Threatened Species Strategy which is currently being prepared. Thank you to all of those who participated.

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2. The views and knowledge of Bininj/Mungguy on Kakadu National Park's threatened species

S Winderlich[1] & A O'Dea[2]

2.1 Introduction

The aims of this symposium on threatened species were (i) to have effective transfer of knowledge between Kakadu National Park staff, researchers, the Kakadu Research Advisory Committee (KRAC) members, stakeholders and Bininj/Mungguy (local indigenous people) on issues relating to the conservation and management of threatened plant and animal species and on some other species of biodiversity or cultural significance; and (ii) to ensure that the outcomes of these discussions are integrated in an appropriate and effective manner into Park management.

Other papers in these proceedings provide summaries and inventories of species currently listed as threatened species under the relevant state and federal legislation. These papers also provide a summary of the current status of these species in Kakadu, an assessment of their threats and management requirements, and a prioritisation for conservation management.

Kakadu National Park is jointly managed between the Australian Government and the Park's traditional owners. All aspects of the park's management are therefore a combination of western park management knowledge and practices and of the knowledge and expertise of the park's traditional owners and other Bininj/Mungguy. In keeping with the joint management status of Kakadu the purpose of this paper and the associated presentation at the symposium is to focus participants on what a selection of Bininj/Mungguy thought and felt about the threatened species in the Park. In so doing it was hoped that through all the subsequent presentations and workshops, participants would use this information to consider how best to respond to the issues raised by Bininj/Mungguy and best inform the management of Kakadu.

Any management action in Kakadu needs to be consistent with the relevant legislation and the Plan of Management (Director of National Parks 2007). Extensive consultation with traditional owners was undertaken in the development of this plan so it reflects the views of a wide cross section of the park's traditional owners. The sections of the plan of management that are relevant to the management of threatened species in Kakadu are included as Appendix 2.1.

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2.2 Methods

Questionnaires were prepared that asked Bininj/Mungguy to respond to several key questions relating to threatened species. The questionnaires were used as the basis for "one-on-one", or small group interviews with traditional owners and other local Bininj/Mungguy. Twenty-seven Bininj/Mungguy were interviewed in Kakadu by park staff over January, February and March 2014. At the start of each interview the purpose of the survey was explained to participants. It was explained that the survey was intended as a means for Bininj/Mungguy to provide their perspective to participants at the symposium and in so doing contribute to the discussion on the management of threatened species.

While it was not possible to survey all Bininj/Mungguy from the area an attempt was made to interview representatives from each clan group and geographic area in Kakadu and in so doing obtain responses from people familiar with each area of the park. A range of age groups were interviewed but there was a focus on current Kakadu Board members and Bininj/Mungguy with a known interest in the flora and fauna of the area. The questionnaire is included as Appendix 2.2.

As part of the interviews, participants were also shown a booklet with photos of 35 mammals, 17 birds, 21 reptiles, four sharks and sawfish, one insect, and 13 plants. These included but were not restricted to threatened species. Note that this set did not include all threatened species recorded from Kakadu (for example, it did not include a set of shorebirds recently listed as threatened). Information was collected on when the animals or plants were last seen, what the threats were, any stories about them, and any suggestions on what can be done to help these plants and animals. A page of this booklet is included as Appendix 2.3, see Figure 1. We acknowledge that photographs may not be as useful for recognition as live specimens or dead specimens mounted in life-like postures (e.g. Ziembicki et al. 2013), but this exercise was more about seeking feedback from Bininj/Mungguy about species that are considered of value or concern, rather than about identification *per se*, and most informants clearly recognised from the presented illustrations those species that they considered important.

- A traffic light system of red, orange and green lights was used to prioritise which animals and plants Bininj/Mungguy were most worried about and were most keen to see something done about. A rating of red represented species of most concern, orange of some concern, and green of no concern or, that respondents didn't know the species. Note that this system did not necessarily prioritise consistently amongst interviewees: some informants were concerned about many species, but other informants had generally lower levels of concern.

- A considerable amount of information was collected and most of it is presented in this paper. The information collected on language names, oral history and cultural stories is presented to some extent in this paper but will mainly be used in the production of a threatened species ready reckoner. The purpose of the ready reckoner, titled *Threatened Species and other animals and plants of interest,* is to increase awareness of threatened species particularly amongst staff, Bininj/Mungguy and other residents of the Kakadu region, and to encourage them to report sightings and observations of these species.

- It is acknowledged that the survey results are not totally representative of the broader indigenous population in the survey region given the selective nature of the sample

and its small size however a good cross section of all the clan groups from Kakadu was achieved. Despite this limitation, the results outline some key issues and concerns from the indigenous groups sampled that do capture the views of the broader population and that are highly relevant to any discussion on the issue of threatened species management in particular and biodiversity conservation issues more generally. This information will inform the park's new plan of management which is currently being developed, and the threatened species strategy for the park which is also currently being developed as an outcome of this symposium.

2.3 Results

The survey results are presented in tables 2.1 & 2. 2 and in appendices 2. 4 & 2.5. The priority assigned to each species is listed using the traffic light system of red (of most concern), orange (of some concern), and green (of no concern or don't know the species). These tables and appendices also note the landscape unit in which the species occurs.

In summary the results are presented in the following format:

1. Appendix 2.4 provides a comprehensive list of threatened species in descending order of priority as identified by Bininj/Mungguy. The responses are presented separately for mammals, birds, reptiles, plants, sharks and rays, and insects. Anectodal information and some cultural information is also presented in this appendix.
2. Table 2.1 presents the 12 species of most concern across all fauna and flora groups in descending order of priority.
3. Table 2.2 presents the 12 species of least concern across all fauna and flora groups.
4. Appendix 2.5 summarises the threats to these species as identified by Bininj/Mungguy.
5. Additional details that have not been captured in this series of tables and appendices are listed under the relevant question in the questionnaire.

Table 2 1 The 12 species of most concern across all fauna and flora groups. Note that for level of concern, red = of most concern, orange = of some concern, and green = of no concern or don't know the species. Note also that the tallies do not always add up to the number of interviewees, because some informants did not pass comment on some species. Species are arranged in descending order of concern.

Species	Habitat	Level of concern		
		Red	Orange	Green
Northern Quoll	Stone country Woodland	13	1	0
Frilled–neck lizard	Woodland	8	3	4
Freshwater Crocodile	Rivers & wetlands	8	1	3
Echidna	Stone country Monsoon forestWoodland	7	6	2
King Brown Snake	Woodland	7	2	3
Yellow-spotted Monitor	Woodland Rivers & wetlands	6	6	0
Oenpelli Python	Stone country	6	3	6
Death Adder (2 species)	Stone country Woodland River & wetland	5	6	2
Mertens Water Monitor	Rivers & wetlands	4	6	2
Olive Python	Stone country Woodland	4	5	6
Emu	Woodland	4	4	7
Water Python	Rivers & wetland	4	4	4

Table 2.2 The 12 species of least concern across all fauna and flora groups.

Conventions as for Table 2.1

Species	Habitat	Level of concern		
		Red	Orange	Green
Speartooth Shark	Rivers & wetlands Coast & tidal flats	0	0	2
Hibbertia pancerea	Stone country	0	0	2
Snubfin dolphin	Coast & Tidal Flats Rivers & Wetlands	0	0	2
Lithomyrtus linariifolius	Stone country	0	0	2
Monocharia hastata	Rivers & wetlands	0	0	2
Sauropus filicinus	Stone country	0	0	2
Yellow-snouted Gecko	Woodland	0	0	2
Leatherback Turtle	Coast & tidal flats	0	0	2
Olive Ridley	Coast & tidal flats	0	0	2

Northern Shrike-tit	Woodland	0	0	2
Jacksonia divisa	Stone country	0	0	0
Golden-backed Tree-rat	Stone country	0	0	0
	Monsoon forest			
	Woodland			

Additional details that have not been captured in this series of tables and appendices are listed below under the relevant question in the questionnaire.

General questions

1. *Are there any plants or animals that you are worried about?*
2. *Which plants or animals?*

- The responses to these questions are shown in Tables 1 & 2 and Appendices 4 & 5.

3. *Why are you worried about these plants or animals?*

- The responses to these questions are presented below and in Appendices 4 & 5
- Late burns in January February can hurt young Yok (bandicoot)
- Stealthy hunters like the cat
- Cane toads
- Fire burning rabbit rat homes
- Numbers are low.
- Pigs dig them out and eat them
- Cats eat birds
- Too much burning
- Cats and dingoes are main threats, sometimes fire (at certain times).
- Climate change. Already some wetlands have salt coming up. Freshwater turtles will have to find a new place, the freshwater fish will have to adapt, frogs will disappear.
- Pigs getting into and damaging the floodplain.

4. *Are there any changes you have noticed? If so what are the changes you have noticed and when do you think they started?*

- Lots of changes – don't see many animals we used to see. Maybe food changes, no food or food gets burnt e.g. when trees are flowering especially bangerreng and yegge wurrgeng. For example Eucalypt Andjelan flowers in wurrgeng so lambalk and wurrk rely on them.
- Angun – sugar bag has changed. Haven't seen it for a long time. Used to eat honey every day. Domestic bee is a problem too.
- Flying fox move to different placest to before, now living in Jabiru.
- Population starting to decline
- Possum not much any more

- Bangerreng we look for ragul and different bird nests. Still a few here and there but some nests get burnt.
- Seasons have changed
- Echidna really hard to find
- When I was younger I see these animals. Not so much now
- Numbers of galawan and turtle are going down. This year not much rain so the weeds are not washed out. Maybe river getting choked up by weed.
- Don't see much bandicoot. Used to be big mobs
- Goannas missing
- Water lilies are covered by Salvinia
- Billabongs covered with para grass, salvinia, mimosa, and mission grass. Everything has changed
- Nowhere to go fishing
- Everything has changed

Book questions (Hand the book to the TOs and ask):

5. *Which plants or animals in this book are most important to you (the traffic light system described in the methods was used to prioritise species)*

Results summarised in tables 1& 2 and presented in Appendix 4.

6. *Do you have any stories about these plants or animals? Cultural stories or memories of the plants or animals*

Some of this information is presented in this paper but it will mainly be included in the threatened species ready reckoner currently being produced.

7. *Can you think of any ways we can help these plants or animals?*

- Do more research
- Check more for bats and mulbbu
- Young people need to learn about species so they know.
- There should be a limit of camp dogs in communities.
- If there is less burning, flying fox will stay in the jungle habitat.
- Do a survey on road kills
- Breed animals like goannas on islands
- People on the Board and GAC need to speak up more
- Collect seeds of endangered species and grow them
- For both plants and animals don't burn when they are breeding or when plants that they eat are flowering
- Careful burning

8. How do you think you could help?

This was not a very productive question and respondents concentrated their responses in this area to question 7 which had more of a collective than individual perspective.

2.4 Discussion

These results provide information that will inform key management plans and strategies for Kakadu National Park. The Kakadu Threatened Species workshop as presented in these proceedings is quite timely in this regard as the park's next plan of management is currently being drafted. One of the outcomes of the workshop is to develop a threatened species strategy for the park and this process is also currently underway. The park also has several specific management plans and strategies that focus on key areas of park management, in particular those focussing on the threats to park values. These include strategies for the management of feral animals, weeds, fire, cultural heritage and climate change. These results will ensure that the views of traditional owners and other Bininj/Mungguy in relation to threatened species are considered in the preparation, review and implementation of these strategies and the park management plan.

As part of the development of and implementation of the threatened species strategy, there will need to be an agreed approach to prioritise the multiple threatened species of Kakadu with the view of allocating finite resources to best effect. The priorities articulated by Bininj/Mungguy as shown in this paper will be one of several key considerations in this exercise.

As the results in Appendix 2.1 indicate, in most categories of fauna the Bininj/Mungguy views and level of concern on the top 10 species listed in each category is reasonably clear. However after the first two mammals which rated highly, the level of concern fell away significantly. While for birds the rating was more consistent for most of the top 10 ranked species, overall they received a lower rating than mammals and reptiles. As a group reptiles were allocated the greatest level of concern and therefore the highest priority. In the case of sharks and rays (four species) and insects (one species) there were too few species listed to make a meaningful comment in this regard. For plants however no species were listed of being of any significant concern.

This is reflected in Table 2.1 (the 12 species of most concern across all fauna and flora groups) where for fauna two mammal and one bird species were listed in the top 12. The table was dominated by reptiles (nine species). No plants, sharks or rays or insects made the top 12. Conversely Table 2.2 (the 12 species of least concern across all fauna and flora groups) listed five plants, one shark, one bird, two mammal and three reptiles.

These results provide information that is relevant to any prioritisation of threatened species. When the broader prioritisation exercise occurs it will be interesting to contrast the levels of concern and priority assigned to the same group of plants and animals by other experts and stakeholders.

Without pre-empting the results of a broader prioritisation exercise it is already clear that there will be some species assigned totally different valuations, which will result in a range of different levels of concern and priority orders. This reflects the different values that influence the management of a complex and cross-cultural park such as Kakadu. A species that may be highly significant genetically or ecologically to western science may be one that is unfamiliar and of relatively little concern to Bininj/Mungguy because it is from habitat where it is not often encountered: for example a plant with a limited

distribution in a remote and rarely visited part of the escarpment, a shark which lives underwater in murky tidal river environments, a secretive gecko found only in one area of Kakadu, or a tree rat that has not been seen in the park since 1969.

Alternatively, it may be that certain species are simply not from their country or not culturally significant as a food species or having a significant place in traditional law and mythology. Several species are also very difficult to differentiate between, so they can be either grouped or are not identified correctly. This is supported in several instances in this exercise where species were either not scored at all or given a green light indicating Bininj/Mungguy were not really concerned for this species. However on closer examination many of these species that received a green rating were accompanied by comments such as:

- They are around but I wouldn't know one from the other. I didn't realise there were so many of them (comments in relation to small mice and rats).
- I never saw one. They are very rare and hard to find.
- Don't know dolphins or turtles, I am a freshwater lady
- Never saw them. I want to see this. Never see it here. Don't know it.
- Never seen this one.
- There are lots of types of wamba (shark) so don't know.

This resulted in the green category being re-defined to being either of "no concern or don't know the species" which was a more accurate reflection of the situation.

Results from this study are largely consistent with a previous study undertaken in the park to establish the status and distribution in Kakadu National Park of several key species (Press 1986). That study found that species of economic importance as a food resource or those closely associated with living areas or with seasonal changes were far better known by traditional owners than species that were not. Equally, species that were most often encountered or utilised had a more complex classification and description than those that were not. These species would most likely have individual species' names and at times different names for the males and females of the species. Other smaller animals would often be classified under a generic name. For example native rats and mice are often grouped under the generic name of "mulbu" rather than have individual names (Press 1986), which was the case in this current study as well.

These results demonstrate the challenge in bringing together often quite different sets of values in any exercise that attempts to assign priorities to Kakadu's large number of threatened species to assist in the allocating of finite resources.

Threats to, and changing status of, threatened species

As with other recent assessments of indigenous knowledge of the changing status of wildlife in northern Australia (notably Ziembicki et al. 2013), this study reported several clear cases of recent marked declines for some animal species (e.g. emu, northern quoll, brush-tailed possum, echidna, tree-rats), with such observations largely consistent with results from monitoring and other studies. In other cases, Bininj/Mungguy were unsure about population trends.

Many Bininj/Mungguy informants suggested reasons for the decline of some threatened and other species. A comprehensive list of the threats identified by Bininj/Mungguy is shown in Appendix 2.5. In summary the threats listed are consistent with those generally listed (as reported in other chapters in these proceedings) and include:

- Fire
- Feral animals including rats, cats, dogs, pigs and feral bees (but no mention of the larger ungulate pest species and their impact).
- Weeds
- Climate change and changing seasons
- Cyclones

Perhaps less predictably the list of threats also included:

- Indigenous hunting
- Road kill
- Fans (particularly the impact on micro bats)
- Disease
- Tourists (this was in reference to disturbance to White- throated grass wrens).

Appendix 2.5 also groups the threats to individual species according to the landscape unit(s) that they occur in. This will assist in the development of the implementation plan for the strategy and identify where a more landscape management approach can be taken for a suite of species being impacted by the same threat. For example, appropriate fire management in the stone country has a positive impact on at least 10 mammal species, two bird species, one insect, and one plant species from the list identified by Bininj/Mungguy.

This does not detract from the fact that there will be instances when specific and fine scale actions may be required for individual species, but there will be cases where a broader landscape based management action is the most appropriate.

Issues to follow up

This survey provided some interesting information but also identified some areas for follow up investigation.

There is a need to follow up on plants as they are either genuinely of less concern to Bininj/Mungguy, or, more likely, the level of awareness surrounding many of these species (particularly those restricted to remote areas) is not high. It may be beneficial for researchers and Park managers to provide more appropriate information to Bininj/Mungguy about such poorly-known threatened species, and to continue to provide opportunities for involvement in research, monitoring and management programs.

There were some contrasting responses among informants with some species being considered to be of great concern and rare by some respondents, while others rated them as common and of little concern. There are many possible reasons for this ranging from a need to check identification of the species, to the fact that people are often more familiar with animals and plants from their country and not necessarily that of others.

For example, stone country people, freshwater people, and salt water people are not necessarily familiar with animals only occurring in other people's country.

Several respondents mentioned areas where they regularly saw rare species such as:

- Oenpelli pythons
- Giant Obiri Skink
- Red Goshawk
- Yellow Chat

These species are typically very difficult to find, at times leading to assumptions about their population status. It would be a significant outcome if this process identified populations of these rare and sometimes very cryptic species. Potentially this would allow the consideration of targeted management programs to be put in place for these species in those locations. Following this issue up with the respective respondents would be a useful exercise.

The responses to the question "Can you think of any ways we can help these animals?" were also not extensive. There is an opportunity to reopen this discussion, which would give park managers and Bininj/Mungguy an opportunity for further engagement on this issue and to be able to discuss a much wider range of options.

2.5. Conclusion

This paper illustrates that like much of the broader Australian community the traditional owners and other Bininj/Mungguy of Kakadu have significant concerns about the park's threatened species. One major area of concern is the uncertainty surrounding the causes of threatened species' decline. There is a strong desire to do something about the problem, but a lack of clarity as to what action should be taken.

It is clear that there is no one size fits all approach to this complex issue. There are significant knowledge gaps in both indigenous and non-indigenous expertise, which makes responding to the issue a significant challenge. We are dealing with a changing landscape and diversity of expertise, views and perceptions which adds to the complexity. Hence, our approach needs to be dynamic and flexible in order to address the many species-specific and landscape-scale challenges.

The park needs to continue placing a priority on working with neighbours, particularly neighbouring Indigenous Protected Areas and other indigenous ranger groups to promote an across tenure approach. The park needs to implement targeted management, research and monitoring programs. The effectiveness of threatened species management actions also needs to be monitored and evaluated against agreed performance criteria. The new plan of management and threatened species strategy needs to incorporate many of the concerns expressed by Bininj/Mungguy in this paper and also needs to set out a framework to work closely with the traditional owners and other Bininj/Mungguy in planning and implementing threatened species' management programs.

Acknowledgments

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APPENDIX 2.1: Contents of the Kakadu National Park 5th Plan of Management (2007–2014) relevant to Threatened Species

Management actions in Kakadu need to be consistent with the EPBC Act and the Plan of Management (Director of Parks 2007). Discussion and actions relating to threatened species are found in section 5.8 of the current plan. The contents of this section are summarised below. Details not specifically relevant to the management of threatened species have been omitted.

5.8 Native plants and animals

Our aim

Through working with Bininj, ecological processes are maintained to ensure the viability of populations of native plants and animals currently occurring in Kakadu.

What we are going to do?

Policies

5.8.2 Bininj and Balanda knowledge of and priorities related to the management of native plants and animals and their habitats will be incorporated into management programs.

5.8.3 The Director will encourage and support Bininj to:

- be involved in research and surveys of native plants and animals
- carry out land management work e.g. fire, weed and feral animal management, and record their knowledge of native plants and animals and their habitats.

5.8.4 Data on the location of EPBC Act and Northern Territory listed plant and animal species and others of conservation or cultural significance will be maintained and management programs and activities will ensure that they are protected from inappropriate disturbance.

5.8.5 Monitoring programs will be directed at indicator species identified in regard to major threats and management issues such as fire, weeds and feral animals (see Section 8.6, Research and monitoring).

5.8.6 The Director will support research and monitoring programs for EPBC Act and Northern Territory listed plants and animals, and others of conservation or cultural significance.

5.8.10 The Director will cooperate with Northern Territory management agencies in the protection of native plants and animals within the Kakadu region.

Actions

5.8.15 Implement relevant actions from species threat abatement and recovery plans.

5.8.16 Update the Park's database of EPBC Act listed species and species of conservation or cultural significance at least once every three years.

5.8.20 Continue specific research into the longer-term impacts of the cane toad and potential natural recovery of animal populations such as the northern quoll and goannas.

APPENDIX 2.2: Bininj/Mungguy Questionnaire on threatened species of Kakadu National Park

Questions about threatened species of Kakadu National Park

Names of participants:

Date:

Other people present:

Film: (YES)/ (NO)

Introduction: Explain about the Threatened Species workshop March 26 and 27. Explain that this will be to look at plants and animals that we are worries about because there are not many of them, their numbers are going down, or they only live in a small area.

General questions:

1. *Are there any plants or animals that you are worried about?*
2. *Which plants or animals?*
3. *Why are you worried about these plants or animals?*
4. *Are there any changes you have noticed?*
5. *If so what are the changes you have noticed and when do you think they started?*

Book questions (Hand the book to the participants and ask):

6. *Which plants or animals in this book are most important to you*
7. *Do you have any stories about these plants or animals? Cultural stories or memories of the plants or animals.*
8. *Can you think of any ways we can help these plants or animals?*
9. *How do you think you could help?*

At the end thank the participants and ask them to report when they see these kinds of plants and animals to Park staff so we can learn more about where they are. The book will be available to TOs and staff as soon as possible to help.

APPENDIX 2.3: Sample page from the booklet with photos of threatened and other species that was used to obtain information from traditional owners and Bininj/Mungguy

Species	
Kakadu Dunnart	 Photo Ian Morris
Sandstone False Antechinus	 Photo Anne O'Dea
Arnhem Land Rock Rat	 Photo Anne O'Dea
Common Rock Rat	 Photo Ian Morris
Calabys Pebble-mound Mouse	 Photo Michelle Hatt

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APPENDIX 2.4: Threatened species in Priority order

Note that we editorialise (in brackets and italics) on informants' comments in a few cases, when the given information suggests a misidentification.

Red: of most concern **Orange: of some concern** **Green: of no concern or don't know the species**

MAMMALS

Species	Red	Orange	Green	Comments
Northern Quoll • Stone country • Woodland	13	1	0	• My sister got bitten by Njenma! • Haven't seen them for a while. They normally live in rock but used to see them here too. • Males have a short life - just mate & die. • Of most concern. Cane toads & cats are a problem. The population is starting to decline. • Quoll has dug a djang on the Arnhem land side. We don't see them anymore. • Has been at the causeway at Kapalga & the Mamukala Road • Pleased to hear about comeback • I see them every now and then. • Totem of the Nayinngul family. Used to see big mob. Now only see a couple. That's why the boys are wearing the name for rangers. Named by the old man, so keep eyes open for this one so the kids with the story know what it looks like.
Echidna • Stone country • Monsoon forest • Woodland	7	6	2	• Got them at Kapalga • See once a week or month. Eat this one night time sometimes. • I eat it - even fresh road kill. Delicious. Few people hunt them now. I do hunt them in the cold time. Heard they taste nice. One of those unique animals. • Fight story with almangiyi (turtle) • I had one and someone sold it to a teacher or someone. I got upset. • My favourite for eating. Good tucker. Don't see much. You do see their marks. They grow in Yekke. • I don't see them much. We used to see more. I saw a big one at my place. Grandkids wouldn't let me eat it. • Really hard to find. Not much. Most concern. Nothing. Very worried. • Never saw many. Fire concern
Ghost Bat • Stone country • Woodland	3	2	4	• Small ones are killed by fans. Not these. • See them all the time, used to fly into my house when the power went out. • Old people used to say Buma buma & Namandi (devil) • Different to other bats. Can be killed by fans • I See a lot at Lightning dreaming. • I haven't seen or heard as much them as much as we used to. We can't say their name.
Dusky Rat • Rivers & wetlands	3	1	4	• See them on floodplain • Still plenty living on the hymenachne. • Big mobs. They make holes in mud or grass like water rats • I see them after the rain. Numbers are going down.
Small mice and rats in	2	6	3	• Hard to see them out bush. When burning all the rats come out

general (mulbbu) • All landscape types				• They are around but I wouldn't know one from the other. I didn't realise there were so many of them. • Mekinj Valley big mobs are in sheets of iron. • Had a pet female mulbbu for nearly one year but died last week used to hide behind fridge dog probably killed it • When we used to mow the lawn we used to see rats everywhere, but not now • Don't see them very much now. Used to be more • We should go looking at night. I want to see them more. • Concern for mulbbu especially in the escarpment. • There is a djang for mulbbu. Lots of different sizes and snout.
Black Wallaroo • Stone country	2	4	4	• Big mob. We get many. Good tucker • I love them. I want to try eating them. I never tried. There's a big mob on a spot on Jim Jim Road and on the Old Darwin Rd. • Concern of changing seasons and when rain comes. Hard to find them • They're around but not big numbers. (yummy) • They get moved on by fire • Don't see much. You used to see them driving out to East Alligator.
Sugar Glider • Woodland	2	3	4	• Still see him. He's OK. See him at Kapalga, only once or twice • Still around. I had a pet one. I used to have one. I'd carry it in a billy can. One night 2 buffalo were watching, we heard them crashing, I was up in a tree. I fed him djilli djilli, water lily & meat & damper & woolly bark leaf. He used to climb up & eat flower then come back. • Not much disappearing as well. Don't see them at all. We used to see them - used to get them at Nourlangie Camp. We would carry them around all day in our hair. We used to listen to him when I was a little girl camping and lots of trees were flowering. We'd hear them gliding from tree to tree. They eat fresh leaves too. Don't burn their food (flowers).
Northern Brush-tailed Phascogale • Woodland	2	2	2	• You can still hear them; maybe they're sensitive to fire. little known about them • I don't see it any more but if you look you'll see it. • On the roads very late at night. Used to be plentiful. Saw one driving late after cards coming from Jabiru to Jim Jim. Of most concern. • Don't know it.
Delicate mouse • Woodland	2	2	1	• pirnti = desert name pop not sure. • White one. I know this one, I see them especially after flood near the house.
Arnhem Land Rock Rat • Stone country • Monsoon forest	2	2	1	• Everywhere. Seen Oenpelli Road. Probably more numbers then the Kakadu Dunnart. • Most concern because they live in Stone country. Mainly fire & predators like cat are a threat.
Common Rock-rat • Stone country	2	2	1	• Here all the time. • Most concern because they live in Stone country. Mainly fire & predators like cat are a threat.
Kakadu Dunnart • Stone country	2	2	1	• Trapping at Kapalga *(wrong ID this is not a Woodland species)*. Never seen before • Escarpment country, not around Patonga. • See them once a month. Ran into my house to get away from snakes. Bring back numbers in the Canon Hill area. • Most concern because they live in Stone country. Mainly fire & predators like cat are a threat.
Sandstone False Antechinus • Stone country	2	2	0	• Never seen it. • Most concern because they live in Stone country. Mainly fire & predators like cat are a threat.

Kakadu Pebble- Mouse • Stone country	2	2	0	• See it at Gunbalanya • Most concern because they live in Stone country. Mainly fire & predators like cat are a threat.
Northern brown bandicoot • Woodland	1	3	5	• See big mob at Mamukala but not at Gunbalanya. They are good tucker • See them at night near South Alligator flood plain and Mumukala • Lots of them on the Canon Hill Rd. Plenty still. All sizes. Must be alright. • They dig in the ground to make a nest. We use to feed them at Christian Outreach. • We eat yok but there are not many in Oenpelli. I don't know why numbers are dropping I think dingo or cat. Fire doesn't really affect them because they see/smell fire & go away. • Need to be careful burning in the wet season because they nest. Best to burn straight after Andudjmi finish (late Jan to late Feb for wet season burn). • Don't see much at Gunbalanya. Used to get them when we went for yam. Make a fire in hollow log to make smoke, Then kill it. Tastes like rabbit. • Big Mob Road kill
Black-footed Tree-rat • Woodland	1	3	3	• We don't see them much ever. Nothing. Never see at Patonga • They steal your tucker. I see it at outstation Maningrida. I find him night time when I walk around. • There was biggest mob on one tree at Aurora a few years ago. • People don't avoid them on the road. Road kill especially around Kakadu lodge.
Pale Field-Rat • Woodland • Rivers & wetlands	1	3	1	• Everywhere. Saw it in Maningrida last year • There used to be a big mob at homestead. They used to destroy my garden. I feel sorry for them. My friends giving me a hard time. Mulbu but some people know this one because of tunnels
Brush-tailed Rabbit Rat • Woodland	1	3	0	• Numbers are declining. We used to see them. Fire is burning their homes and domestic animals like domestic cats are a concern because they are a stealthy predator.
Golden Bandicoot • Stone country	1	2	2	• Seen at Kapalga shed – (*probably wrong ID as this is a Stone country animal not woodland)* • Rock country yok. I have seen it. • See them at billabong. We are losing them. • Seen a long time ago in Kakadu. Smaller than yok • Don't know it
Nabarlek • Stone country	1	1	3	• I see them at Gunbalanya. They are too small to eat. He's gamak. He has a song and story. Big mob other side of Gunbalanya. Fire is a problem. Lots everywhere Budbon Gundjeihmi • Difference between Narbaalek and Short-eared rock-wallaby not obvious I'll have to take note (look for this more grey/silver one). • Nabarlek godjekgodjek (move around). He has a song and story Granma used to tell a story and song. Concern of changing seasons and when rain comes. • *(Many people don't seem to differentiate between Narbalek and Short-eared Rock-Wallaby)*
Short-eared Rock-Wallaby • Stone country	1	0	10	• Difference with Narbalek not obvious. same but different to badbong • Concern of changing seasons and when rain comes. • Numbers are high. lots everywhere. I see this one. Live at Spring Peak Hill. • See everywhere, East Alligator upstream. Story about badbong wordj menj. Fell in the water. • *(Many people don't seem to differentiate between Narbalek and Short-eared Rock-Wallaby)*
Rock Ringtail Possum • Stone country	0	6	3	• See them sometimes • Big mob at Kapalga when we used to go night shooting *(probably wrong ID as this is a Stone country not woodland species)*

				• Don’t see many. I think they are disappearing as well. Sometimes see them at night. • Change in numbers wouldn’t be noticed • People used to eat them but not now. Old people like to eat them . • Maybe too much fire in woodland. Used to have pet possum. Don’t see so many around as when I was little. Don't never see it. Never really did.
Little red flying fox • Monsoon forest	0	5	8	• Big mob of these. Lots of flying fox. Everyone knows these. Everywhere lots of them • People don’t eat now because of disease. • I eat that one, but not for a while because they all shifted to Jabiru. There's the odd bunch on South Alligator River. Black one is called Ngangamu in Gundjeihmi. More lighter than gulaban. • Some concern. Flying fox bring diseases. • Numbers coming back up. Seen at rainforest near East Alligator and Bindjil Bindjil. We used to roast them in the ground. They are good to eat if you have asthma.
Northern Leaf-nosed Bat • Stone country • Woodland	0	4	2	• There is another name we can't mention. It is important. • Don’t see around the camp. • *(many people did not differentiate between different micro-bats)*
Northern Brushtail Possum • Woodland	0	3	3	• See them now and then. See this possum at Kapalga • Big mob around. Lucky I don't eat the anymore. Only when a kid gets one. Their hair looks like a cat. Yuck! At Nankeen about 35 years ago they used to be plentiful. On every tree. • I think they are disappearing as well. Sometimes see them at night. • Don’t see many. Numbers going down. Old people at Mekinj used to see the fingernail marks on white gum trees. Now you don't see.
Arnhem Leaf-nosed Bat • Stone country	0	3	2	• We don't normally go looking in rocks so I don't know how they are going. We need to check. • Don’t see around the camp. Some concern for all bats because of roadkill. • *(many people did not differentiate between different micro-bats)*
Grassland Melomys • Woodland • Rivers & wetlands	0	3	1	• See it take over. • We didn't see them for a while.
Bare-rumped Sheathtail Bat • Woodland	0	2	2	• Come out for flowers at night. Check monsoon forest near ruins at Kapalga • Need to check them. • *(many people did not differentiate between different micro-bats)*
Red-cheeked Dunnart • Woodland • Rivers & wetlands	0	2	1	• See them up in the rocks and hollow logs
Fawn Antechinus • Woodland	0	2	0	• No comments
Water Mouse • Rivers & wetlands Coast & tidal flats	0	2	0	• No comments
Dugong • Coast & tidal flats	0	1	4	• Everywhere. Seem to be right where I live don’t know what the seagrass is doing. Not many people hunt them. • Good eating. They use the oil when you boil the tail. Rub it into your skin and it is absorbed into the skin then the muscle then the bones to make you strong. You can also rub it into your hair. That's why Tiwi people have hair down to their bum. Making my mouth water. Lovely but tough skin.

				• Tucker! I don't know about this one because I don't get to look around. • I love dugong as an animal - and to eat occasionally when meat is given to me. I wouldn't shoot it. I'm worried because countrymen eat them - cook them like bullock.
Water rat • Rivers & wetlands • Coast & tidal flats	0	1	2	• See them at Kapalga. See them at billabong or flood plain when we go out hunting. • Live in the water. Eat mussels and andjimdjim (water pandanus) nut. • We look for tracks when we hunt, but not seen for a while.
Common Planigale • Woodland • Rivers & wetlands	0	1	1	• Plenty of these. • Don't know it. Some concern especially because of cats.
Long-tailed Planigale • Woodland • Rivers & wetlands	0	1	0	• No comments –possibly not in Kakadu anyway
Indopacific humpback dolphin • Coast & tidal flats • Rivers & wetlands	0	0	4	• Around. They're there • We used to camp at Munmarlary. In the morning we would see them. • I love them and want to pat them. • Don't know dolphins. I'm a freshwater lady.
Snubfin dolphin • Coast & Tidal Flats • Rivers & Wetlands	0	0	2	• I love them and want to pat them. • Don't know dolphins. I'm a freshwater lady.
Golden-backed Tree-rat • Stone country • Monsoon forest • Woodland	0	0	0	• No comments

BIRDS

Species	Red	Orange	Green	Comments
Emu • Woodland	4	4	7	• Everywhere. Lots of emu at Kapalga. Around. See lots of them around. • We see it. Its totem/dreaming. We ate it last week on the coast road. • Not much. Don't see them much • We do eat them, but last seen about 2004. Fire burns their food supply. • Numbers are dropping. Don't see them much. Wildflower band sings a song about a woman who becomes an emu. • Find one or two now, but they do travel in groups. I wish would shoot only one and leave the others. Don't see them much. They eat palm fruit.
Australian Bustard • Woodland • Rivers & wetlands	4	4	3	• See them at South Alligator & Nardab floodplains & Old Darwin Road • A couple at South Alligator • We used to dig the babies out & hang them up. Kids used to do cruel things. They used to kill them, cook & eat them • I do eat it but it's not my favourite food. I ate one last year - so fat! More of them than before especially on Boggy Plains. I love them. They're beautiful. They're starting to show up on the South Alligator River floodplain on Old Jim Jim Road. • See him a lot still. Has a dreaming on East Alligator River - Benuk Kadjang

				• Good tucker. Not many around. not much. Numbers very low. Saw 2. • Two hanging around the wetlands. Leaving them to bring numbers back. • Saw one Wednesday near Gunbalanya but not as many numbers now.
Spotted Nightjar • Woodland	4	3	1	• Seen at Kapalga. See sometimes. See now and then Jim Jim & Nourlangie. • If young girls see it they hold their breath as they go past or they get bigger boobs. • Never saw them much • Road-kills down on road near South Alligator • *(This one has cultural significance and is clearly differentiated form the Australian Owlet Nightjar)*
Gouldian Finch • Woodland	3	1	2	• Still see them around. • I used to see them but they move to water and feed. Fire affects movement. • My goal to take photos of them
White-throated Grasswren • Stone country	2	1	2	• I could have seen them. Not sure. • They make the noise of the name. I heard that name. • Saw them on the survey past Namarrgon. They're fast and they don't fly much. They hide themselves. Listen, they talk. Did survey. Would like to look for them again. • We don't see them. • Most concern because a lot of tourists and fire concerns.
Partridge Pigeon • Woodland	1	5	7	• Lots of them. Lots at Patonga. Seen along the road. Everywhere. Biggest mob of these in the wild. I haven't eaten one for 5 years. Big mob around. • See some but not many. sometimes • Numbers down at Jim Jim Ranger Station & Red Lily Billabong. • Good tucker but we don't eat them anymore because we worry about them. Bangerreng we look for Ragul and different bird nests. Still a few here and there but some nests get burnt. • They sometimes fly off at the last minute from cars. Cats can hunt them.
Chestnut-quilled Rock-Pigeon • Stone country	1	3	3	• See them in the rock country. They're OK. • I would like to taste them. I think the numbers are going down at Narmarrgon. • Most concern because of fire
Rainbow Pitta • Monsoon forest	1	3	1	• We get them in Manbinik area. In jungle, rain forest • I love that. No change, See them now and then like always. • I see them at Maguk. Ask other countrymen.Seen at Gunlom. • Don't know it.
Hooded Parrot Woodland	1	0	2	• In the morning • *(Not found in Nth Kakadu so not known by many respondents)*
Masked Owl • Woodland	0	2	4	• See them around most of the time • Love these. Didn't know the difference between them and barn/grass owls. • Concerned for raptors and owls because of what they eat especially with cane toads around. • See them everywhere They sit in the mahogany tree. Iwaidja Garrangal. Dreaming site at Indjuwandjuwa. You see 3 stripes on the escarpment when you stand at the rocks where the burial site is. *(Most people could not differentiate between this and the Grass owl)*

Black-breasted Buzzard • Woodland	0	2	2	• Seen at Mamukala. Seen around. Seen at Duwhar • Concerned for raptors and owls because of what they eat especially with cane toads around. • See them around but slowing down number • Don't know it.
Red Goshawk • Woodland • Rivers & Wetlands	0	1	4	• Everywhere. See them hanging around when we're plucking gooses. • *(possible wrong ID this sounds like Whistling Kite)* • Not marram (that's whistling kite). I do see them now and then. • Sometimes round here. We see them flying. Down near Gungurul • Don't know it. *(Most people could not differentiate between this and the whistling kite)*
Australian Owlet-nightjar • Woodland	0	1	3	• I see this one • See sometimes.
Yellow Chat • Rivers & Wetlands • Coast & Tidal flats	0	1	3	• I never saw one. • You see them around if you're out and about. See them in the dry. • I have seen it. They fly really fast and low on the floodplain similar to the flock finch. • They are very rare & hard to find
Peregrine Falcon • Stone country • Woodland	0	1	2	• Seen around. Pick up snakes. Really fast like Karrkein. • Concerned for raptors and owls because of what they eat especially with cane toads around. • Don't know it.
Grass Owl • Woodland	0	1	0	• Concerned for raptors and owls because of what they eat especially with cane toads around. • *(Most people could not differentiate between this and the masked owl)*
Northern Shrike-tit • Woodland	0	0	2	• Never saw them. I want to see this. Never see it here. Don't know it.

REPTILES

Species	Red	Orange	Green	Comments
Frill–neck lizard • Woodland	8	3	4	• See them around. Lots of them on dirty roads. Seen at Kapalga • Everywhere, good eating: old people like them. Eat with rice. • See them in wet season, or dry season in tree. Dropping numbers. • Still see big mob on trees, but not on the road. • Haven't seen for a while. See them every now and then still but danger from cars. They like living life next to the fast lane. Only seen one this year • Numbers going down. Used to see them on each tree when we were hunting. Saw one this morning.
Freshwater Crocodile • Rivers & wetlands	8	1	3	• Lots down Jim Jim way. Still there. When we go spring area swimming, we see them. • Went down when toads arrived but coming back. • Concerned because of saltwater crocs. Would be good to survey for these at Deaf Adder and Lightning Dreaming. We bump into them on croc surveys. • Most concern because they might eat cane toad tadpoles. • Numbers are dropping in Mekinj valley.
King Brown Snake • Woodland	7	2	3	• Lots of them. Everywhere. Water python & king brown mate. When I was small we killed water python and king brown chased us. Ilewarrba = Iwaidja for king brown. Still everywhere - like Gunbalanya billabong.

				• I hate that. I don't like the look of it - thick all the way to the tail. I see beautiful ones on my road, but much less now. Seen once at South Alligator. Not much. not seen many • Don't see them much anymore. Numbers are going down with came toads. Colour changing? • Very few sightings. Old man one at CSIRO boat shed at Kapalga. Has cultural significance.
Yellow-spotted Monitor • Woodland • Rivers & wetlands	6	6	0	• See them on South Alligator floodplain towards Jabiru. Found one on Kakadu highway. • I found my first one at Mudginberri. It was a really big one. • South Alligator: Not many. They used to live at the fig tree at South Alligator- Bring back. • Doesn't think they'll disappear. Saw one at Mamukala last year & this year • I see them now and then still. Not much. • Proper galawan you see at creeks, water courses and billabongs. • Big concern! They're not here anymore - not ever now. Sad. Road issues • All gone. Big problem. Kids don't know what they look like. There used to be many.
Oenpelli Python • Stone country	6	3	6	• East alligator lots of them long time. Still see them • I only saw one once when I was hunting porcupine, I don't eat them. Not interested. • Live in caves. Saw 4m one near Mirray turn off. • I saw a young one under the bonnet of my motor vehicle at Mekinj Valley turn off short cut after leaving it there for 2 weeks. After the floods there are many in the Gunbalanya houses. • Good sign they're here. I feel they are ok. They are seen in warrdeken • On the road. See them not far from the escarpment. • I saw one in southern valley Gunlom a few years ago. • They are still hanging around. They're harmless. Leave them alone.They should stay on country. • Never seen for a long time. Used to see them. Don't see them much anymore.
Death Adder (2 species) • Stone country • Woodland • River & wetland	5	6	2	• Doesn't look for them. Never saw them much. We used to see more. Not so much anymore. • I don't see them at all - ever. I saw one on the floodplain when my sister was pregnant. It went into a crack on the floodplain. • There a few at East Alligator. South Alligator floodplain & Kapalga turn off • Used to be big mob at East Alligator. Still see a few there at old man's camp. Still see tracks. • Numbers are going down. Cane Toad • Saw 1 small one seen at South Alligator rainforest • Not much don't see that much. We say Godjewarre when we walk in the bush which means watch out for this one.
Mertens Water Monitor • Rivers & wetlands	4	6	2	• Lots of them. Still see. Seen at Kapalga • We hunt this one. • Some concern because my countrymen may not realise numbers are dying off. They might kill it especially kids. • See them around. Around but road kill. Not much. We used to see them before. • Numbers going down. When we go swimming we don't see them any more.
Olive Python • Stone country • Woodland	4	5	6	• Lots around. Hotspot at Mirray turn off to Old Darwin Road turn off. • From South Aliigator floodplain to Jabiru. 1 seen at Kapalga • Plenty still, especially in Yekke. Not going down. Same taste like water python. • Don't see them much anymore. Road kill issues. Decreasing numbers. Cane Toad a problem. • Old people eat it. I let them go these days. They used to taste better when I was young. They're getting lesser. I see a lot of young ones on the road - a lot of road kill. People are not kind to animals. They might eat cane toads. • Don't see them.

Water Python • Rivers & wetland	4	4	4	• Lots in Billabong, sometimes they are quiet borloko or some cheeky one especially on the flood plain if they cheeky then Nabang is their father. • A lot around. Everywhere. Numbers still pretty high • I love that. I can eat that - good eating. I had one last year and I showed my kid how to eat it. I only kill them to eat now and then. There are many around and they are increasing - all sizes on Yellow Water and the South Alligator Channel. • Linked to dadbe in story. Good eating. • Old people used to eat them. Some borlokko seem to cross with another species, maybe dadbe. Colour same but bigger nose at Ngara billabong. • Now and again we see them. Not much. Losing numbers. • They eat goose eggs. Used to be good for food, used to see big mob in wet , since cane toads not so much Used to be good for food, used to see big mob in wet , since cane toads not so much .We used to see them at Mary river when we went hunting.

Flatback Turtle • Coast & tidal flats	4	3	3	• Gamak. Still OK. Seen many (Field Island). • West alligator, seen the turtle when the tide was come in. • Not sure, no pigs on Field Island. Should check Middle Beach. • Don't see them much.I don't see these
Mangrove Monitor • Coast &tTidal flats	3	2	1	• Yes. Dig for them eggs. Good to eat. • South Alligator rainforest. Sometimes see them but used to see them a lot before. • Just about finished but you see them on some floodplain like Boggy Plain.
Mitchell's Water Monitor • Rivers & wetlands	3	1	1	• Some concern because my countrymen may not realise numbers are dying off. They might kill it especially kids.
Giant Obiri Skink • Stone country	1	3	1	• See them everywhere • I never saw one before the one that was trapped at Lightning dreaming. • Don't know it • I think numbers are dropping, but I do see them. • Not much. Used to be big mob at Nawurlandja & Burrungai but now nothing • You only see the end bit disappearing under rock. Now nothing.
Northern Giant Cave Gecko • Stone country	1	2	5	• See big mob at Djuwarr • I hate all geckos. Seen n the cave at Deaf Adder. A rock fell down and you can't go there now. • I know this one. Makes a gecko sound: St st • Dropping numbers. Sometimes see it.Not much. Sometimes find baby ones. • Numbers are starting to decline. Haven't seen them for a while. Cats eat them.
Northern Knob-tailed Gecko • Stone country	1	2	5	• Big mob rDjabilukgu. See them at JimJim, Twin Falls & Djuwarr don't go near him (story) • He's cute, as long as he stays in the Stone country. • Big mob at Merl. Sweet. Chase young women. I love him. Has a man story. • Dropping numbers but we do see them. Not much • Has cultural significance.

Green Turtle • Coast & tidal flats	1	0	2	• Don't see them much. • I'm a freshwater woman so don't know sea turtle • I love eating them but only sometimes because only 2 or 3 are hunted at a time. • Big food source
Blue tongue lizard (2 people only) • Woodland	0	1	0	• Never saw them much. Quick. Has babies in Gudjewk. Nephew had one big one last year as a pet. • Used to be good eating but I haven't seen them around for a while. They should be out and about now (end of wet). We had a pet one with a pet cat at Patonga and the lizard ate the kittens. I never ate one since I saw that they can eat anything.
Loggerhead Turtle • Coast & tidal flats	0	1	2	• I'm a freshwater woman so don't know sea turtle
Hawksbill Turtle • Coast & tidal flats	0	0	3	• No comments
Yellow-snouted Gecko • Woodland	0	0	2	• Never seen this one. • *(only found at Kapalga in Kakadu so not known by many people)*
Leatherback Turtle • Coast & tidal flats	0	0	2	• We don't eat this one • I'm a freshwater woman so don't know sea turtle
Olive Ridley Coast & tidal flats	0	0	2	• Goulburn mob eat it. We don't. • I'm a freshwater woman so don't know sea turtle

PLANTS

(The knowledge about plants expressed by respondents was not extensive. Most people only knew about Cycad, Graveside acacia, Cypress pine (Anlarr) Allosycarpia (Anbinik) and Yams

Species	Red	Orange	Green	Comments
Allosyncarpia ternate • Stone country • Monsoon forest	1	2	2	• Warddeken want to protect them. Dropping numbers. • I love them. I'm worried because fire burns them out. I want to grow some. • Endangered plant. Collect seed to protect it so if something happens it is protected
Acacia sp. Graveside Gorge • Stone country	1	1	3	• Beautiful. Many seeds. I got to get some to grow in the nursery. I know it personally. • Toxic. When brown soak for a long time first (a month).
Cycas armstrongii • Woodland	0	4	2	• Didn't know they're here. • They only grow in one place I know of on the way to Jim Jim falls and a fireplot. • See 2 to 3 all the time. Rocky country. Pityrodia is their campground. • Some concern. • Don't see this one but similar to another one. • Mandinjku. Darwin road and Maningrida big mob and a few. We used to eat the fruit.

Yams • Woodland • Monsoon forest • Rivers & wetlands	0	4	1	• Karrbarrda (K) Lungun (I). All gamak. • Some concern because of fire and pigs digging. • Sometimes collect them at night time usually before dry season. Some pigs are terrible. • We make pigs of ourselves over these. Aboriginal people today just leave a hole. They don't leave it to regrow. • Lot of places I knew from growing up all gone now. Pig eating them. I grow my own garrbarrda and Angindjek yam.
Bolbitis quoyana • Stone country • Monsoon forest	0	3	4	• Barrk walk in the wet. Gamak. • I have seen a rock with engraved fossil. Similar leaves. • Need to check out some other places since they are only known from one place. • Should be looked after so it doesn't become endangered.
Callitris intratropica • Stone country • Woodland	0	1	4	• Get many. Is taking over. • Might be at Maguk. • See it in rocky country and springs - Mandjewk time.
Utricularia dunstaniae • Rivers & wetlands	0	1	2	• I know it. Killed by cyclone in Mekinj valley • They can become endangered. Best to collect seed and grow them.
Hibiscus brennanii • Stone country	0	1	2	• Make a spear or use as string to wrap paperbark around meat etc. • Normally found in the river. Medicine
Freycinetia excelsa • Monsoon forest	0	0	3	• It cuts me in the springs in the Stone country. • Big mob at Mekinj Valley near paperbark. Manngoy name of flower.
Hibbertia pancerea • Stone country	0	0	2	• No comments
Lithomyrtus linariifolius • Stone country	0	0	2	• No comments
Monocharia hastata • Rivers & wetlands	0	0	2	• Blue type at Gunbalanya. •
Sauropus filicinus • Stone country	0	0	2	• No comments
Jacksonia divisa • Stone country	0	0	0	• No comments

SHARKS AND RAYS

Species	Red	Orange	Green	Comments
Large tooth Sawfish • Rivers & wetlands • Coast & tidal flats	3	4	0	• I see them when I'm fishing but I don't eat them. • See them at South Alligator crossing on Old Darwin Rd. See them in Mary river • Behind canon hill rock. When you spear it, if you miss he will chase you with his saw. Iwaidja name gumbugumbu like toilet. • Climate change is a threat.
Dwarf Sawfish • Rivers & wetlands • Coast & tidal flats	0	1	1	• Saw one at Indjuwandjuwa. Used to see them when I was young. • Problem. Mekinj Valley has big ones. The water dropped down last dry season after the funeral and they all died.

Northern River Shark • Rivers & wetlands • Coast & tidal flats	0	0	2	• There are lots of types of wamba so don't know. • Cahills crossing & cannon hill • You cut off the tail and drain the blood to make a nice fillet. I never ate it.
Speartooth Shark • Rivers & wetlands • Coast & tidal flats	0	0	2	• There are lots of types of wamba so don't know. • When the tide comes up we see them. They have a long nose so we know it's not bullshark.

INSECTS

Species	Red	Orange	Green	Comments
Leichhardt's Grasshopper • Stone country	4	3	0	• Check Koongarra lease area • Sometimes see them but not much. Cannon Hill seen them once a year. • Maybe we should fence where there's large numbers and keep fire out. Use poison and a fire break and make little fires. There are too many hot fires. • Most concern, especially with fire. There was a fire at Gubara from Wirnmiyurr

OTHER SPECIES MENTIONED OF CONCERN

Mammal	Bird	Reptile	Plant	Fish & Ampbians	Insect
Black flying fox (gulaban) Red kangaroo (antilopine wallaroo)	Wedge-tailed Eagle Magpie geese	Estuarine crocodile File snake,legless lizards freshwater turtles	White lilly good for snake bites	Freshwater fish Frogs	Native bees (sugar bag)

APPENDIX 2.5 SUMMARY OF THREATS TO THREATENED SPECIES IDENTIFIED BY BININJ/MUNGGUY

Threat	Species	Landscape unit
Fire	Small mice in general	All landscape units
	Small mice in general –Kakadu Dunnart , Sandstone False Antechinus, Arnhem Land Rock Rat, Common Rock Rat, Kakadu Pebble- mouse, Rock Ringtail, Narbalek, Short-eared Rock-Wallaby, Black Wallaroo, Echidna Chestnut-quilled Rock-Pigeon, White-throated Grass-Wren Leichhardt's grasshopper Allosyncarpia ternata	Stone country
	Brush-tailed Rabbit Rat, Northern Brush-tailed Phascogale Emu, Partridge Pigeon, Gouldian Finch	Woodland
	Echidna	Monsoon forest

	Allosyncarpia ternata	
Feral Animals All references to feral animals are included here but where specific feral species were mentioned they have been repeated below as well.	Small mice in general Yams	All landscape units
	Small mice in general- Kakadu Dunnart, Sandstone False Antechinus, Arnhem Land Rock Rat, Common Rock Rat, Kakadu Pebble-mouse, Northern Quoll. Peregrine Falcon, Black-breasted Buzzard, Masked Owl, Grass Owl Olive Python, Death Adder, Northern Giant Cave Gecko Native bees	Stone country
	Brush-tailed Rabbit Rat, Common planigale, Northern Quoll, Northern Brown Bandicoot Peregrine Falcon, Partridge Pigeon Olive Python, Death Adder, King Brown Snake Native bees	Woodland
	Common planigale Death Adder, Water Python, Fresh Water Crocodile	Rivers & wetlands
	Flatback Turtle	Coast and tidal flats
Cats (also included in feral animal category)	Small mice in general	All landscape units
	Small mice in general- Kakadu Dunnart, Sandstone False Antechinus, Arnhem Land Rock Rat, Common Rock Rat, Kakadu Pebble-mouse, Northern Quoll. Northern Giant Cave Gecko	Stone country
	Brush-tailed Rabbit Rat, Common planigale, Northern Quoll, Northern Brown Bandicoot Partridge Pigeon	Woodland
Dog - including camp dogs (also included in feral animal category)	Small mice in general	All landscape units
	Northern Bandicoot	Woodland
Cane Toads (also included in feral animal category)	Northern Quoll Peregrine Falcon Olive Python, Death Adder	Stone country
	Northern Quoll Peregrine Falcon, Black-breasted Buzzard, Masked Owl, Grass Owl Olive Python, Death Adder, King Brown Snake	Woodland

	Death Adder, Water Python, Fresh Water Crocodile (including young eating tadpoles)	Rivers & wetlands
Pigs (also included in feral animal category)	Yams	All Landscape types
	Flatback Turtle	Coast& tidal flats
Feral bees (also included in feral animal category)	Native Bees	Woodland
	Native Bees	Stone country
Weeds	Billabongs covered with para grass, salvinia, mimosa, and mission grass. Water lilies covered, nowhere to go fishing Numbers of galawan and turtle are going down. This year not much rain so the weeds are not washed out. Maybe river getting choked up by weed.	Rivers & wetlands
Road Kill	Arnhem Leaf-nosed bat Olive Python	Stone country
	Black-footed Tree Rat, Northern Brown Bandicoot, Northern Brush-tailed Phascogale Spotted Nightjar Olive Python	Woodland
	Mertens Water Monitor	Rivers & wetlands
Fans (ceiling)	Bats in general	All landscape units
	Ghost Bat	Stone country
	Ghost Bat	Woodland
Disease	Little Red Flying Fox	Monsoon forest
Hunting	Dugong	Coast& tidal flats
	Bustard, Emu, Partridge pigeon Yam	Woodland
	Bustard Yam	Rivers &wetland
	Yam	Monsoon forest
Tourists	White-throated Grass-Wren	Stone country
Climate Change & Changing seasons	Black Wallaroo Narbalek Short-eared Rock wallaby	Stone country
	Large tooth Sawfish	Rivers & wetlands
	Large tooth Sawfish	Coast& tidal flats
Cyclone	Utricularia dunstaniae	Rivers & Wetlands

3. Threatened plants in Kakadu: past, present and future

ID Cowie[1] & DT Liddle[2]

3.1 Introduction: threatened plant species occurring in Kakadu National Park

Kakadu National Park has a rich and diverse floristic heritage. The Western Arnhem Land escarpment and plateau is the major centre of plant endemism and diversity in Northern Territory supporting 172 endemic species and is significant on an international scale (Woinarski et al. 2006, Harrison et al. 2009). The north western margin of the plateau has the highest concentrations of endemic species and these species are also frequently 'short range endemics'. Species distributions show something of a 'Galapagos effect' with aggregations of different endemic and often threatened species associated with particular outlier groups, gorge systems or sections of the escarpment, e.g. Mt Brockman outlier – *Hibiscus brennanii*, *Sauropus filicinus*, *Triodia radonensis*; Northern outliers – *Boronia suberosa*, *Gardenia jabiluka*, *Hibbertia brennanii*; East Alligator outliers – *Hibiscus symonii*, *Neobyrnsia suberosa*, *Pityrodia byrnesii*, *Stylidium notable*, *Indigofera adenotricha*. At the generic level, this endemism can be expressed as a geographically sequential series of allopatric, restricted endemics occurring sympatrically with a number of more or less widespread taxa. This pattern is evident to varying degrees in genera such as *Boronia*, *Calytrix*, *Hibiscus*, *Hibbertia*, *Grevillea*, *Lithomyrtus*, *Micraira*, *Stylidium* and *Triodia*. Consequently, Kakadu NP has probably the most diverse flora in the Northern Territory comprising approximately 1870 plant taxa, with 20–30 species endemic to Kakadu itself and several hundred endemic to the western Arnhem Land plateau and escarpment. While the flora is among the best documented in the Northern Territory as a result of more than 40 years of survey and ecological research, the taxonomic description and conservation assessment of the flora is far from complete. Knowledge about the distribution, abundance, population trends, threats and management requirements of most of Kakadu's threatened plant species is quite limited.

Plant species in Kakadu are listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and the Territory Parks and Wildlife Conservation Act 2000 (TPWC Act), but are sparsely represented on the IUCN Red List. The criteria used to assess taxa are similar in both the Northern Territory and Commonwealth systems but the latter lacks the equivalent of criterion D2 (population size very small or restricted) in the IUCN system (IUCN 2001; TSSC undated). While there is some overlap between the EPBC and TPWCA species lists for Kakadu, the differences are more striking. One reason is that the TPWC Act is subject to more frequent and rigorous reviews (at 5-yearly intervals) than the more ad hoc reviews of the EPBC Act. The latter lags some time behind the Northern Territory list and the two are brought into alignment through a periodic review process which depends largely on the Northern Territory listings for its information. Also, the EPBC listings tend to exclude species whose distribution extends interstate or overseas and where the species

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are not known to be threatened in those areas; thus the EPBC list for Northern Territory includes mostly Northern Territory endemic species.

Fifteen (including one doubtful) threatened species and one threatened community are recorded as occurring in Kakadu (Table 3.1). Two species are listed under both EPBC and TPWCA, while one species and one plant community are listed federally but not in the Northern Territory (which does not have legislation for listing threatened communities). An additional 12 species are listed under Northern Territory legislation and are under consideration for national listing.

Table 3.1 Threatened plant species recorded from Kakadu NP and their broad habitat preferences. Conservation status codes: CR=Critically Endangered; EN=endangered; VU=vulnerable. Note: * = NT Endemic; + Kakadu Endemic; ^ = Reports of *Cycas armstrongii* from Kakadu need further investigation (see text).

Species or community	EPBC Act Status	NTPWC Act Status	Broad habitat
+*Acacia* sp. Graveside Gorge (=*Acacia equisetifola* Maslin & Cowie ined.)	CR	CR	sandstone shrubland complex
Bolbitis quoyana		VU	wet gorge (sandstone)
*^*Cycas armstrongii*		VU	woodland (lowland)
Dienia montana (=Malaxis latifolia)		VU	rainforest (lowland)
Freycinetia excelsa		VU	rainforest (sandstone)
**Hibbertia brennanii*		VU	sandstone shrubland complex
+*Hibbertia pancerea*		VU	sandstone shrubland complex
Hibbertia sp. South Magela		VU	sandstone shrubland complex (cliffs)
+*Hibbertia tricornis*		VU	sandstone shrubland complex
+*Hibiscus brennanii*	VU	VU	sandstone shrubland complex
+*Jacksonia divisa*		VU	sandstone shrubland complex
**Lithomyrtus linariifolia*		VU	sandstone shrubland complex
Monochoria hastata		VU	wetlands (floodplains)
**Sauropus filicinus*	VU	DD	sandstone shrubland complex (cliffs)
Utricularia dunstaniae		VU	poorly drained sandsheets (lowland)
Arnhem Plateau Sandstone Shrubland Complex	EN		

Most of the species involved are endemic to the Northern Territory and have restricted distributions associated with the western Arnhem Land escarpment, with five of these

also endemic to Kakadu. A further five species occur outside the Northern Territory, either interstate (*Utricularia dunstaniae*) or overseas (*Monochoria hastata)* or both *(Bolbitis quoyana*, *Dienia montana, Freycinetia excelsa*). As they are relatively obscure most of the threatened plants have no common names. Most are associated with sandstone habitats, mostly shrublands or woodlands although in a few cases wet gorges or rainforest. One species is from lowland rainforest and another is a wetland species. Reports of *Cycas armstrongii* from Kakadu need further investigation - records of *Cycas* from the Goodpala-Gimbat-Jim Jim area are now regarded as *C. conferta* while plants from the Mt Bundey area are regarded as hybrids of *C. armstrongii* and *C. conferta.*

The species considered threatened in Kakadu NP have changed considerably over the past 25 years as further general and targeted surveys have been conducted and information about distribution, abundance and threats has become more complete (Briggs & Leigh 1988, Cowie 2005, Kerrigan 2003, 2004, Leach et al. 1992). With 133 data deficient taxa known from Kakadu (and over 900 known in NT), refinement of threatened species listings is likely to continue for many years as additional information is gathered. Rare species are usually too rare for the park-wide biodiversity monitoring program, based on 136 permanent 'fire plots', to provide insights into distribution, basic population parameters and trends (Edwards et al. 2003). Changes in species concepts resulting from taxonomic research can also affect conservation assessments over time. For example work on Northern Territory *Cycas* resulted in recognition of several additional species with narrower species concepts where three more broadly circumscribed species had previously been accepted (Chergwin & Wigston 1993, Hill 1993, 1994, 1996; Maconochie 1978). Conservation assessments and listings rely on a solid taxonomic foundation but in some cases species are not well circumscribed, with the original species concepts well over 100 years old, based on very little data (specimens) and with little subsequent critical examination.

In addition to the threatened taxa listed in Table 3.1, many additional species found in Kakadu are at risk of qualifying for a threatened category over the next 10 years (Tables 3.2, 3.3). Some 133 data deficient taxa – those rare or rarely recorded, but with insufficient information to assess against IUCN criteria – are known from the Park and listed as Data Deficient under Northern Territory legislation. Many of these appear to be as rare as or rarer than some of the threatened species, and it is certain that some will prove to be threatened following further survey. A further 67 species from Kakadu are regarded as Near Threatened under Northern Territory legislation. Species in this category are regarded as having small populations or limited extent of occurrence such that they could quickly become threatened by grassy weed invasion, changed fire regimes, climate change, introduced plant pathogens (myrtle rust) or some combination of these factors. An additional 'at risk' group consists of species which are currently more common but likely to decline.

Table 3.2 Groups and examples of species considered at risk of decline in future.

Common name/ category	Scientific name	Major habitat	Rationale
Near Threatened species	**67 taxa (examples below)**	**mostly sandstone**	**small populations or limited extent of occurrence such that could quickly become threatened by weed invasion, changed fire regimes, climate change, myrtle rust or some combination of these.**
	Acacia amanda	Eucalypt woodland	shrub; 13 records, Extent of occurrence 9 km^2; southern Kakadu; resprouts after fire, no obvious threats.
	Acacia rigescens	sandstone woodlands and shrublands	shrub or small tree; 4 localities, Extent of occurrence now known to be much greater than 21 km^2 as at 2010; no evidence of decline and no strong threats.
	Boronia suberosa	sandstone cliffs	55 records, Extent of occurrence 8 km^2; cliff specialist; has had targeted survey and delisted as a consequence; no obvious threats.
	Dichapetalum timoriense	sandstone gorges	104 records, Extent of occurrence 238 km^2; has had targeted survey and delisted as a consequence; no obvious threats.
	Gleichenia dicarpa	gorges	fern; one known locality near Twin Falls; stochastic events a possible threat.
	Hibbertia auriculiflora subsp. *auriculiflora*	sandstone	shrub; 4 records, Extent of occurrence 35 km^2
	Hibbertia extrorsa	sandstone	shrub; 3 records, Extent of occurrence 232 km^2
	Hibbertia guttata	sandstone	shrub; 13 records, Extent of occurrence 66 km^2
	Hildegardia australiensis	sandstone scree and gorges, limestone	deciduous tree; c. 8 small populations from Pul Pul to Mann River Gorge; Extent of occurrence 3558 km^2
	Hibiscus symonii	sandstone	shrub; Ubirr area; restricted range endemic; locally common but extent of occurrence 5 km^2
	Melaleuca stipitata	stony hills	small tree; Bukbukluk to Fergusson R; 3 localities; extent of occurrence 22 km^2 but area of occupancy is very low
	Microlepia speluncae	mesic sandstone gorges	robust fern; 1 locality, Extent of occurrence unknown, but very small; stochastic events a threat but otherwise appears secure
	Stylidium notabile	sandstone (overhangs)	annual herb; 4 locations, Extent of occurrence 20 km^2; population size is plausibly very small, but there is no evidence of decline and no clear threats
	Triodia uniaristata	sandstone	Spinifex; 7 records, Extent of occurrence 143 km^2
Data Deficient species	**133 species (examples below)**	**mostly sandstone**	**many are rarer than threatened species, but less well understood**
	Corchorus obclavatus	sandstone	shrub; 2 localities (northern Outliers and Twin Falls); Extent of occurrence not known
	Hibbertia fractiflexa subsp. *filicaulis*	sandstone	subshrub; 3 locations, Extent of occurrence 212 km^2
	Hibbertia incompta	sandstone	subshrub; 2 known locations, Extent of occurrence 205 km^2

	Hibbertia ligulata	lowland, tall E. tetrodonta forest	subshrub; 2 known locations; Extent of occurrence not known; Belyangardy Spring area; apparently resprouts after fire.
	Indigofera adenotricha	sandstone	shrub; not relocated in 3 targeted surveys; 2 known localities; Extent of occurrence not known
	Microcorys elliptica	sandstone cliffs	subshrub, cliff specialist, at low densities; 11 locations, Extent of occurrence 217 $km^{2;}$ no obvious threats, Near Threatened probably appropriate
	Pityrodia byrnesii	sandstone	restricted endemic shrub; East Alligator area; seven localities; extent of occurrence 42 km^2
	Solanum sejunctum	sandstone	restricted endemic shrub; 10 locations, Extent of occurrence 126 km^2
	Spermacoce brevidens	sandstone (ish)	restricted endemic herb; 7 records, Extent of occurrence 1 km^2
	Triodia radonensis	sandstone	restricted endemic Spinifex; 1 records, Extent of occurrence unknown, probably very small.
Other species	*Callitris intratropica*		common but declining
	Allosyncarpia ternata	stone country	common but likely to decline with grassy weed invasion or changed fire regimes; Myrtle rust is a significant potential threat.
	Myrtaceae	those in humid habitats, such as floodplain back-swamps, springs, water falls and protected gorges.	Myrtle rust
	Cephalomanes obscurum	riparian	disjunct fern; just out of Kakadu (Magela Ck); listed as EN in NT; may be found in Kakadu
	various yams		common but likely to decline with grassy weed invasion or changed fire regimes
	savanna fruit trees (e.g. *Persoonia, Terminalia, Buchanania*)		common but likely to decline with grassy weed invasion or changed fire regimes
	Alloteropsis semialata		common; ecologically important; marker of fire and grazing regimes; likely to decline with grassy weed invasion or changed fire regimes
	Hymenachne acutigluma	wetlands	common but likely to decline with grassy weed invasion (Olive Hymenachne, Para grass); rising sea levels.
	Eleocharis sphacelata	wetlands	common but likely to decline with grassy weed invasion (Olive Hymenachne, Para grass); rising sea levels
	Obligate-seeding shrubs e.g. *Petraeomyrtus* (*Regelia) punicea*	stone country	many decreasing; marker of fire regimes;

3.2 The status and trends of threatened plants in Kakadu

For most threatened plant species, population trends are poorly known, while estimates of population size, extent of occurrence and area of occupancy vary from reasonably reliable to highly uncertain (Table 3.3). Information on population status, monitoring and trends are summarised in Table 3.3 and are drawn from various survey reports and information sheets: *Acacia* sp. Graveside Gorge (Kerrigan 2003, 2004; Kerrigan et al. 2007), *Bolbitis quoyana* (Cowie & Westaway 2013a), *Cycas armstrongii* (Liddle 2009), *Dienia montana* (Kerrigan 2004, Kerrigan & Cowie 2007c), *Freycinetia excelsa* (Kerrigan et al. 2007), *Hibbertia brennanii* (Westaway & Cowie 2013a), *H. pancerea* (Westaway & Cowie 2013b), *H.* sp. South Magela (Cowie 2005, Westaway & Cowie 2013c), *H. tricornis* (Westaway & Cowie 2013d), *Hibiscus brennanii* (Kerrigan 2003, 2004, Kerrigan & Cowie 2007a), *Jacksonia divisa* (Cowie & Westaway 2013b), *Lithomyrtus linariifolia* (Kerrigan 2003, 2004, Kerrigan & Cowie 2007b), *Sauropus filicinus* (Kerrigan 2003, 2004, Kerrigan & Cowie 2007e), *Monochoria hastata* (Kerrigan 2003, 2004, Kerrigan & Cowie 2007d), *Utricularia dunstaniae* (Kerrigan & Cowie 2007f; 2013), available from http://www.lrm.nt.gov.au/plants-and-animals/threatened-species/specieslist#plants). While monitoring plots have been established for some species, there has been little effective monitoring of populations. Consequently, the effectiveness of management cannot be assessed or easily refined and it is difficult to prioritise management actions between species.

There has been some (but limited) targeted survey for seven species; another eight species lack even this. While general flora surveys have often provided the first indication of which species are rare and threatened (or data deficient), targeted surveys have allowed refinement of our knowledge of distribution, abundance, and threats and improved our understanding of species biology. This improved information base has resulted in a more robust set of listings overall as a consequence some species have been 'delisted' and other species listed for the first time.

Single monitoring plots have been established for five threatened plant species - *Acacia* sp. Graveside Gorge, *Hibiscus brennanii*, *Lithomyrtus linariifolia*, *Monochoria hastata* and *Sauropus filicinus* but there has been little follow up assessment of these. For a few additional species, there has been formal or informal reassessment. Anecdotal reports suggest that the small population of *Bolbitis* has declined due to scouring from flooding of the narrow, otherwise protected gorge it inhabits. The population of *Dienia montana* (formerly *Malaxis latifolia*) was not relocated during a 2003 survey but there have been no attempts at relocation since. The species dies back to a tuber during unfavourable periods and this may make it difficult to locate.

In assessing the risk of extinction of some fern and orchid species, the possible effects of immigration and long distance dispersal in founding or maintaining populations must be considered. In the NT, many fern and orchid species in wet rainforest or gorge habitats exhibit a pattern of highly disjunct distributions with small subpopulations and short geographic ranges. Long distance dispersal events are considered disproportionably important in determining the distribution pattern of ferns. A single fern plant can produce millions of dust-like spores with dispersal of some spores over thousands of kilometres being possible but rare (Keesler 2010). Orchid seeds are similarly minute and presumably subject to similar dispersal forces. While immigration and long distance dispersal can be inferred, the frequency and importance of these events is unclear. For some species, it may be rare and too infrequent to downgrade the category when the

IUCN regional algorithm is applied (IUCN 2003, Kessler 2010). It is also possible that current highly disjunct distributions are a product of vicariance, by which an original contiguous population has been fragmented by long term climate change or geological processes.

Data derived from long-term monitoring plots established in Kakadu National Park in the mid-1990s illustrate that the condition of much of the flora of the Arnhem Plateau Sandstone Shrubland Complex is in decline. Following extensive fires in the ecological community in 2001, 2004 and 2006, Kakadu National Park has developed a fire management plan which incorporates threshold criteria specifically for the Arnhem Plateau (Petty et al. 2007). Obligate seeder taxa (those regenerating from seed after fire with little capacity to regenerate vegetatively) with maturation periods in excess of five years are especially vulnerable to extensive and frequent fires (Yates et al. 2008). Assessment of the impacts of fire regimes on Arnhem Plateau obligate seeder species derived from 48 monitoring plots, (Russell-Smith et al. unpublished data) show that those requiring four or more years to attain sexual maturity were lost where fires occurred at frequencies of four or more fires over the fifteen year (1995–2009) assessment period. This equates to an annual fire frequency of 0.27, or one fire every 3.75 years. That same assessment also showed that 53% of the entire mapped Sandstone Shrubland Complex experienced four or more fires over that period, and 30% of the Complex experienced five or more fires (i.e. an annual fire frequency of 0.33, or one fire every three years).

Table 3.3 Population status, monitoring and trends in threatened plant species recorded from Kakadu NP. ?= a high degree of uncertainty.

Scientific name	% Kakadu range: total range	Extent of occurrence	Population size (mature individuals)	Trend	Monitoring programs and survey
+*Acacia* sp. Graveside Gorge (=*Acacia equisetifola* Maslin & Cowie ined.)	100	<<1 km^2	850-950	increase?	occasional monitoring; DLRM survey; monitoring plot established
Bolbitis quoyana	5 (but 100% of NT records)	<1 ha	200	decrease	no monitoring; incidental survey; anecdotal reports
*^*Cycas armstrongii*	<5?	46,000 km^2	100,000	decrease	monitoring established but not in Kakadu
Dienia montana (=*Malaxis latifolia*)	5 (but 100% of NT records)	<1 ha	27	decrease?	no monitoring; DLRM survey, not relocated 2003
Freycinetia excelsa	5	51,690 km^2	<1,000	unknown	no monitoring; no targeted survey
**Hibbertia brennanii*	50	18 km^2	>1,000	unknown	no monitoring; no targeted survey
+*Hibbertia pancerea*	100	2 ha	? very small	unknown	no monitoring; no targeted survey; some plants in fire plot 121
**Hibbertia* sp. South Magela	90	1 km^2	<1,000	unknown	no monitoring; initial DLRM survey
+*Hibbertia tricornis*	100	? very small	? very small	unknown	no monitoring; no targeted survey
+*Hibiscus brennanii*	100	1.5 km^2	441	unknown	no monitoring; DLRM survey; monitoring plot established
+*Jacksonia divisa*	100	<2 km^2	< 1,000?	unknown	no monitoring; no targeted survey
**Lithomyrtus linariifolia*	90	3,411 km^2	> 200?	unknown	no monitoring; DLRM survey; monitoring plot established
Monocharia hastata	5	3,487 km^2	5,000	unknown	occasional monitoring; DLRM survey; monitoring plot established
**Sauropus filicinus*	95	229 km^2	>66	unknown	no monitoring; DLRM survey; monitoring plot established
Utricularia dunstaniae	5	<2,000 km^2	<1,000?	unknown	no monitoring; no targeted survey

3.3 Management requirements and current management

No threatened plant species in Kakadu is currently the subject of a formal Recovery Plan under the EPBC Act. However, management actions have been recommended in various studies and in the Northern Territory Threatened Species.

Information Sheets available for all species (see http://www.lrm.nt.gov.au/plants-and-animals/threatened-species/specieslist#plants). In addition, the Northern Territory has a Cycad management plan which provides for the management and sustainable harvesting of all Northern Territory Cycad species including *C. armstrongii* (Liddle 2009). Threatened plants in Kakadu have been the subject of some targeted surveys and monitoring plots have been set up for several species. However, these have rarely been reassessed and there has been little species specific management. In most cases current management is based on quite limited knowledge, and often on educated but little tested assumptions about life history and population biology. While there has been very limited monitoring, better fire management has probably improved the situation for some species. Long term weed management programs have reduced the threats for others. In terms of threats, distribution and ability to respond to management, three broad groups of plants can be identified.

The first group consists of species more or less endemic to Kakadu, found in sandstone shrublands and with a medium level threat from inappropriate fire regimes (*Acacia* sp. Graveside Gorge, *Hibbertia brennanii*, *H. pancerea*, *H. tricornis*, *Hibiscus brennanii*, *Jacksonia divisa*, *Lithomyrtus linariifolia*). The key contemporary management issue for this group of species and the Arnhem Plateau Shrubland Complex flora in general is the high frequency of very extensive, relatively non-patchy and severe late dry season wildfires (Yates et al. 2008, Edwards & Russell-Smith 2009). These species are fire sensitive obligate seeders, frequently found only in longer-unburnt and fire protected pockets amongst sandstone boulders and outcrops. Recurring fires at short intervals (<5 years) have been observed to cause localised loss of longer maturing obligate seeder taxa at monitoring plots within Kakadu and Nitmiluk National Park (Russell-Smith 2006, Russell-Smith et al. unpublished; J Russell-Smith pers. comm. 2011).

While, there has been improved fire management of the Arnhem Plateau Shrubland Complex recently, some species may require individually targeted fire management. Relying on general fire management strategies leaves room for a considerable amount of variation in the fire regime experienced by particular threatened species with very small extents of occurrence. Such species may have their entire population severely affected by a few adverse fire events. What would be a local extinction event of little consequence for a more widespread species could be catastrophic for a highly restricted one. In order to maintain populations and foster recovery, fire management would be improved by geographically targeting the needs of particular species.

While this group is generally likely to respond to better fire management, research and monitoring are needed to ensure that specific management is suited to the varying requirements of individual species. Some species such as *Hibiscus*, *Acacia* and probably *Jacksonia* can show mass recruitment from long-lived soil-stored seed following a fire event, with the population peaking, plants subsequently senescing and eventually the population declining a number of years after fire. However, seed longevity, conditions required for recruitment, life history parameters and hence optimum fire free periods are not well understood for many species. Observations about the persistence of long-lived,

soil stored seed may not hold in all situations. Despite apparent prolific production of seed by some *Acacia* spp., very low to non-existent soil seedbanks have been recorded in extensive soil-seedbank germination studies in samples taken from under *Acacia* stands in western Arnhem Land sandstone habitats (J. Russell-Smith, unpublished data), perhaps due to seed predation. However, plants like the fleshy-fruited *Lithomyrtus* may have entirely different dispersal and post fire recruitment strategies.

Establishment of ex-situ populations, either in the wild or in cultivation is a viable option for this group and would provide some additional security. At the simplest level plants could be introduced to cultivation at minimal cost with the involvement of various partners and with little effort. This would also have the benefit of raising community awareness of the species and issues. However, we believe that efforts at ex-situ conservation should be additional to, rather than replace, in-situ conservation activities such as management, monitoring and research.

Considering the Arnhem Plateau Shrubland Complex more generally, available information indicates that around 50% of the constituent shrub taxa are obligate seeders. As many as 10% exhibit primary juvenile periods (the time taken to onset of maturation) of five years and more (Russell-Smith et al. 1998, Russell-Smith et al. unpublished). While the majority of these obligate seeders comprise species with persistent soil seedbanks (e.g. *Acacia* and most legumes, *Hibbertia* and *Hibiscus*) which may be able to persist in the face of at least some repeat short-interval fires, others like the long-lived serotinous shrub, *Petraeomyrtus punicea* (rock myrtle) do not exhibit this capacity (Russell-Smith 2006). Even allowing for some degree of fire patchiness in sandstone terrain, the high frequency of large fires documented for western Arnhem Land is a significant threat to the ecological community, especially when it is considered that patch sizes of sandstone heath habitats are typically very small (median 3 ha; Price et al. 2003, Edwards & Russell-Smith 2009). Implementation of a fire management plan which incorporates threshold criteria specifically for the Arnhem Plateau has improved the situation for this ecological community (Petty et al. 2007, Murphy 2013).

The second group of species has populations highly constrained by the naturally available habitat and comprises species that are restricted to specialized habitats. Within this group two cliff-dwelling species nearly endemic to Kakadu (*Hibbertia* sp. South Magela, *Sauropus filicinus*) have at most low level threats and are not likely to respond strongly to management. They have small geographic ranges and are probably isolated by dispersal barriers from similar nearby habitat, which may support related taxa. Suitable habitat available to the species is likely to already be fully occupied.

Two highly disjunct species are known in Northern Territory only from single locations in Kakadu but also occur interstate and overseas. The fern *Bolbitis quoyana* is highly constrained by the limited immediately available habitat (a protected wet gorge) but is threatened by stochastic events (flooding) that are difficult to manage. It is known in Northern Territory from only one gorge system at Dinner Creek in Kakadu. The ground orchid *Dienia montana* has not been relocated since its initial discovery in NT in rainforest at a spring on Munmarlary, but requires further targeted survey, perhaps in a different season. The species may be threatened by feral animals or floods. A third species, *Freycinetia excelsa* is similarly habitat constrained but has a relatively wide but sparse distribution in Northern Territory and also occurs elsewhere in Australia and overseas. Elsewhere in the NT this species is considered to be under a low to moderate level of threat from feral pigs, however, the single known extant population in Kakadu, on sandstone at Dinner Creek, is to a large degree protected from pigs by its topographic

position. For these three species, establishment of ex-situ populations, either in the wild or in cultivation, is probably one of the best available management options and should be seriously considered.

The third group consists of disparate? lowland species with a small part of their range in Kakadu but with varying threats and management needs. It includes *Monochoria hastata* which is threatened by saltwater intrusion, grassy weed invasion and perhaps also successional changes in wetland vegetation. *Utricularia dunstaniae* and *Cycas armstrongii* are relatively widespread and suffering reduction in the vicinity of Darwin but are vastly different in their abundance. The former occurs in very small patches of an unusual sandy wetland habitat and the latter across broad areas of woodland in the Darwin area.

Table 3.4 Recommended and prioritised research, management and monitoring actions for threatened plant species occurring in Kakadu. High priority actions are marked in bold. Assessment of biology may include fecundity, flowering and fruiting phenology, reproductive success, seed and seedbank longevity, germination requirements and response of seeds, seedlings and adults to fire. Note: * = NT Endemic; + Kakadu Endemic; ^ = Occurrence in Kakadu needs further investigation (see text).

Species or community	Actions		
	Research	Management	Monitoring
+*Acacia* sp. Graveside Gorge (=*Acacia equisetifola* Maslin & Cowie ined.) (Group 1)	**assess abundance, distribution, biology and threats, especially fire (high)**	**targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population; establish ex-situ populations (by seed) (high)**	**implement / recommence specific monitoring program to establish the persistence of seedlings and time to reproductive maturity (high)**
Bolbitis quoyana (Group 2)	assess abundance, distribution (new populations)	flood scour threat difficult to manage; **establish ex-situ populations (high)**	**implement specific monitoring program (high)**
*^*Cycas armstrongii* (Group 3)	assess abundance, occurrence, distribution, threats	fire and weed management to reduce fire severity and/or frequency, if applicable	maintain monitoring program, if applicable
Dienia montana *(=Malaxis latifolia)* (Group 2)	**improve detection methodology; assess abundance, distribution and threats (high)**	feral animal control & exclusion as determined by research and monitoring; establish ex-situ populations	implement specific monitoring program
Freycinetia excelsa (Group 2)	assess abundance, distribution and threats	feral animal control?; Tiwi Recovery Plan 2007	implement specific monitoring program
**Hibbertia brennanii* (Group 1)	assess abundance, distribution, biology and threats (medium)	targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population	**implement specific monitoring program (high)**

[+]*Hibbertia pancerea* (Group 1)	**assess abundance, distribution, biology and threats (high)**	targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population; establish ex-situ populations	assess utility of Fire Plot data for monitoring and implement specific monitoring program if required
**Hibbertia sp. South Magela* (Group 2)	assess abundance, distribution and threats	no obvious threats; (listed because of very small population)	implement specific monitoring program
[+]*Hibbertia tricornis* (Group 1)	**assess abundance, distribution, biology and threats (high)**	targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population; establish ex-situ populations	implement specific monitoring program
[+]*Hibiscus brennanii* (Group 1)	assess abundance, distribution, biology and threats	**targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population (high)**; establish ex-situ populations	**reactivate specific monitoring program (high)**
[+]*Jacksonia divisa* (Group 1)	**assess abundance, distribution, biology and threats (high)**	**targeted fire management to reduce fire severity and/or frequency to levels needed to sustain population (high)**; establish ex-situ populations	**establish and implement specific monitoring program (high)**
**Lithomyrtus linariifolia* (Group 1)	assess abundance, distribution, biology and threats	**reduce fire severity and/or frequency in stone country (high)**	**reactivate specific monitoring program (high)**
Monochoria hastata (Group 3)	assess abundance, distribution, biology and threats, response to grass invasion (medium)	control weeds in wetlands; control saltwater intrusion; establish ex-situ populations	reactivate specific monitoring program (medium)
**Sauropus filicinus* (Group 2)	assess abundance, distribution, taxonomy, biology and threats	no obvious threats	reactivate specific monitoring program
Utricularia dunstaniae (Group 3)	improve detection methodology; assess abundance, distribution and threats	no immediate threats in Kakadu	implement specific monitoring program
Arnhem Plateau Sandstone Shrubland Complex		**maintain reduced fire severity and/or frequency in stone country (high);**	**continue monitoring program (high)**

3.4 Priorities for management

Priorities for research, management and monitoring for each species are summarised in Table 3.4. These priorities are drawn in part from existing threatened species information sheets and previous survey reports but are also based on the likely ability to respond to management and the proportion of the taxon's range within Kakadu.

For many species there is an element (or even a high degree) of uncertainty regarding their status in Kakadu and a clear priority is to clarify this status. While clarifying threats and management needs are of primary importance for many species, for some such as *Cycas armstrongii* which may not even occur in Kakadu, their distribution and abundance in the Park also needs to be established. There is also a large pool of rare Data Deficient species requiring resolution of their status. On past experience, some of these will certainly warrant a threatened status although the majority are likely to be coded as Near Threatened or even Least Concern once more is known of their distribution, abundance and threats.

For most sandstone shrubland species and the sandstone shrubland community itself, inappropriate fire regimes are the primary or a major threat and the management of fire is a high priority. Indications are that fire management of this community has improved over the last few years. However, untargeted broad-scale fire management is something of a 'blunt instrument' for managing species of highly restricted distribution (or restricted plant communities such as rainforest). There is a clear need to refine the fire management of individual threatened species through monitoring and develop more targeted fire management. Establishment conditions and fire regimes favouring fleshy-fruited species (perhaps with short-lived seeds) such as *Lithomyrtus* may well be quite different to those encouraging regeneration of hard-seeded species such as *Acacia, Jacksonia* and *Hibiscus*. While the ongoing fire-plot monitoring program has provided feedback on the effectiveness of fire management in the sandstone shrubland complex in general, it provides little direct feedback for most threatened plant species. In several cases monitoring plots are already established for particular species but there has been little follow-up assessment. Without monitoring it is difficult to either evaluate the effectiveness of management or to refine management to suit the needs of individual species.

Weeds are a major threat for a number of species either through direct displacement of native species or through indirect effects on fire regimes or both. Long term weed management programs have been very important in preventing the decline of a suite of wetland species and woodland species not yet listed as threatened. Some threatened species – *Monochoria hastata* in particular – would probably have declined without *Mimosa* control. Grassy weeds may be a long term threat not just for species in lowland woodlands and wetlands. Gamba grass colonizes steep sandstone road cuttings around Darwin (albeit with relatively low biomass) and may have some capacity to colonise sandstone shrublands, affecting fire regimes there. Annual Mission Grass *Cenchrus pedicellatus* (formerly *Pennisetum pedicellatum*) has been found thriving amongst sandstone outcrops on the Fish River escarpment. Olive Hymenachne (*Hymenachne amplexicaule*) and Para Grass (*Urochloa mutica*) appear to largely displace a suite of native wetland species. However, the IUCN criteria are such that widespread but depleted species may not qualify for a threatened status until populations are at very low levels (Criteria B, C, D) because the time scales involved are too long to quality under Criteria A and E or there are insufficient data to substantiate a quantitative analysis of the probability of extinction

(Criterion E). As stated in the IUCN guidelines the "Criteria are designed to identify taxa that exhibit symptoms of endangerment, and not simply depletion or conservation priority" (IUCN 2011).

For species highly constrained by the amount of available habitat such as those in wet gorges, in lowland spring rainforests and dwelling on cliff faces, establishment of ex-situ populations is a high priority where there are significant threats (e.g. *Bolbitis quoyana*, *Dienia montana,* perhaps *Freycinetia excelsa*). Some restricted, habitat constrained species have low level threats and establishment of ex-situ populations is probably the only option to increase population size but of low priority. For many species ex-situ populations can provide an extra layer of insurance and collection of small amounts of propagation material could readily be included in a monitoring or survey program at little additional cost. Involvement of suitable partners in the process would help to minimise costs. Growing plants in places where they can be readily observed by managers and scientists can also provide useful information on life history parameters which can help inform management. An additional advantage of establishing ex-situ populations it that they can raise the profile of conservation programs and awareness of threatened species. However, such a program should not be to the detriment of *in situ* management and monitoring. Not all species may be easy to propagate and the commitment of substantial resources to solving the issues involved would need to be carefully weighed against the benefits.

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4. Threatened invertebrates in Kakadu National Park

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4.1 Introduction

Invertebrates are the backbone of biodiversity, with insects alone possibly contributing more than 90% of all animal species (Wilson 1988). Invertebrates also play dominant roles in the functioning of ecosystems, maintaining healthy soils, driving nutrient cycling and energy flow, and regulating plant productivity and reproduction (Wilson 1987). Despite this, invertebrates generally attract little attention in conservation management.

Kakadu National Park harbours many thousands of insect species, with some having high public profiles. These include the striking Leichhardt's grasshopper (*Petasida epiphiggera*), one of Australia's most colourful insects and of high cultural significance for local Aboriginal people (Figure 4.1), and the Cathedral termite (*Nasutitermes triodiae*), whose spectacular mounds are a prominent feature of Kakadu's savanna landscapes (Figure 4.2). Some aquatic species, such as cherabin (*Macrobrachium* spp.), crayfish (*Cherax* spp.), crabs (*Austrothelphusa* spp.) and freshwater mussels (*Velesunio angasi*), are important food sources for local Aboriginal communities. However, the vast majority of invertebrate species in Kakadu are poorly known even by specialist scientists, and it is likely that a substantial proportion has not yet even been collected. The major processes that threaten Kakadu's plants and vertebrates – inappropriate fire regimes, weeds, feral animals and climate change – all have potentially important influences on invertebrate species. However, for all but the most common and conspicuous species, there is simply insufficient information available for assessing their conservation status. Largely because of this, none are officially listed as threatened under either Commonwealth or Northern Territory (NT) legislation.

Currently, 33 NT invertebrate species are listed under the *Territory Parks and Wildlife Conservation Act 2000*, but almost all (31) of these are short-range endemic land snails occurring predominantly in the MacDonnell Ranges of central Australia and on limestone outcrops in the Victoria River District. An additional two species of butterflies are listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and national recovery plans have been prepared for these. These two species are now listed as 'Near Threatened' under NT legislation. Most research on threatened NT invertebrates has focused on status evaluation according to IUCN criteria, resolving their taxonomy, understanding their ecology, and identifying threatening processes. There has been little attempt to implement management actions to mitigate threats, or to monitor the effectiveness of management.

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Figure 4.1 The magnificent Leichhardt's grasshopper (*Petasida epiphiggera*) occurs primarily in the sandstone country of the western Arnhem Land plateau, where it specialises on aromatic shrub species of *Pityrodia* (Lamiaceae). It has special spiritual significance for the local Jawoyn people, who associate it with the 'lightning man' (Namarrgon) responsible for wet season storms. Photo: M. F. Braby.

Figure 4.2 The giant mounds of the Cathedral termite (*Nasutitermes triodiae*) are a spectacular feature of Kakadu's savanna landscapes. Photo: A. N. Andersen.

The International Union for the Conservation of Nature maintains an international threatened species list (the IUCN Red List), and this includes seven Kakadu species (including some very recent additions), all of which are aquatic with highly restricted distributions (Table 4.1). The assessment of criteria for IUCN listing is far more precautionary than that applied under Australian (including NT) legislation. For example,

under the IUCN mining is listed as a threat to three species, despite not occurring anywhere near the relevant populations, and there is no evidence that the other threats listed (cane toads and tourism) are actually affecting the relevant species. Indeed, there is no direct evidence that populations of any of the listed species are actually declining (no information on population trends are available). However, the IUCN listing demonstrates that threatened invertebrate species represent an important issue for Kakadu.

Table 4.1 Kakadu invertebrate species included in the IUCN's Red List. Threatening processes include potential threats.

Species	Distribution	Threats	IUCN Listing
Freshwater shrimps			
Leptopalaemon gibbosus	Endemic to stonecountry of KNP	Cane toads	Vulnerable
L. glabrus	Endemic to stone country of KNP	Cane toads	Critically Endangered
L. magelensis	Endemic to stonecountry of, KNP	Cane toads	Vulnerable
Dragonflies and damselflies			
Antipodogomphus dentosus (Top End Dragon)	Fragmented, KNP and Katherine	Uranium mining and tourism	Vulnerable
Eurysticta coomalie (Coomalie Pin)	KNP and other NT localities	none provided	Near Threatened
Hemigomphus magela (Kakadu Vicetail)	Fragmented, KNP and Litchfield NP	Uranium mining and tourism	Vulnerable
Lithosticta macra (Rock Narrow-wing)	Endemic to stone-country of KNP	Increased mining and tourism	Vulnerable

4.2 The Kakadu invertebrate fauna

Despite a paucity of information, it is clear that Kakadu supports a diverse and biogeographically significant invertebrate fauna (Press et al. 1995). The first systematic surveys of invertebrates in the region were conducted in the early 1970s, as part of the Alligator Rivers fact-finding study (CSIRO 1973). These surveys yielded approximately 4,500 species, but even at the time it was recognised that this represented just a fraction of the total fauna. There has been a substantial research effort over the ensuing decades, especially on the aquatic fauna, which has been targeted by the Environmental Research Institute of the Supervising Scientist for environmental monitoring in relation to mining. Most of Kakadu's aquatic macro-invertebrate groups, including dragonflies (Odonata; 78 species from 50 genera), mayflies (Ephemeroptera; 25 species from 14 genera), caddis flies (Trichoptera; 105 species from 21 genera), non-biting midges (Diptera: Chironomidiae; 122 species from 43 genera), molluscs (13 species from 12 genera) and decapod crustaceans (20 species from 7 genera), have been comprehensively documented (Watson & Abbey 1980, Finlayson et al. 2006, Garcia et al. 2011).

In contrast, there is virtually no major terrestrial invertebrate group in Kakadu that has been comprehensively documented. The most notable exception is the high-profile, day-flying group - butterflies. The fact-finding study of the early 1970s recorded 63 butterfly species (Common 1973), and a subsequent study of Kakadu monsoon forests recorded 49 butterfly species (Kikkawa & Monteith , Monteith 1982). Currently, 86 butterfly species and 15 species of day-flying moths have been recorded from Kakadu (MF Braby, unpublished data). The butterflies represent more than two-thirds of the entire Top End fauna of approximately 125 species. Kakadu's grasshopper fauna has also been reasonably well documented, with 161 species from 90 genera recorded (Andersen et al. 2000). There have been substantial studies on a few other terrestrial groups, notably ants (Andersen 1991a, b, 1993) and termites (Braithwaite et al. 1988), but these have not been systematically surveyed throughout Kakadu.

This paper focuses on macro-invertebrates (generally classified as those >0.5 mm), but Kakadu's streams and other wetlands also support a diverse fauna of micro-invertebrates. A study of lowland billabongs of Magela Creek found the micro-fauna to be dominated by Rotifers with 227 species, representing 80% of all micro-invertebrate species (Tait et al. 1984). The remainder of the micro-fauna consisted of the micro-crustacean groups Cladocera (35 species), Copepoda (14) and Ostracoda (5). A large proportion of species were littoral or epiphytic.

4.3 Levels of endemism

An assessment of levels of endemism within Kakadu's invertebrate fauna is severely limited by a broader lack of understanding of the distribution of invertebrate species across the Top End and elsewhere in northern Australia. However, it is clear that, as for plants and vertebrates, levels of endemism are particularly high in the sandstone country of the western Arnhem Land plateau, much of which is included in Kakadu (Woinarski et al. 2009). The freshwater invertebrate fauna of this region is especially notable, and includes an endemic genus of palaemonid shrimps (*Leptopalaemon*) (Bruce 1993, Bruce & Short 1993, Short et al. 2013), as well as an endemic genus of phreatoicidean isopod (*Eophreatoicus*) that has exceptional species-level diversity (Wilson et al. 2009). Most of these macro-crustacean species have very restricted distributions, often limited to single streams, seeps or springs. Some of the major aquatic insect groups of the western Arnhem Land plateau and escarpments also have endemic elements. For example, two damselflies (*Lithostica macra* and *Indolestes obiri*) are confined to this region (Garcia et al. 2011). Many of the endemic species have broader biogeographic significance. For example, the fauna includes an NT endemic dragonfly, the Kakadu Vicetail (*Hemigomphus magela*) (also occurring in Litchfield National Park), which is the only species of its genus occurring outside eastern Australia (Watson et al. 1991).

Despite less available information, it is clear that levels of endemism are also very high in terrestrial insects. For example, at least 11 grasshopper species are endemic to the Arnhem escarpment and plateau (Andersen et al. 2000). This does not include Leichhardt's grasshopper (Figure 4.1), which also occurs in a few other sandstone regions in the northern NT (Lowe 1995, Wilson et al. 2003). The sandstone ant fauna of western Arnhem Land includes the endemic *Aphaenogaster reicheli* (known only from Podocarpus Canyon, Shattuck 2008), and an undescribed species group of *Meranoplus* that is most unlike other members of this hyperdiverse genus (Andersen 2006). It also supports highly disjunct populations of species that occur more than a thousand kilometres from their nearest conspecifics (Woinarski et al. 2009). Among the butterflies, Braby (2008)

noted a relatively low level of endemism from central Arnhem Land, with one species (*Taractrocera ilia*) and two subspecies endemic to the area. One of these subspecies is the striking Kakadu Swordtail (*Protographium leosthenes geimbia*), a large papilionid that is restricted to the monsoon forests of the sandstone escarpments of western Arnhem Land (Figure 4.3). The other subspecies is currently undescribed. Perhaps more significantly is the remarkable level of endemism among the agaristine day-flying moths; 14 of Australia's 44 species occur in Kakadu (Nielsen et al. 1996), three of which are undescribed, narrow-range endemics (MF Braby, unpublished data). Most species in this subfamily have relatively broad distributions, and nowhere else in Australia has this level of endemism.

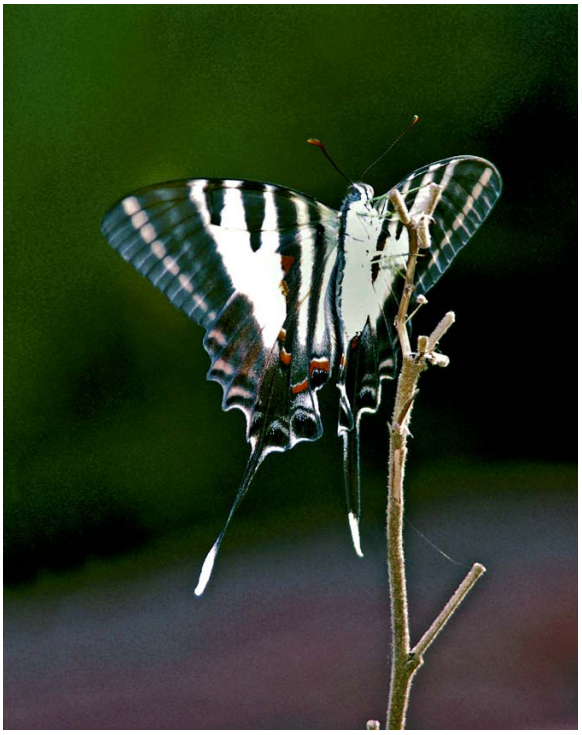

Figure 4.3 The Kakadu Swordtail (*Protographium leosthenes geimbia*) is endemic to sandstone escarpments and gorges of western Arnhem Land, where it specialises on the monsoon forest vine *Melodorum rupestre* (Annonaceae). Photo: I. Morris.

4.4 Conservation management

As previously mentioned, all the ecological processes that threaten plants and vertebrate animals through habitat modification are also likely to act as threatening processes for invertebrates. Threats common to many of these invertebrates include habitat loss or degradation through altered fire regimes, habitat modification through weed invasion (especially exotic grasses), disturbance by feral animals, and climate change. However, there is little information on the extent to which such threatening processes are actually affecting the distribution, abundance and conservation status of invertebrate species. One major exception is the effects of fire on ants – fire has a major impact on the structure of ant communities in the Top End (Andersen 1991a, Andersen et al. 2006), but does not appear to be a conservation threat to them (Andersen & Hoffmann 2011). The effects of fire on arthropods more broadly have been studied (Andersen & Müller 2000), but not from a conservation perspective. The effects of weeds and feral animals on Kakadu's invertebrates are almost totally unknown. Of particular concern are the effects of the introduced pasture grasses Mission grass (*Pennisetum pedicellatum* and *P.*

polystachion) and Gamba grass (*Andropogon gayanus*) on fire regimes. These grasses occur at higher biomass than do native grasses, and cure later in the dry season, resulting in fires of unusually high intensity (Setterfield et al. 2010). Such fires can greatly simplify savanna habitat structure through high tree mortality, and can promote penetration of fire into fire-sensitive habitats. The responses of Kakadu's aquatic invertebrates to different fire regimes (Douglas et al. 2003), invasive wetland grasses (Douglas & O'Connor 1999) and tourism (turbidity effects downstream of a popular creek crossing; Stowar 1997) have also been investigated.

Kakadu's invertebrate fauna is potentially threatened by a range of other ecological processes that are generally not considered to be so important for plants and vertebrate animals. One of these is mining, particularly through contamination of waterways. An operating uranium mine, Ranger, holds leases within Kakadu, and potential impacts arising from minewater discharges in the summer wet season have been intensively monitored. Results of biological monitoring, including macro-invertebrate sampling, are reported each year by the Supervising Scientist (http://www.environment.gov.au/science/ssd/publications#annual). In the receiving waters outside of the Ranger minesite, no adverse impacts upon macro-invertebrate communities have ever been reported since mining commenced in 1980. A potential risk identified with proposed underground mining of the Jabiluka uranium deposit was effects of dewatering on locally-endemic phreatoicidean isopods (*Eophreatoicus* spp.; Wilson et al. 2009) (Supervising Scientist unpublished reports). The impacts of past mining in Kakadu have also been studied. In particular, a small mine above Rockhole Mine Creek, a tributary of the South Alligator River, discharges small quantities of acidic, metal-rich waters to the creek throughout the year. While impacts upon macroinvertebrates of the small creek have been reported, the quantities of polluted minewaters are too small to adversely affect biological communities in the South Alligator River (Faith et al. 1995, Finlayson et al. 2006).

Another threatening process that especially targets invertebrates is invasion by exotic ants. Several of the world's worst invasive ant species are established in northern Australia, and two in particular represent a serious conservation risk to Kakadu. One of these is the African big-headed ant (*Pheidole megacephala*), which is common in most major towns of the Top End. It has invaded rainforest at Howard Springs near Darwin, with a devastating impact on the native invertebrate fauna (Hoffmann et al. 1999; Hoffmann & Parr 2008). It previously occurred in the settlements of Jabiru and Cooinda within Kakadu, but these populations have been successfully eradicated (Hoffmann & O'Connor 2004). The second species is the yellow crazy ant (*Anoplolepis gracilipes*), which is notorious for causing ecological 'meltdown' of rainforest ecosystems on Christmas Island (O'Dowd et al. 2003). This species has invaded natural habitat throughout northeastern Arnhem Land (Hoffmann & Saul 2010), and is therefore of significant risk of being introduced to Kakadu.

Finally, the cane toad *Bufo marinus* is well known as a serious conservation threat throughout northern Australia because of its toxicity to native vertebrate predators. Cane toads have also been recognised as a serious threat for short-range endemic aquatic invertebrates that either feed on tadpoles, are exposed to cane toad toxins that have leaked into the water, or suffer from competition by tadpoles for food or oxygen in the low nutrient/flow environments late in the dry season (van Dam et al. 2002). Cane toads are the major threatening process for the three freshwater shrimps included on the IUCN Red List (Table 1). However, the threat of cane toads extends much more broadly

for invertebrates, given that the cane toad is a voracious predator and invertebrates form the bulk of its prey.

For effective conservation management in Kakadu, there is a clear need to markedly improve our knowledge of invertebrates, especially for terrestrial groups. To this end, in 2012 invertebrates were included for the first time in faunal surveys of Kakadu's 136 long-term monitoring plots (see Woinarski et al. 2010 for plot details). Ants are being surveyed at all the plots, and surveys of a range of other invertebrate groups (butterflies, dung beetles, ground spiders, dragonflies) are being piloted at a subset of sites. These surveys will provide critical information on patterns of distribution for representative terrestrial invertebrate groups, as well as baseline information for ongoing monitoring.

However, this is just a start. We recognise three priorities for future research to underpin effective conservation management of Kakadu's invertebrates. First, it is clear from the limited information available that the stone country of Kakadu and adjacent western Arnhem Land is a nationally significant centre of endemism for invertebrates. There is a pressing need to improve our understanding of levels of endemism in the many less well-known invertebrate groups. Particular priority should be given to terrestrial groups with limited dispersal capability, such as arachnids, land snails and non-flying insects. Second, although it has been recognised that cane toads represent a peculiar threat to a range of aquatic invertebrates that are endemic to the sandstone country, there is no information on actual impacts. This needs to be addressed. It might not be feasible to control cane toads at the landscape scale, but they can be fenced out from isolated water bodies that are critical habitat for endangered aquatic invertebrates. Third, we need to improve our understanding of the importance to invertebrates of the key processes that threaten plants and vertebrates, notably fire, invasive species and feral animals. Finally, invertebrates can play an important role in the broader conservation management of Kakadu through their role as bio-indicators of ecological change. In particular, ants have been widely used as bio-indicators in Australia (Andersen & Majer 2004), including in Kakadu in the context of ecosystem restoration following mining (Andersen 1993).

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5 Threatened fishes and marine turtles of Kakadu National Park (with notes on marine mammals)

PM Kyne[1]

5.1 Introduction: threatened fish and marine turtle species occurring in Kakadu National Park

5.1.1 Background

Despite Kakadu National Park encompassing only a small area of estuarine and marine environments, this habitat together with the Park's rivers, make it internationally significant for threatened euryhaline elasmobranchs (sharks and rays capable of tolerating a wide range of salinity). Ongoing survey work is documenting populations of a number of key species in the Alligator Rivers system (PM Kyne et al. unpublished data), and indeed Kakadu National Park is the only large protected area anywhere in the world that provides refuge for these species. Additionally, one species of threatened marine turtle, the Flatback Turtle *Natator depressus*, nests annually in the Park, which is a locally and regionally important rookery (Schäuble et al. 2006). Other marine turtles occur on occasion in Kakadu waters, but given that only minimal areas of their habitat are included in the Park boundaries and they do not generally nest there, the Park is not considered important for these species. There are no national or Northern Territory (NT) listed threatened marine mammals in Kakadu National Park, although three species (two cetaceans and one sirenian) of conservation concern are noteworthy. There are also no national or NT listed threatened bony fishes (teleosts) in Kakadu National Park, although a brief discussion on some conservation issues related to bony fishes is provided.

Species which are listed under a threatened category in Australian (*Environment Protection and Biodiversity Conservation Act* 1999; 'EPBC Act') or NT (*Territory Parks and Wildlife Conservation Act* 2000) legislation are considered here. Additional reference may be made to global listings on the IUCN Red List of Threatened Species (the 'IUCN Red List') (IUCN 2013). Although the process and criteria for eligibility on these lists are broadly similar, they are not totally aligned and differences in listings are evident. In part, this may reflect geographical scope, as assessments are undertaken at the Territory, national or international level (for all species considered here, their distribution extends outside of the NT). The status of marine turtles demonstrates when geographical scope can affect listings, and this is particularly evident with the Flatback Turtle, which nests in Kakadu National Park. At both the international and Territory level, its Data Deficient listing reflects that 'sufficient information is lacking to make a sound status assessment' (IUCN 2012), although it is a listed threatened species nationally (on the EPBC).

With respect to the euryhaline elasmobranchs, all sawfish species (family Pristidae) have just been reassessed at the international level by the IUCN Shark Specialist Group, while

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the river sharks (genus *Glyphis*) are due for reassessment in the near future. These global reassessments can assist informing updates at the national and Territory level. Although species are reviewed at the Territory level at approximately 5 year intervals, recent reviews failed to incorporate more up-to-date information, and disparities between the three different lists remain (see Table 5.1). As is presently undertaken with Australian birds (see Garnett et al. 2011), an independent decadal-scale review of the conservation status of all elasmobranchs is required, with the aim of assessing species for the IUCN Red List and feeding these down to update national and Territory listings.

Until recently the status of euryhaline elasmobranchs, marine turtles and marine mammals was very poorly understood in Kakadu National Park. And while recent and ongoing work is providing new information, there remain many knowledge gaps. Further research, surveys and monitoring are required to ascertain distributions, abundance, population trends, threats and management requirements.

Under the National Environmental Research Program (NERP), a large-scale project is researching the euryhaline elasmobranch community of Kakadu National Park (and the NT more widely) during 2012–2014. It is anticipated that this project ('Supporting Management of Listed and Rare Species' or 'the NERP sawfish and river shark project') will inform updates of conservation assessments (for river sharks in particular).

Here I primarily consider the threatened euryhaline elasmobranch community of Kakadu National Park, as well as the Flatback Turtle. A summary of the current status of these species in Kakadu National Park is provided, and then priorities for conservation and management are indicated.

5.1.2 Overview of species

The four threatened elasmobranchs and five threatened marine turtles occurring in Kakadu National Park are listed in Table 5.1. Additional species of relevance which can be considered of conservation concern (although not EPBC or NT listed), or have not yet been recorded but possibly occur in Kakadu National Park, are listed in Table 5.2.

Table 5.1 List of threatened elasmobranch and marine turtle species recorded from Kakadu National Park. Conservation status: CR=Critically Endangered; EN=Endangered; VU=Vulnerable; LC=Least Concern; DD=Data Deficient.

Common name	Scientific name	EPBC listed	NT listed	IUCN Red List
Elasmobranchs				
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
Marine turtles				
Flatback Turtle	*Natator depressus*	VU	DD	DD
Green Turtle	*Chelonia mydas*	VU	LC	EN
Olive Ridley	*Lepidochelys olivacea*	EN	DD	VU

Hawksbill Turtle	*Eretmochelys imbricata*	VU	VU	CR
Loggerhead Turtle	*Caretta caretta*	EN	VU	EN

Table 5.2 Additional elasmobranchs and marine mammals of conservation concern occurring or possibly occurring in Kakadu National Park. Conservation status: CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near Threatened.

Common name	Scientific name	EPBC listed	NT listed	IUCN Red List
Elasmobranchs				
Bull Shark	*Carcharhinus leucas*	-	-	NT
Narrow Sawfish	*Anoxypristis cuspidata*	-	-	EN
Green Sawfish*	*Pristis zijsron*	VU	VU	CR
Marine Mammals				
Dugong	*Dugong dugon*	-	-	VU
Australian Snubfin Dolphin	*Orcaella heinsohni*	-	-	NT
Indo-Pacific Humpback Dolphin	*Sousa chinensis*	-	-	NT

*not yet recorded from Kakadu NP

5.1.3 Euryhaline elasmobranchs

Threatened euryhaline elasmobranchs of Kakadu National Park comprise river sharks of the genus *Glyphis* and sawfishes of the genus *Pristis* (Table 5.1 & Figure 5.1). Given the euryhaline nature of these species, they utilise a variety of aquatic habitats, although it is the Largetooth Sawfish *Pristis pristis* which displays the most diverse habitat utilisation (Table 5.3).

Table 5.3 Broad environments utilised by threatened euryhaline elasmobranch species in Kakadu National Park.

Common name	Environment
Northern River Shark	rivers (tidal), estuaries, marine
Speartooth Shark	rivers (tidal), estuaries, [marine?]
Dwarf Sawfish	rivers (tidal), estuaries, marine
Largetooth Sawfish	rivers (tidal), rivers (upstream), floodplains, billabongs, estuaries, marine

Globally, the five known river shark species are restricted to tropical rivers, estuaries and marine waters of the Indo-West Pacific, with two species (both EPBC and NT listed) occupying restricted distributions and habitats in northern Australia; both Australian species occur in Kakadu National Park (Compagno et al. 2008, Last & Stevens 2009,

Pillans et al. 2010). The Northern River Shark *Glyphis garricki* is known only from northwestern Western Australia (King Sound, Joseph Bonaparte Gulf, Ord River, King River), the NT (Adelaide River, South Alligator River, East Alligator River, Wessel Islands) and from southern Papua New Guinea (Compagno et al. 2008, Pillans et al. 2010). The Speartooth Shark *G. glyphis* is known only from the NT (Adelaide River, West Alligator River, South Alligator River, East Alligator River, Murganella Creek), Cape York Peninsula in Queensland (Wenlock River, Ducie River, Port Musgrave, Bizant River; no records in the latter location since 1983) and southern Papua New Guinea (Compagno et al. 2008, Pillans et al. 2010).

The more common and widespread Bull Shark *Carcharhinus leucas* is considered Near Threatened globally on the IUCN Red List (Table 5.2). However, this assessment is out-dated and a re-evaluation of its status globally and in Australia is required. While population trend information is not available for this species in Kakadu National Park, juveniles are abundant in both the South and East Alligator Rivers (and probably elsewhere) where they occur sympatrically with both river shark species (PM Kyne et al. unpublished data).

The sawfishes are arguably one of the world's most threatened fish families, with all five species listed as Critically Endangered or Endangered on the IUCN Red List (IUCN 2013). Four of these species occur across northern Australia, with records of three in Kakadu National Park.

The EPBC and NT listed Largetooth Sawfish (formerly known in the Indo-West Pacific as the Freshwater Sawfish *P. microdon*; see Faria et al. 2013) occurs globally in four widely separated populations: the Indo-West Pacific, Eastern Pacific, Western Atlantic and Eastern Atlantic, and was formerly the widest-ranging of the sawfish species. In Australia, the Largetooth Sawfish occurs from the north-eastern coast of Queensland to the Kimberley region of Western Australia (it has also been recorded as a vagrant to the southwest) (Last & Stevens 2009).

In contrast to the Largetooth Sawfish, the Dwarf Sawfish *P. clavata* has the most restricted distribution of any sawfish species. Although it was apparently once widespread in the Indo-West Pacific, it now appears to be restricted to northern Australia from the Gulf of Carpentaria to the northern Pilbara region of Western Australia (Kyne et al. 2013b).

The IUCN listed Narrow Sawfish *Anoxypristis cuspidata* (Table 5.2) occurs in estuarine areas of Kakadu National Park, including neonate (newborn) juveniles in the South Alligator River estuary, suggesting that the area is a pupping ground and nursery area for the species (PM Kyne et al. unpublished data).

Finally, the Green Sawfish *P. zijsron*, an EPBC and NT listed threatened species (Table 5.2), has not been recorded within Kakadu National Park, despite it ranging across northern Australia (Last & Stevens 2009). It does not enter rivers as regularly as the Largetooth Sawfish and Dwarf Sawfish, but may occur in nearshore estuarine areas of the Park. Further survey work may document this species in the Park in the future. Further discussion of sawfishes in Kakadu National Park will focus on Largetooth and Dwarf Sawfish, but management aimed at these species in estuarine areas of the Park would also benefit the Narrow and Green Sawfish (if the latter was shown to occur there).

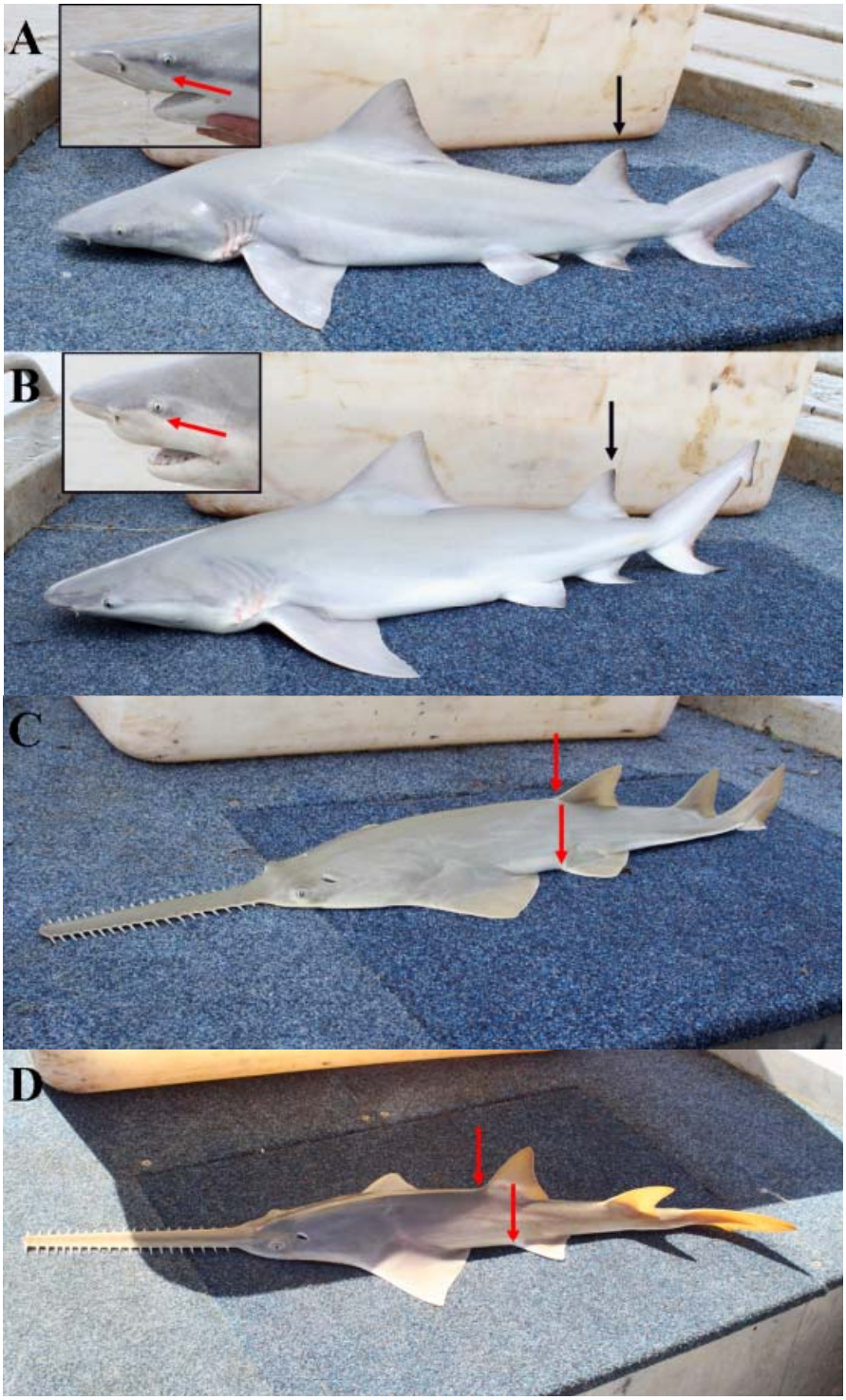

Figure 5.1 Threatened euryhaline elasmobranchs of Kakadu National Park. A. Northern River Shark *Glyphis garricki*; B. Speartooth Shark *Glyphis glyphis*; C. Dwarf Sawfish *Pristis clavata*; D. Largetooth Sawfish *Pristis pristis*. Red arrows point to the key character to separate similar species in the field: Northern River Shark from Speartooth Shark: waterline mark is more than an eye diameter below eye in Northern River Shark (A) while the waterline mark is just below eye in Speartooth Shark (B). River sharks (genus *Glyphis*) are easily separated from the Bull Shark *Carcharhinus leucas* by their large second dorsal fin (black arrow). Dwarf Sawfish from Largetooth Sawfish: front of the first dorsal fin is over, or slightly behind, the origin of the pelvic fins in Dwarf Sawfish (C) while the front of the first dorsal fin is well forward of the pelvic fins in Largetooth Sawfish (D). See Last and Stevens (2009) for further identification features. Photos by Peter Kyne.

5.1.4 Bony fishes

There are no listed threatened bony fishes in Kakadu National Park. However, the freshwater and estuarine bony fish community of the Park requires some consideration here. There are a number of range restricted freshwater fishes with a large proportion of their range in Kakadu National Park, such as Midgley's Grunter *Pingalla midgleyi*, Magela Hardyhead *Craterocephalus marianae* and *Hypseleotris barrawayi*. For other freshwater species (i.e. *Mogurnda* spp. and *Melanotaenia* spp.), taxonomic resolution is required which may result in new species with restricted ranges. Recent surveys of the South Alligator River estuary fish community have also revealed potential new range restricted estuarine species (M Hammer, pers. comm.). An assessment of the status of any range restricted fish species is recommended.

5.1.5 Marine turtles

Of the six marine turtle species occurring across northern Australia, there are reports of Flatback Turtle, Green Turtle *Chelonia mydas*, Olive Ridley Turtle *Lepidochelys olivacea*, and Hawksbill Turtle *Eretmochelys imbricata* nesting in Kakadu, with records of Loggerhead Turtles *Caretta caretta* (which does not nest in the NT) also occurring around the Kakadu coastline (Winderlich 1998). Of all of these species, however, only the Flatback Turtle (Figure 5.2) has been recorded nesting in the Park during monitoring and research since the 1990s (Winderlich 1998, Schäuble et al. 2006, Chatto & Baker 2008). The Flatback Turtle has a restricted distribution in Australia, southern New Guinea and eastern Indonesia. This species nests only in northern Australia, from the Pilbara region of Western Australia to Mon Repos in southern Queensland (Chatto & Baker 2008). The occurrence of the other species listed in Table 5.1 in Kakadu National Park is limited, and given the extensive global range of these species and the fact that important breeding and feeding areas all exist outside of the Park, Kakadu National Park does not represent any real significance for these species and they are accordingly not considered further here.

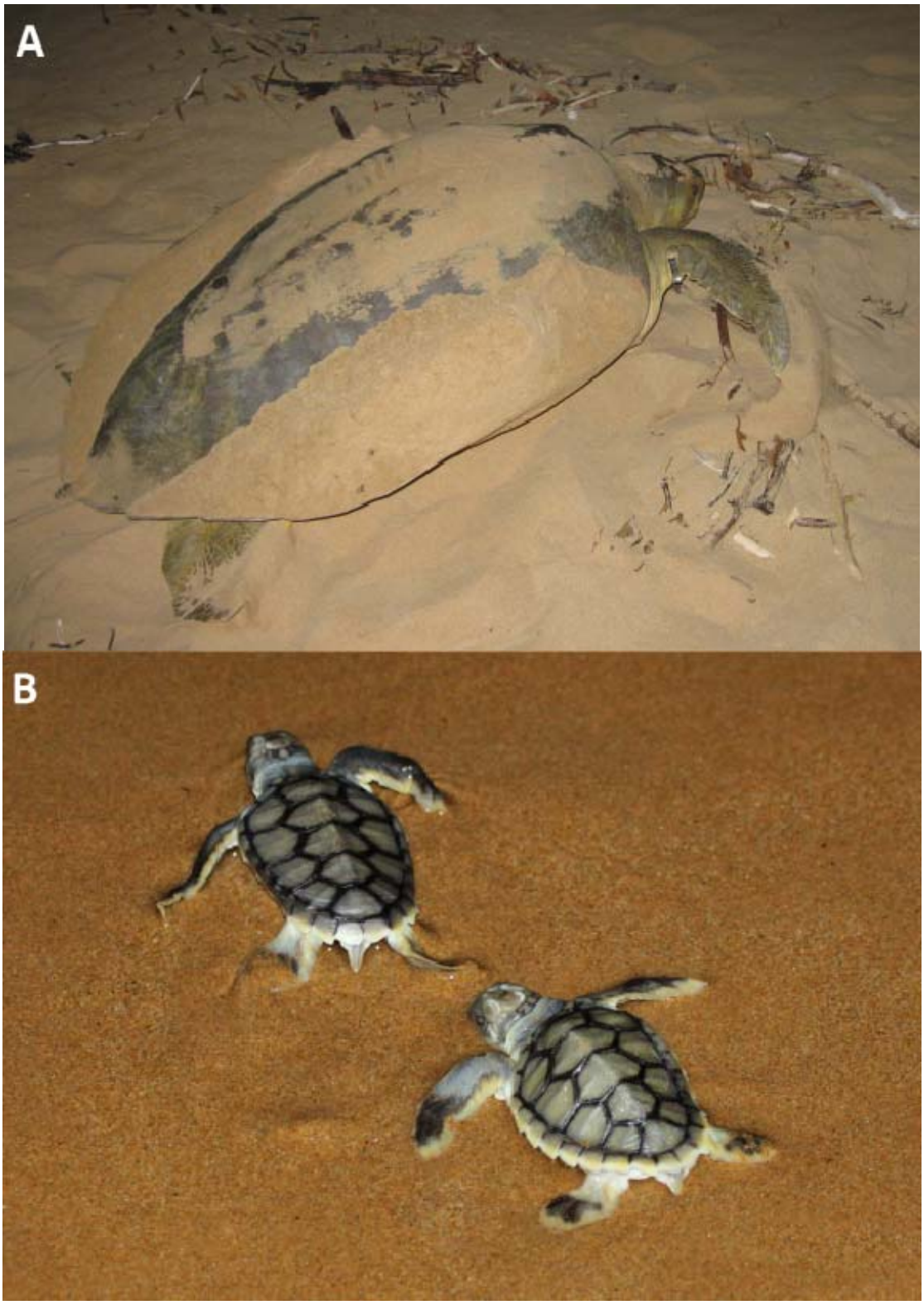

Figure 5.2 Flatback Turtle *Natator depressus*. (A) adult female returning to the water after nesting. (B) hatchlings. This is the only marine turtle to regularly nest in Kakadu National Park. The relatively small but locally and regionally important rookery on Field Island is the subject of a long-term monitoring program. Photos by Micha Jackson.

5.1.6 Marine mammals

There are no EPBC or NT listed threatened marine mammals occurring in Kakadu National Park. The Dugong *Dugong dugon* is not considered to be threatened at the national or Territory level, although globally it is considered Vulnerable (IUCN 2013). Australia is a global stronghold for Dugong, which is a protected species in Commonwealth and NT waters. There are few records of Dugong in the southern Van Diemen Gulf (PWS 2003, ALA 2013) and this region does not appear to be an important area for this species (see Marsh et al. 2002 for a review of status in the NT). Although it is likely to occur on occasion within Park boundaries, it is not discussed further here.

Conservation concern has been expressed for two species of cetaceans, the Australian Snubfin Dolphin *Orcaella heinsohni* and the Indo-Pacific Humpback Dolphin *Sousa chinensis*, both of which occur in small numbers in Kakadu National Park (Palmer 2011). These two species are listed as Near Threatened on the IUCN Red List, but are not listed as threatened at the national or Territory level. A project surveying these two species was undertaken in Kakadu National Park and surrounding waters from 2007 to 2011 and the Park is considered to hold secure populations of these species (Palmer 2011).

5.2 The status and trends of threatened fishes and marine turtles in Kakadu

The following sections will deal only with the four EPBC and NT listed euryhaline elasmobranchs occurring in Kakadu National Park and the one listed marine turtle which regularly nests in Kakadu National Park. Species in Table 5.2 will not be considered further.

5.2.1 Euryhaline elasmobranchs

Sawfishes globally have suffered drastic declines and localised extinctions, with the principal cause being targeted and incidental bycatch in commercial fisheries. Habitat loss and alteration, bycatch in recreational fisheries, Indigenous harvest, collection for display in aquaria and marine debris are also threats (DSEWPaC 2011). Threats to river sharks are similar, although their threatened listings are also based on suspected small population sizes and limited distributions. Marine turtles are threatened globally from bycatch in commercial fisheries, coastal development and habitat loss, Indigenous harvest, egg predation by introduced animals (such as pigs) and marine debris (Environment Australia 2003).

While the significant threat of commercial fisheries does not occur within Kakadu National Park, other threats do operate in the Park. Furthermore, all of these species are mobile and are potentially subject to the threat of bycatch in commercial fisheries once they leave Park boundaries. Sawfishes and river sharks are a recorded bycatch of the NT Barramundi Fishery which operates in Van Diemen Gulf (Field et al. 2008). The intrinsic life history characteristics of sawfishes, sharks and marine turtles increase their overall vulnerability; late age at maturity, low reproductive rate and long lifespan are all features of their biology (Simpfendorfer 2000, Environment Australia 2003, Pillans et al. 2010).

For the four threatened euryhaline elasmobranchs in Kakadu National Park, there are no available estimate of population sizes in the Park, and no robust information on current trends in population sizes. This lack of information constrains the capacity of managers to prioritise between species, and hampers the ability to assess the success of management actions. However, the NERP sawfish and river shark project will be able to

provide more robust knowledge of population status in the near future (PM Kyne et al. unpublished data).

River sharks have historically been overlooked and we are only now beginning to understand the importance of Kakadu National Park for the Northern River Shark and the Speartooth Shark. The Northern River Shark was only formally described in 2008. At the same time, the taxonomic status of northern Australian Speartooth Shark was resolved; that is, it was shown to be the same as specimens from southern Papua New Guinea, and it was redescribed by Compagno et al. (2008) as *G. glyphis*. The previous taxonomic uncertainty, as well as confusion and misidentification with the more commonly encountered Bull Shark, has limited the available information on the distribution, abundance and occurrence of river sharks not only in Kakadu National Park, but across their distribution.

Larson (1999, 2000, 2002) conducted estuarine fish surveys in Kakadu National Park and provided the first records of *Glyphis* sp. from the East, South and West Alligator Rivers (Larson 2000). These collections were later identified to include both Northern River Shark and Speartooth Shark. Pillans et al. (2010) reviewed all records of both river sharks in Australia, documenting 32 records of Northern River Shark and 106 records of Speartooth Shark from across their Australian range. Morgan et al. (2011) subsequently provided an additional 12 Northern River Shark records from Western Australia. More comprehensive sampling under the NERP sawfish and river shark project has revealed significant populations of both species in the South Alligator River (the only river sampled for river sharks under the project thus far) (PM Kyne et al. unpublished data).

For the Northern River Shark, records from NERP project sampling in Kakadu National Park considerably exceed the total number previously known from across the entire range of the species. With present knowledge, Kakadu National Park can be considered one of two known international hotspots for Northern River Sharks, the other being the King Sound region of Western Australia (Pillans et al. 2010, Morgan et al. 2011). In Kakadu National Park, neonates through to adults have been recorded in tidal reaches and estuarine waters of the South Alligator River. The presence of neonates indicates that this river is a nursery area for the species, and can be considered critical habitat and internationally important. Adults were previously unknown from rivers and were specified in the literature as being marine and estuarine only (Pillans et al. 2010).

For the Speartooth Shark, records from NERP project sampling in Kakadu National Park are approaching those of the other known international hotspot for this species, the Adelaide River of the NT (Queensland's Wenlock River/Ducie River/Port Musgrave system is another apparent centre of abundance) (Pillans et al. 2010). In Kakadu National Park, neonates and juveniles have been recorded in tidal reaches and estuarine waters of the South Alligator River, again indicating the importance of the system as a nursery area. Adult Speartooth Sharks have never been caught or observed anywhere and their habitat and distribution is unknown. Like the Northern River Shark, they are presumed to be estuarine and marine occurring. This is the world's only large (based on other *Glyphis* species and the size of examined subadults, a maximum size of 2.5–3.0 m is likely; Pillans et al. 2010) predator for which adults have never been seen, and represents a major research challenge to determine their occurrence, in order to inform management.

Further sampling of remote Australian rivers may reveal additional sizeable populations of river sharks, but as is currently known, Kakadu National Park is of critical importance for these two threatened species.

Sawfish populations globally have suffered massive declines and regional and localised population depletions (see 2013 Red List assessments for the most recent summary of sawfish status; IUCN 2013). Northern Australia represents one of the last, if not the only, viable population stronghold for sawfishes in the Indo-West Pacific, and for the two threatened species occurring in Kakadu National Park, is of international significance.

Larson (2002) provided the first record of Dwarf Sawfish in Kakadu National Park, an individual caught in the South Alligator River estuary. NERP sawfish and river shark project surveys have subsequently recorded six individuals in the South Alligator River system, including two first year animals upstream of the estuary in tidal reaches of the river (PM Kyne et al. unpublished data). This represents a previously undocumented nursery area for Dwarf Sawfish.

Kakadu National Park has long been known to represent nursery habitat for the Largetooth Sawfish. Adult females of this species give birth ('pup') in estuarine waters with juveniles migrating upstream into freshwater environments where they spend around 4–5 years before returning to coastal and marine waters (Thorburn et al. 2007). In Kakadu National Park, the species has been recorded in tidal downstream and upstream freshwater reaches of rivers, floodplains and billabongs. The habitat requirements (and subsequently, the management requirements) of this species therefore differ to the other threatened euryhaline elasmobranchs occurring in the Park. The status of the species in Kakadu National Park, and more broadly across the NT is being investigated by the NERP sawfish and river shark project. The species appears to now be rare in the Park, with considerable sampling during 2012–2013 locating only a small number of individuals. Given global and national declines in this species (Stevens et al. 2005, Kyne et al. 2013a), there is little doubt that the population was once more robust in the Park.

5.2.2 Flatback Turtle

Flatback Turtles predominantly nest on islands, and this is evident in the Van Diemen Gulf region where there is only limited sandy beach habitat on the mainland coastline (Chatto & Baker 2008). While there is a nesting beach on the mainland between the Wildman and West Alligator Rivers, Chatto & Baker (2008) recorded only a small number of tracks/nests on this beach and Schäuble et al. (2006) reported only 1–2 nesting turtles per night. More important is the small sandy beach on Field Island at the mouth of the South Alligator River. This beach has been the subject of Flatback Turtle monitoring since 1990 and is locally and regionally important given the lack of suitable nesting beaches in Van Diemen Gulf. It is also a key monitoring site nationally (Schäuble et al. 2006). Between 1990 and 2001, the number of individuals nesting ranged from 13–44 per year with an average of 2.7–5.1 nesting attempts per night; maximum counts for a single night over the period varied between 6 and 16 (Schäuble et al. 2006). Between 2002 and 2012, the average number of turtles per night ranged from 2.9 to 5.7 and the average number of nests per night ranged from 2.3 to 4.6 (A O'Dea, pers. comm). The total number of nests recorded during surveys between 2002 and 2012 (12–23 survey nights annually) was 37–89 with 70–90% of turtles successfully nesting (A O'Dea, pers. comm).

Schäuble et al. (2006) notes that the levels of nesting on Field Island are relatively small when compared with many other rookeries. At the largest rookery, Crab Island in the northeastern Gulf of Carpentaria, Limpus et al. (1993) documented 68–235 (average 132.7) Flatback Turtles per night over a two week survey. Still, Kakadu National Park is

locally and regionally important with the surveys indicating that the nesting 'population' has been stable over the period 1990–2012.

5.3 Current management and management requirements

5.3.1 Background

Recovery plans provide prioritised research and management actions and a strategic framework for the conservation of Australia's threatened species; a recovery plan is prepared for every species nationally listed as threatened. On Commonwealth lands (such as Kakadu National Park), these plans must be implemented (this requirement is stipulated in the EPBC Act). There is a draft multispecies recovery plan for sawfishes and river sharks (DSEWPaC 2011), with the final recovery plan expected to be released in mid-2014 (A Leedman, pers. comm). There is an existing recovery plan for marine turtles (Environment Australia 2003) which is currently in the process of being updated (H Marsh, pers. comm).

5.3.2 Euryhaline elasmobranchs

Sawfishes and river sharks are protected species and are therefore prohibited no-take species for commercial and recreational fisheries (only the latter operates in Kakadu National Park). Fisheries signage at Kakadu National Park public boat ramps specifies the protected status of these species. However, identification of river sharks from Bull Sharks (which may be retained) remains an issue. Indigenous harvest is not subject to management and both sawfishes and river sharks are known to be taken in Kakadu National Park (PM Kyne, unpublished data), although the level of harvest has not been quantified.

The national and international importance of Kakadu National Park for the four threatened euryhaline elasmobranchs cannot be overlooked. It is indeed the only large protected area in the world in which significant areas of critical habitat for these species occurs. The Park represents nursery areas (and possibly breeding areas) for all species. The species share similar habitats, all occurring in the tidal reaches and estuaries of Kakadu's rivers. Management within the Park therefore needs to focus on these habitats. Research is underway to determine how these species utilise the available habitat and what the habitat requirements for each species are. Additionally, management needs to consider a whole of landscape approach for Largetooth Sawfish given its reliance on a diversity of aquatic habitats. Connectivity of these habitats is particularly important for this species, and also for the river sharks which require estuarine-river connectivity. Any loss of connectivity (i.e. through barrages etc.) can severely alter movement and upstream migration patterns for euryhaline elasmobranchs (Morgan et al. 2005).

5.3.3 Marine turtles

The objectives stipulated in the existing recovery plan for marine turtles (Environment Australia 2003) are summarised in Table 5.4. Not all subcomponents of these objectives are relevant to Kakadu National Park. Through monitoring and management activities on Field Island, this recovery plan has been reasonably well implemented in Kakadu National Park.

Marine turtle management in Kakadu National Park centres largely on nesting habitat management and conservation, and the on-going annual monitoring of nesting turtles.

Maintaining suitable nesting habitat on Field Island and minimising disturbance to this is critical.

Table 5.4 Summary of objectives (Australia-wide) stipulated in the marine turtle recovery plan. From Environment Australia (2003).

Objective	Subcomponents
A. Reduce the mortality of marine turtles	1. Bycatch of marine turtles in fisheries
	2. Customary harvest by Aboriginal and Torres Strait Islander people
	3. Marine debris
	4. Shark control activities
	5. Boat strike
	6. Pearl farming and other aquaculture activities
	7. Defence activities
B. Develop programs and protocols to monitor marine turtle populations in Australian waters	1. Monitor key populations and stranded marine turtles
	2. Measuring recovery
	3. Genetic identification of Australian marine turtle populations
C. Manage factors that impact on successful marine turtle nesting	1. Light pollution
	2. Tourism and recreational activities
	3. Vehicle damage
	4. Faunal predation of marine turtle eggs
D. Identify and protect habitats that are critical to the survival of marine turtles	1. Land use and water quality
	2. Loss of sea grass or benthic habitat
	3. Oil spills and operational discharges
	4. Noise
E. Communicate the results of recovery actions and educate stakeholders	1. Communicating results of recovery actions
	2. Education, public awareness and community involvement
	3. Indigenous coastal community network
F. Conserve shared marine turtle populations in the Asia/Pacific Region	1. Marine turtle conservation in the Asia/Pacific region

5.3.4 The management challenge

The euryhaline nature of the threatened sawfishes and river sharks means that they freely move outside Park boundaries and into waters where other threatening processes occur

(such as being caught as bycatch in commercial fisheries which do not operate in the Park). Similarly, marine turtles disperse very widely, and local and regional threats to Flatback Turtles operate outside of the Park. The challenge is to manage Kakadu's populations of all these species both through management within the Park, but importantly, by engaging with stakeholders outside Park boundaries. Management to conserve/recover viable populations within Kakadu National Park is not possible by focusing only on management within the Park.

There is little understanding of how changing climate will impact upon elasmobranchs in Kakadu National Park, although euryhaline species are more vulnerable to a variety of climate change factors (such as changed freshwater input, temperature and severe weather) than other species (Chin et al. 2010). An understanding of how changing climate will affect the threatened euryhaline elasmobranchs of Kakadu National Park is required, particularly through an assessment of how habitat might be altered.

5.4. Priorities for management

Priority actions for research, management and monitoring of threatened euryhaline elasmobranchs and marine turtles in Kakadu National Park are:

- Undertake basic research on the ecological requirements of euryhaline elasmobranchs within Kakadu National Park, including but not limited to, occurrence, movement and habitat use (underway).
- Undertake studies (using satellite tagging) to determine the movements and feeding grounds of Flatback Turtles that nest on Field Island.
- Define, and if necessary, enhance management of, critical habitat (nursery, foraging, predator avoidance) for sawfishes and river sharks.
- Engage Traditional Owners in threatened species research and management activities;
- Evaluate the level of Indigenous harvest of sawfishes and sharks in Kakadu National Park, and work together with Traditional Owners to promote sustainable harvest, or voluntary limits on harvest (if appropriate).
- Promote the national and international value of Kakadu as sawfish/river shark habitat, centring on the fact that it is one of only three large effective protected areas anywhere in the world with remaining sawfish populations (of any species), and that it is the only large protected area in the world with Largetooth Sawfish, Dwarf Sawfish, Northern River Shark and Speartooth Shark populations.
- Evaluate the level of interaction between recreational fishers and sawfish/sharks in Kakadu National Park. If appropriate, implement a catch and release regulation for all sharks (as 'look-alike' species; thus restricting the accidental retention of river sharks misidentified as Bull Sharks) in estuarine and tidal reaches of rivers.
- Promote awareness, outreach and education activities for recreational fishers and local communities regarding sawfishes and river sharks.
- Develop and promote safe-release practices for recreational fishers for incidentally captured sawfish and sharks.

- Evaluate, in collaboration with NT Fisheries, fishing effort and bycatch of sawfishes and river sharks in the NT Barramundi Fishery in areas adjacent to Kakadu National Park.
- Engage collaboratively with local commercial fishing stakeholders (NT Barramundi Fishery, NT Seafood Council, NT Fisheries) to promote awareness of local sawfish and river sharks, and promote established safe-release and handling practices.
- Maintain compliance and enforcement of fishing regulations, including patrols/operations aimed at illegal fishing activities.
- Engage collaboratively with stakeholders regionally, nationally and internationally in the management of global populations of threatened species (marine species can be connected regionally and internationally).
- Maintain estuarine-river-floodplain connectivity
- Examine the potential impacts of changing climate on threatened euryhaline elasmobranchs and their habitat.
- Maintain monitoring programs for sea turtles, sawfishes and river sharks; and,
- Monitor Field Island for introduced predators of turtle eggs (there are currently no introduced predators on the island), and implement control if predators are ever detected.

While there are no threatened cetaceans occurring in Kakadu National Park, Palmer (2011) provides the following management recommendations for coastal dolphins in the Park: raise awareness through interpretive signage and 'slow down' boating signs (to minimise boat strikes), record traditional ecological knowledge on coastal dolphins, and monitor dolphin populations, including through maintaining a sightings database.

Lastly, it is desirable to assess the conservation status of any range-restricted bony fishes of Kakadu National Park.

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6. Threatened reptile and frog species of Kakadu National Park: current status; known and potential threats; and what needs to be done for them?

G Gillespie[1] & A Fisher[1]

6.1 Introduction

Kakadu National Park supports at least 131 non-marine reptile and 27 frog species, an unusually high species richness compared to most other protected areas in Australia. Many of these species have a large proportion of their natural range contained within the Park. Consequently Kakadu National Park plays a key role in the conservation of a large proportion of Top End and Northern Australian reptile and amphibian diversity. Nevertheless, several of these species are considered threatened or have declined in recent years, whilst the status of many other species within the Park is poorly known. Here, we provide an inventory of the currently listed threatened non-marine reptile species occurring in Kakadu National Park, a summary of the current status of these species in the Park, an assessment of their threats and management requirements, and a prioritisation for conservation management.

For Kakadu, the most relevant threatened species listings are those for Australia (under the *Environment Protection and Biodiversity Conservation Act 1999*: 'EPBC Act') and the Northern Territory (under the *Territory Parks and Wildlife Conservation Act 2000*). There is overlap between these lists, and the criteria for eligibility are broadly similar. However there are differences in composition of the lists that reflect, in part, geographical scope – species may be declining rapidly in the Northern Territory but not elsewhere in Australia, or vice-versa. However, other differences between lists relate to relative currency: the Northern Territory list is comprehensively reviewed at c. 5 year intervals (most recently in 2012), whereas the Australian list is modified much more haphazardly. Consequently we include here details of the conservation status identified by both lists.

Seven reptile species occurring in Kakadu National Park are currently considered threatened either in Australia or the Northern Territory (Table 6.1). Three species are considered threatened by both jurisdictions. No frog species are currently considered threatened. None of the threatened species is restricted to Kakadu; however, the Park comprises much of the range (and/or population size) of the Yellow-snouted Gecko, Arnhem Land Skink and Oenpelli Python.

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Table 6.1 List of threatened reptile species recorded from Kakadu National Park. Conservation status codes: EN=endangered; VU=vulnerable.

Common name	Scientific name	EPBCA Listed	NT Listed
Yellow-snouted Gecko	*Lucasium occultum*	EN	VU
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

6.2 Status and accounts of threatened reptile species

The following accounts provide current information on population status and trends of formally listed threatened species in Kakadu National Park:

- The Yellow-snouted Gecko has a highly restricted distribution that includes the Kapalga area of Kakadu (Woinarski et al. 2007). There have been only five records of this species from within Kakadu since 1988 despite intensive searches. This ground-dwelling species is associated with open woodland with red loamy soils (Woinarski et al. 2007). Most individuals located to date have been associated with well developed leaf litter and grass (King et al. 1982, Johansen 2006). Although data are limited, patterns of occurrence suggest that inappropriate fire regimes and spread of introduced pasture species are likely to be key threats to the Yellow-snouted Gecko (Woinarski et al. 2007).
- The Arnhem Land Skink is restricted to the western Arnhem Land sandstone massif with approximately one third of its range contained within Kakadu. The species inhabits rock ledges and crevices and has been recorded at only nine locations in Kakadu. Many individuals were caught as by-catch in mammal surveys at Nawurlandja in the late 1970s, suggesting that it was locally common at that time (Begg et al. 1981). However, subsequent surveys have failed to detect the species in that area (Watson & Woinarski 2003, Armstrong & Dudley 2004, Gillespie et al unpublished data). There have been only four records of this species found in Kakadu since 2002 (Armstrong & Dudley 2004, DLRM unpublished data). The cause(s) of decline of this species are not known but may include predation by feral cats, poisoning from ingestion of Cane Toads and changes in food resources resulting from altered fire regimes (Woinarski et al. 2007).
- Merten's Water Monitor, Mitchell's Water Monitor and the Yellow-spotted Monitor are widely distributed across the Top End and other parts of northern Australia. Merten's Water Monitor and Mitchell's Water Monitor are both aquatic species usually associated with rivers and lagoons. The Yellow-spotted Monitor occurs in a wide range of habitats, including floodplains, woodlands, grasslands and coastal

beaches. Formerly common throughout the region, all of these species have undergone substantial population declines with the arrival of Cane Toads due to poison ingestion (Doody et al. 2009, 2013, Ujvari & Madsen 2009). These declines also occurred in Kakadu National Park (Griffiths & Holland 2004, Griffiths & McKay 2007). Reports suggest that all three species still persist in Kakadu National Park but at densities much lower than historical levels, and local extinctions may have occurred in some areas.

- The Plains Death Adder is distributed across the Top End and through the Gulf country into western Queensland; however the taxonomic status of some populations requires further resolution. The species inhabits floodplains, woodlands and grasslands. This species also appears to have undergone widespread population decline due to poisoning from ingestion of Cane Toads. Phillips et al. (2009) recorded nearly a 90% decline in Plains Death Adder survivorship associated with the arrival of toads. Adult female Plains Death Adders feed mostly on mammals (Webb et al. 2005); however, the decline of small native mammals throughout the range of this species may not only reduce an important component of its natural prey base, but also increase the likelihood of death adders predating toads, thus further reducing survivorship. Inappropriate fire regimes that reduce grass and other ground vegetation cover have also been shown to be detrimental to other death adder species (McDonald et al. 2012).
- The Oenpelli Python is restricted to the western Arnhem Land sandstone massif and approximately one third of its range is contained within Kakadu. The species inhabits the rugged sandstone escarpment and associated gorges, although some individuals have been reported on nearby floodplains. The species has been recorded at only 10 localities in Kakadu (Gillespie et al. unpublished data). There is some anecdotal indication of local declines of this species in some accessible areas of the Park (I. Morris pers. obs.), possibly due to illegal collecting (Woinarski et al. 2007). Targeted surveys for this species at known localities where it has been recorded, as part of the Kakadu Hotspot Survey program between December 2012 and June 2013 failed to locate any individuals (Gillespie et al. unpublished data); however five individuals were found during this survey period to the east of the Park. Little is known about the ecology of the Oenpelli Python, but as with many other large predatory snakes, it probably occurs naturally at low densities, may have low activity levels, spend a large proportion of time sheltering and hidden from detection, thus making it difficult to survey and monitor. Although infrequently encountered, the overall pattern of reports shows no discernible overall decline of this species since the early 1970s when it was first described (G. Gillespie unpublished data); however increased public interest and search effort for this species in recent years may also be influencing this pattern. Several threats are potentially operating that could be contributing to the rarity of this species, or causing populations to decline, including: poaching, changes in mammalian prey resources and predation. The small mammal prey base for juvenile Oenpelli Pythons has undergone catastrophic decline in recent decades (Woinarski et al. 2011). Juvenile Oenpelli Pythons are also within the prey size range of feral cats, which occur throughout the range of the species, and are known to predate small pythons. Inappropriate fire regimes may also have adversely affected this species, either by loss of habitat components, such as tree hollows, which are important for other arboreal python species (see Bryant et al. 2012), or by contributing to reduction of its prey species.

- In addition to species formally listed as threatened, other species occur within Kakadu National Park whose conservation status is currently uncertain or indeterminate. Information on the distributions, population sizes or population trends of these species is insufficient to assess their current conservation status, either broadly throughout the Northern Territory or specifically within the Park (Table 2). In all cases the number of recent records, as collated by NT DLRM and Kakadu National Park, of these species in Kakadu National Park (during the past 10 years) is very low or zero. However, it is likely that many observations of some of these species, either by members of the public or land managers, go unreported; therefore these figures may not be a true indication of the distribution and status of the species.

- In some cases, such as the Blue-tongued Lizard and Stone Country Death Adder, population declines have been reported elsewhere in the Top End, associated with arrival of Cane Toads, and this threat is known to be operating upon populations within the Park. In other cases, such as the Northern Carpet Python and King Brown Snake, declines have been reported elsewhere but the cause(s) is unclear and may also be occurring in the Park. These species feed predominantly on small mammals, which have undergone substantial declines in abundance in recent decades (Woinarski et al. 2013), possibly resulting in a reduction in prey availability. Carpet pythons utilize tree hollows for shelter and leaf litter and ground cover vegetation for shelter and nesting (Shine 1991, Heard et al. 2004, Pearson et al. 2005, Bryant et al. 2012). Inappropriate fire regimes may be reducing the availability of microhabitats critical for persistence of this species.

- For other species, such as the Alligator River Ctenotus, Kakadu Ctenotus, Chameleon Dragon, Taipan, Western Brown Snake, Pig-nosed Turtle and Sandstone Long-necked Turtle, data are simply insufficient to make any informed assessment about their population status or trends.

- To date there is no evidence of declines of any frog species in Kakadu National Park; however three frog species (Giant Frog *Litoria australis*, Northern Dwarf Tree-frog *L. bicolor* and Ornate Burrowing Frog *Platypectrum ornatus*) are listed in the Northern Territory as Data Deficient on the basis of some preliminary indications of decline following the arrival of cane toads. The arrival of Cane Toads may have influenced the dynamics of populations of some species and assemblages (Shine 2010); however there is no evidence to date that any Top End species have declined as a result of toads through predation or competition. Nevertheless, systematic monitoring data on frogs in Kakadu and elsewhere in the Top End is limited, and there is generally high uncertainty in the formal conservation assessments of many species in the region (Gillespie et al. 2011). This is exacerbated by poorly-resolved taxonomy of some genera, such as *Uperoleia* species.

Table 6.2 Reptile species currently considered data deficient or near threatened in Kakadu National Park. DD – Species formally identified as data-deficient in the Northern Territory; NT – Near threatened in the Northern Territory; LC – Least Concern in the Northern Territory.

Species	Comment	Northern Territory Status	Records in Kakadu since 2003
Alligator River Ctenotus *Ctenotus kurnbudj*	No current data on distribution in Kakadu; no data on population trends	DD	0
Arnhemland Ctenotus *Ctenotus arnhemensis*		DD	
Point Stuart Ctenotus *Ctenotus stuarti*		DD	
Kakadu Ctenotus *Ctenotus gagudju*	No current data on distribution in Kakadu; no data on population trends	DD	0
Blue-tongued Lizard *Tiliqua scincoides*	Declined throughout Top End associated with Cane Toad arrival (Price-Rees *et al*. 2010; Brown *et al*. 2013)	DD	3
Chameleon Dragon *Chelosania brunnea*	Limited current data on distribution in Kakadu; no data on population trends	NT	1
Black Spotted Ridge-tailed Monitor *Varanus baritji*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	13
Kimberley Rock Monitor *Varanus glauerti*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	2
Long-tailed Rock Monitor *Varanus glebopalma*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	20
Northern Ridge-tailed Monitor *Varanus primordius*		NT	
Spotted Tree Monitor *Varanus scalaris*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	10

Green Tree Snake *Dendrelaphis punctulata*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	11
Northern Carpet Python *Morelia spilota*	Limited historic or current data on distribution in Kakadu; no data on population trends. Population declines documented in part of range (Brown *et al*. 2013). Likely to be adversely affected by inappropriate fire regimes. Potentially affected by mammal decline	LC	4
Olive Whip Snake *Demansia olivacea*		DD	
Narrow-banded Northern Bandy-bandy *Vermicella multifasciata*		DD	
King Brown Snake *Pseudechis australis*	Declined throughout Top End; population declines documented in part of range preceding Cane Toad arrival (Brown *et al*. 2013). Potentially affected by mammal decline.	NT	16
Western Brown Snake *Pseudonaja nuchalis*	Limited historic or current data, but other large Elapid snakes have declined	LC	4
Taipan *Oxyuranus scutellatus*	Limited historic or current data, but other large Elapid snakes have declined. Potentially affected by mammal decline	DD	2
Stone Country Death Adder Acanthophis sp. nov.	Limited historic or current data; declines reported in congeneric species. Likely to be adversely affected by inappropriate fire regimes. Potentially affected by mammal decline		2
Pig-nosed Turtle *Carettochelys insculpta*	Limited historic or current data on distribution in Kakadu; no data on population trends	NT	1
Sandstone Long-necked Turtle *Chelodina burrungandjii*	Limited historic or current data on distribution in Kakadu; no data on population trends	DD	0

6.3 Characteristics and Trends

Relatively few of the threatened or data-deficient reptile species are considered habitat specialists; five species are restricted to the sandstone escarpment; four are strongly associated with streams and permanent waterbodies; and one species, the Yellow-snouted Gecko, has an association with particular soils and fire regimes. The remaining species have relatively generalized habitat associations but are typically associated with floodplains and lowland woodlands.

The threatened or data-deficient species comprise most of the large reptiles in the Park, including all the large elapid snakes and monitors, and the largest python. These species make up a large component of the terrestrial predator community and their decline may have significant adverse ecological consequences. Evidence already exists that reduction of some of these predators has resulted in meso-predator release of other species, including several colubrid snake species (Doody et al. 2013, Brown et al. 2013), with as yet unknown knock-on effects on smaller vertebrates down the food chain.

In some cases declines are very clearly linked to specific threats, such as poisoning from ingestion of Cane Toads in the case of monitor lizards, elapid snakes and Blue-tongue Lizards. These species comprise most of the habitat generalists that have declined. Many of these declines were predicted before the arrival of toads (Smith & Phillips 2006), and populations of most of these species may recover in time through natural selection of toad avoidance (Woinarski et al. 2007). However, the rate, magnitude and geographical pattern of recoveries is unknown, and is conditional on the persistence of viable populations, and the particular life history, ecological and behavioural characteristics of species. Other factors may also be contributing to the decline of some of these species; for instance there is some evidence that declines of the King Brown Snake commenced prior to arrival of Toads (Brown et al. 2013), possibly in response to mammal declines.

In many cases, such as with the Oenpelli Python, Arnhem Land Rock Skink and some data-deficient species, the nature of declines (magnitude and/or cause) is unclear. This reflects firstly, major knowledge gaps in our understanding of the past and present distribution of these species, and how these relate to extraneous environmental factors; and secondly, the presence of several contrasting potential threatening processes operating in the Park, including: inappropriate fire regimes; introduced predators and resultant changes in prey base; and potentially complex interactions and cascading ecological effects of these processes.

Compared with mammal and bird species, information on population trends for many of the reptile and frog species in Kakadu is poor. The existing general fauna fire plot monitoring program has provided reasonable data for many small reptile species in Kakadu; however, this monitoring has been inadequate for large predatory species that occur at low densities (e.g. large snake and monitor species), rare or patchily distributed species, and frogs and other species with highly variable activity patterns. Consequently, apart from specific targeted studies on selected species, such as monitors (Griffiths & Holland 2004), information on population trends for most large reptile and frog species is very poor. A consequence of this is that declines of some species will be detected much later than when they become in trouble.

6.4 Current Management and Management Requirements

The paucity of knowledge of distribution and current population status and trends of most threatened and data-deficient reptile species means that there is less certainty about their conservation status compared with mammals. Consequently more species may be threatened than current information suggests.

Compared with the information available for mammals, there is relatively limited existing knowledge of the ecology of many threatened and data-deficient reptile species in Kakadu. Whilst some inferences can be made from studies of congeneric species from other regions, this is limited for some endemic species that lack ecological analogues, such as Oenpelli Pythons. Furthermore, for the most part our knowledge of relationships between threats and species is poor, limiting the development of targeted management actions. None of the EPBCA listed threatened species have recovery plans.

For species whose status in Kakadu is poorly resolved, there is a priority to clarify that status (particularly in relation to threats), through targeted surveys. Furthermore, systems are required for better capture and management of information informally gathered on rare or cryptic species by Park Staff, visiting researchers and members of the public, as this is a valuable source of baseline distributional data for some threatened and data-deficient species.

Carefully designed monitoring programs, complementing existing biodiversity monitoring programs, are required to evaluate population trends of potentially declining species, as well as those that may recover after Cane Toads. Targeted research is required to improve knowledge of impacts of other key threatening processes on threatened species, in particular fire and feral cats, and how to manage them.

Currently no management initiatives are available to mitigate the impacts of Cane Toads, because the technology does not exist to eradicate or suppress toad populations in any part of the Park. Apart from allowing natural evolutionary processes to operate on extant populations of effected species, management should be focussed on other, more pervasive threats, where intervention may be effective and beneficial.

As for mammals, there is a high priority across species to manage fire in a manner that more effectively targets increased retention of longer-unburnt woodlands. For some species, there is a high priority to control feral cats. The nature of these threats, the types of species adversely affected and the nature of the environment under management means that an adaptive experimental approach needs to be adopted. This approach will enable structured management intervention to be undertaken, coupled with tightly-focused monitoring to assess its effectiveness.

The challenges posed by the targeted management of fire and feral cats means that intervention is likely to be most effective in localised areas. The most beneficial outcomes will be achieved at sites that hold significant populations of particular threatened species. Such sites need to be identified across taxonomic groups.

As with mammals, we note that integration of actions across species, and ongoing review and refinement of conservation efforts, would be substantially facilitated by the establishment of a Recovery Team or analogous advisory group.

Furthermore, we recommend that annual reporting for Kakadu NP should include consistent indices that measure trends for threatened reptile species and the mitigation of their threats.

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7 Threatened birds of Kakadu National Park: which species?; how are they faring? and what needs to be done for them?

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7.1 Introduction: threatened bird species occurring in Kakadu National Park

Following decades of systematic fauna survey and records by resident and visiting observers, the composition of the bird fauna of Kakadu National Park is well known. However, the listing of threatened bird species found in Kakadu is fluid, and knowledge about the distribution, abundance, population trends, threats and management requirements of most of Kakadu's threatened bird species is limited. Here, we provide an inventory of the currently listed threatened bird species occurring in Kakadu National Park. We provide a summary of the current status of these species in Kakadu National Park, and then indicate priorities for conservation management.

For Kakadu National Park, the most relevant threatened species listings are those for Australia (under the *Environment Protection and Biodiversity Conservation Act 1999*: 'EPBC Act') and the Northern Territory (under the *Territory Parks and Wildlife Conservation Act 2000*). Although there is much overlap between these lists, and the criteria for eligibility are broadly similar, there are also notable differences in composition of the lists. In part, this may reflect geographical scope – species may be declining rapidly in the Northern Territory but not elsewhere in Australia, or vice-versa. However, much of the difference between lists also relates to its currency: the Northern Territory list is comprehensively reviewed at c. 5 year intervals, whereas the Australian list is modified much more haphazardly. This latter shortcoming may change imminently, with the likelihood that the independent decadal-scale reviews of the conservation status of all Australian bird species (and subspecies) (most recently Garnett et al. 2011) will be used as a basis for comprehensive changes to the birds included in the national threatened species listing. With that outcome in mind, we include here details of the conservation status recommended by Garnett et al. (2011).

The EPBC Act also provides some protection for species recognised as 'migratory' and 'marine' (including many bird species); and the Australian government is also committed to the protection of species listed in multinational treaties as migratory (notably the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention)) and in a set of bilateral treaties for birds (the Japan-Australia Migratory Bird Agreement, the China-Australia Migratory Bird Agreement and the Republic of Korea-Australia Migratory Bird Agreement). Although many Kakadu bird species are included in these lists, they are not the focus of this paper.

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The 20 threatened bird species (and subspecies) occurring in Kakadu National Park are listed in Table 7.1.

Table 7.1 List of threatened bird species recorded from Kakadu National Park. Conservation status codes: EN=endangered; VU=vulnerable; NT=near threatened

common name	scientific name	EPBCA listed	NT listed	recommended (Garnett *et al.* 2011)
Partridge Pigeon (eastern)	*Geophaps smithii smithii*	VU	VU	VU
Red Goshawk	*Erythrotriorchis radiatus*	VU	VU	NT
Masked Owl (northern)	*Tyto novaehollandiae kimberli*	VU	VU	VU
Yellow Chat (Alligator Rivers)	*Epthianura crocea tunneyi*	EN	EN	EN
Crested Shrike-tit (northern)	*Falcunculus frontatus whitei*	VU	NT	-
Gouldian Finch	*Erythrura gouldiae*	EN	VU	NT
Grey Falcon	*Falco hypoleucos*	-	VU	VU
White-throated Grass-wren	*Amytornis woodwardi*	-	VU	VU
Red Knot (New Siberian Islands)	*Calidris canutus piersmai*	-	VU**	VU
Red Knot (north-eastern Siberia)	*Calidris canutus rogersi*	-	VU**	VU
Great Knot	*Calidris tenuirostris*	-	VU	VU
Curlew Sandpiper	*Calidris ferruginea*	-	VU	VU
Greater Sand Plover (Mongolian)	*Charadrius leschenaultii leschenaultii*	-	VU	VU
Lesser Sand Plover (Mongolian)	*Charadrius mongolus mongolus*	-	VU**	EN
Lesser Sand Plover (Kamchatkan)	*Charadrius mongolus stegmanni*	-	VU**	EN
Asian Dowitcher*	*Limnodromus semipalmatus*	-	VU	NT
Bar-tailed Godwit (western Alaskan)	*Limosa lapponica baueri*	-	VU**	VU
Bar-tailed Godwit (northern Siberian)	*Limosa lapponica menzbieri*	-	VU**	VU
Eastern Curlew	*Numenius madagascariensis*	-	VU	VU
Australian Painted Snipe*	*Rostratula australis*	VU	VU	EN

* few if any records from Kakadu NP

** listed at species level

This is a large complement of threatened bird species. The significance of Kakadu for threatened bird species is recognised globally by its inclusion within three contiguous 'Important Bird Areas' (Dutson et al. 2009), Arnhem Plateau, Kakadu Savanna and Alligator Rivers Floodplains, defined by threshold numbers of globally threatened bird species, representative populations of restricted-range species and significance for congregating species. Monitoring of threatened species is an expected practice in such areas.

Kakadu's threatened bird species fall broadly into two groups: resident landbirds (Partridge Pigeon, Red Goshawk, Masked Owl, Yellow Chat, Crested Shrike-tit, Gouldian Finch, White-throated Grass-wren and Grey Falcon (although the last may be only an occasional visitor)) and migratory shorebirds (Red Knot, Great Knot, Curlew Sandpiper, Great Sand Plover, Lesser Sand Plover, Asian Dowitcher and Bar-tailed Godwit). Unlike the other shorebirds, the Australian Painted Snipe is not an inter-continental migrant, but probably disperses widely within Australia, and is only an occasional visitor to Kakadu.

None of the threatened species is restricted to Kakadu; however Kakadu comprises most of the range (and population size) of the White-throated Grass-wren and Yellow Chat (Alligator Rivers), and much of that of the Partridge Pigeon (eastern). Most of the threatened terrestrial birds occur in lowland woodlands, but the Yellow Chat is restricted to floodplains and the White-throated Grass-wren to the stone country.

Table 7.2 Broad landscapes occupied by threatened bird species in Kakadu, and an estimate of the extent of their range in Kakadu relative to their entire range. Note that for at least some of the migratory shorebird species, Kakadu may occasionally hold >1% of the global population.

common name	landscape association	% Kakadu: total range
Partridge Pigeon (eastern)	lowland woodlands	30
Red Goshawk	lowland woodlands	5-10
Masked Owl (northern)	lowland woodlands	<5
Yellow Chat (Alligator Rivers)	floodplains	70
Crested Shrike-tit (northern)	lowland woodlands	5-10
Gouldian Finch	lowland woodlands (stony hills)	<5
Grey Falcon	lowland woodlands; floodplains	<5
White-throated Grass-wren	stone country	50
Red Knot (New Siberian Islands)	coastal	<5
Red Knot (north-eastern Siberia)	coastal	<5
Great Knot	coastal	<5
Curlew Sandpiper	coastal	<5
Greater Sand Plover (Mongolian)	coastal	<5
Lesser Sand Plover (Mongolian)	coastal	<5
Lesser Sand Plover (Kamchatkan)	coastal	<5
Asian Dowitcher*	coastal	<5
Bar-tailed Godwit (western Alaskan)	coastal	<5
Bar-tailed Godwit (northern Siberian)	coastal	<5

Eastern Curlew	coastal; wetlands	<5
Australian Painted Snipe*	wetlands	<5

7.2 The status and trends of threatened birds in Kakadu

For most of the eight resident threatened birds in Kakadu, there is no available estimate of population size in the Park, and no robust information on current trends in population size. This lack of information constrains the ability to prioritise between species, and hampers the ability to assess the success of management actions.

The Park's main biodiversity monitoring program, based on 136 fixed 'fire plots' sampled at c. 5 year intervals, provides some information on trends for two of the threatened bird species. Over the most recent sampling period (from a baseline in 2001–04 to re-sampling in 2007–09), the Partridge Pigeon declined significantly (by 79%) from a mean abundance of 0.24 to 0.05 individuals per plot, and the White-throated Grass-wren declined significantly from a mean abundance of 0.09 to 0 individuals per plot (Woinarski et al. 2012). However the number of plots from which these two bird species were recorded was relatively few (12 for the Partridge Pigeon and six for the White-throated Grass-wren), suggesting that the fire-plot monitoring is not a particularly powerful protocol for monitoring trends in these species. For the other six resident threatened bird species, the fire-plot monitoring provided no records and hence no information on population trends.

There is some scattered information on the status of some of Kakadu's threatened terrestrial bird species. For the Red Goshawk, Aumann and Baker-Gabb (1991) described some ecological studies in the 1980s, including some assessment of density and population size in Kakadu. For the Northern Shrike-tit, Simon Ward (NT Department of Natural Resources, Environment, the Arts and Sport) conducted some limited targeted surveys in 2009 (prompted in part by some unconfirmed recent records), but did not record the species and the search results were not published. For the Masked Owl, 68 Kakadu sites were sampled in 2010 as part of a more systematic sampling across parts of the Top End; Masked Owls were reported from only one of those Kakadu sites (Ward 2010). For the Yellow Chat, Armstrong (2004) conducted a more intensive systematic search and documented all known records. For the White-throated Grass-wren, recent targeted sampling in Kakadu (Mahney et al. 2011) and in adjacent areas of Warddeken IPA (Warddeken Land Management Limited 2013) provides some assessment of current distribution and abundance, and is broadly comparable in protocol to a benchmark similar sampling in 1987-88 (Noske 1992). An intensive ecological study of Partridge Pigeons (Fraser 2001, Fraser et al. 2003) provided some information on abundance, habitat requirements and threats.

For the threatened migratory shorebirds, there is some historic assessments of status in Kakadu (e.g. Bamford 1990), some more recent broader regional (Top End) assessment of status (Chatto 2003), but ongoing national monitoring does not include sampling in Kakadu. Rapid and severe declines (of >30%) in global population size in the last few decades (due to habitat loss mostly in parts of their Asian range) have been reported for all migratory shorebird taxa listed in Table 7.1 (Garnett et al. 2011), and it is likely that this rate of decline is manifest in the population size of birds visiting Kakadu.

7.3 Management requirements and current management

Recovery Plans provide prioritised research and management actions and a strategic framework for the conservation of Australia's threatened species. On Commonwealth lands (such as Kakadu), these Plans must be implemented. There are existing Recovery Plans for the Partridge Pigeon (Woinarski 2004), Masked Owl (Woinarski 2004), Crested Shrike-tit (Woinarski 2004), Gouldian Finch (O'Malley 2006) and Red Goshawk (DERM 2012). The actions described in those plans are summarised in Table 7.3. There has been little implementation of these actions in Kakadu (or elsewhere). Garnett et al. (2011) provides more recent advice on research and management priorities for most of the threatened taxa, but this is relatively general.

Table 7.3 Summary of actions stipulated in Recovery Plans for threatened species occurring in Kakadu

Recovery Plan	actions			
	general	**research**	**management**	**monitoring**
Partridge Pigeon	establish and operate a Recovery Team	assess relative impacts of threats	maintain and enhance habitat suitability, through fire management; minimise impacts of spread of exotic pasture grasses	
Crested Shrike-tit	establish and operate a Recovery Team	assess population size, distribution and habitat		
Masked Owl	establish and operate a Recovery Team	assess population size, distribution and habitat		
Red Goshawk		collate information on known nest sites; produce descriptive maps of important habitat; conduct searches to identify previously unknown nest sites; identify important populations and nest sites	ensure known information about nest sites is secure	monitor at least 20 nest sites each year to determine territory occupancy and productivity
Gouldian Finch	administer the recovery team effectively; develop linkages with other species recovery programs	test ideal parameters for patch-burning regimes, and assess response	reduce the frequency, extent and/or intensity of late dry season fires at key sites; incorporate adaptive burning strategies into management plans; enhance feral animal control;	refine techniques to develop a standardised population monitoring method; establish a network of monitoring sites in key habitat areas and implement annual monitoring at these; regularly review and report on monitoring results

Information on threats and management requirements varies across the set of threatened terrestrial birds, although in most cases the available information is limited.

For the Partridge Pigeon, research has demonstrated that habitat suitability is influenced by fire regimes, with a clear preference for patchy small-scale fires (mosaic burning)

(Fraser et al. 2003). There is no relevant evidence (for or against) but it is likely that the species may also benefit from wet season burning (which would reduce risks of fire causing nest failure). Given that Partridge Pigeons forage, nest and roost on the ground, it is likely that feral cats are a major predator. As with other lowland species, it is likely that the Partridge Pigeon would be disadvantaged by increases in invasive grasses (especially gamba and mission grasses) because these would fuel more high intensity fires and because their dense biomass would reduce efficiency of foraging on the ground.

For the White-throated Grass-wren, there is some evidence for a preference for relatively old spinifex (Noske 1992), suggesting that a management objective should be to reduce the incidence of high intensity fires in the stone country, particularly in areas that hold important subpopulations of this species, and also to reduce their scale, in order to allow relatively rapid recolonisation of recently burnt areas from areas retaining old growth spinifex.

For the Gouldian Finch, research has demonstrated short- and medium-term responses to fire regimes, with habitat suitability broadly optimised with increase in fire patchiness and decrease in the incidence of high intensity light dry season fires (Maute 2012). This species is also likely to be disadvantaged by spread of invasive pasture grasses, as it has not colonised areas where these grasses occur.

There is little information on threats to the Yellow Chat, but it may be disadvantaged by habitat degradation associated caused by feral pigs and buffaloes; and its floodplain habitat may be diminished by saltwater intrusion (Armstrong 2004). Further research should provide a more secure foundation for refined management advice.

The management requirements of Masked Owl, Red Goshawk, Crested Shrike-tit and Grey Falcon are poorly known. It is plausible that the first three of these lowland species would be disadvantaged by high intensity and extensive wildlife. The Masked Owl may also have been affected by declines in mammal populations.

7.4. Priorities for management

Based in part on recommendations from the existing Recovery Plans (where available) (Table 7.3), and on prioritisation based on the proportion of the taxon's range within Kakadu (Table 7.2), priority actions for research, management and monitoring of the threatened terrestrial birds are summarised in Table 7.4.

Table 7.4 Recommended and prioritised research, management and monitoring actions for threatened terrestrial bird occurring in Kakadu. High priority actions are marked in bold.

common name	priorities		
	research	management	monitoring
Partridge Pigeon (eastern)	assess impacts of feral cats (medium); assess responses to wet season burning (medium)	**increase patchiness of fires in lowland areas (high); reduce abundance of cats (high); minimise distribution and abundance of gamba and mission grasses (high)**	**establish and implement specific monitoring program (high)**; maintain fire-plot monitoring (medium)
Red Goshawk	assess population size and distribution (low); identify threats (particularly effects of fire regimes) and		establish and implement specific monitoring program (linked to national program) (low)

	management requirements (low)		
Masked Owl (northern)	assess population size and distribution (medium); identify threats and management requirements (low)	increase extent of longer-unburnt areas in lowlands (low)	establish and implement specific monitoring program (medium)
Yellow Chat (Alligator Rivers)	**assess population size and distribution (including delineation of key sites) (high); identify threats and management requirements (high)**	reduce abundance of buffalo and pigs around key sites (medium)	**establish and implement specific monitoring program (high)**
Crested Shrike-tit (northern)	assess population size and distribution (low)	increase extent of longer-unburnt areas in lowlands (low)	If populations found, institute specific monitoring program (low)
Gouldian Finch	assess population size and distribution (especially breeding areas) (low)	increase patchiness of fires in lowland areas (low)	establish and implement specific monitoring program (low)
Grey Falcon	collate previous and ongoing records (low)		
White-throated Grass-wren	**continue to define fine-scale distribution to locate groups for targeted protection (high)**; refine relationships with fire history (medium); assess population size (medium)	**increase extent of longer-unburnt areas in stone country, particularly around known groups (high)**	**establish and implement specific monitoring program (high)**; maintain fire-plot monitoring (medium)

In addition to these taxon-specific actions, we note that integration of actions across species, and ongoing review and refinement of conservation efforts, would be substantially facilitated by the establishment of a Recovery Team or analogous advisory group.

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8 Threatened terrestrial mammals of Kakadu National Park: which species?; how are they faring? and what needs to be done for them?

J Woinarski[1] & A. Fisher[2]

8.1 Introduction: threatened terrestrial mammal species occurring in Kakadu National Park

Kakadu National Park supports an unusually large complement of threatened mammal species. However, the status of most of these species in Kakadu is deteriorating, in some cases catastrophically. There has been relatively little management focused specifically on these threatened mammal species. Here, we provide an inventory of the currently listed threatened terrestrial mammal species occurring in Kakadu, a summary of the current status of these species in Kakadu, an assessment of their threats and management requirements, and a prioritisation for conservation management.

For Kakadu, the most relevant threatened species listings are those for Australia (under the *Environment Protection and Biodiversity Conservation Act 1999*: 'EPBC Act') and the Northern Territory (under the *Territory Parks and Wildlife Conservation Act 2000*). Although there is much overlap between these lists, and the criteria for eligibility are broadly similar, there are also notable differences in composition of the lists. In part, this may reflect geographical scope – species may be declining rapidly in the Northern Territory but not elsewhere in Australia, or vice-versa. However, much of the difference between lists also relates to its currency: the Northern Territory list is comprehensively reviewed at c. 5 year intervals (most recently in 2012), whereas the Australian list is modified much more haphazardly. This latter shortcoming may change in the short- to medium-term, with the likelihood that independent decadal-scale reviews of the conservation status of all Australian mammal species (and subspecies) (Woinarski et al. 2013a) will be used as a basis for comprehensive changes to the mammals included in the national threatened species listing. With that outcome in mind, we include here details of the conservation status recommended by Woinarski et al. (2013a).

Note that threatened marine mammal species are considered in a separate chapter (Kyne, Chapter 5).

The 17 threatened terrestrial mammal species (and subspecies) occurring in Kakadu National Park are listed in Table 8.1. Broadly, this listing is in three groups, a set of five species extant in Kakadu and currently listed under the EPBC Act (although this includes the Bare-rumped Sheath-tailed Bat, which is unlikely to remain on the threatened species list), a set of four EPBCA-listed species for which there are no (post 1990) records from Kakadu (discussed later), and set of eight species not currently listed under the EPBC

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Act, but listed under Northern Territory legislation and/or have been recommended for national listing by Woinarski et al (2013a).

Table 8.1 List of threatened terrestrial mammal species recorded from Kakadu National Park. Conservation status codes: CR=critically endangered; EN=endangered; VU=vulnerable; NT=near threatened; DD=data deficient.

Common name	Scientific name	EPBCA listed	NT listed	recommended (Woinarski *et al*. 2013a)
Northern Quoll	*Dasyurus hallucatus*	EN	CR	EN
Northern Brush-tailed Phascogale	*Phascogale pirata*	VU	EN	VU
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	VU	EN	VU
Arnhem Rock-rat	*Zyzomys maini*	VU	VU	VU
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus nudicluniatus*	CR	NT	NT
Golden-backed Tree-rat	*Mesembriomys macrurus*	VU	CR	NT
Golden Bandicoot	*Isoodon auratus*	VU	EN	VU
Water Mouse	*Xeromys myoides*	VU	DD	VU
Northern Hopping-mouse	*Notomys aquilo*	VU	VU	VU
Fawn Antechinus	*Antechinus bellus*	-	EN	VU
Nabarlek	*Petrogale concinna*	-	VU	VU*
Arnhem Leaf-nosed Bat	*Hipposideros inornatus*	-	VU	EN
Northern Leaf-nosed Bat	*Hipposideros stenotis*	-	VU	NT
Black-footed Tree-rat	*Mesembriomys gouldii*	-	VU	VU**
Pale Field-rat	*Rattus tunneyi*	-	VU	NT***
Northern Brush-tailed Possum	*Trichosurus vulpecula arnhemensis*	-	NT	VU
Ghost Bat	*Macroderma gigas*	-	NT	VU

* NT for the species; VU for the subspecies *P. c. canescens*

** VU for the species; EN for the subspecies *M. g. gouldii*

*** for the subspecies *R. t. tunneyi* only, the full species being considered Least Concern

None of the threatened terrestrial mammal species is restricted to Kakadu (Table 8.2); however Kakadu comprises most of the range (and/or population size) of the Arnhem Leaf-nosed Bat and Arnhem Rock-rat, and much of the range (and/or total population size) of the Fawn Antechinus, Black-footed Tree-rat, Nabarlek and Northern Brush-tailed Possum. The threatened terrestrial mammals occur mostly in lowland woodlands and/or in the stone country (Table 8.2).

Table 8.2 Broad landscapes occupied by threatened bird species in Kakadu, and an estimate of the extent of their range in Kakadu relative to their entire range.

Common name	Landscape association	% Kakadu: total range
Northern Brush-tailed Phascogale	lowland woodlands	40
Fawn Antechinus	lowland woodlands	40
Northern Brush-tailed Possum	lowland woodlands, rainforests	20
Brush-tailed Rabbit-rat	lowland woodlands	<5
Black-footed Tree-rat	lowland woodlands	30
Pale Field-rat	lowland woodlands	10
Bare-rumped Sheath-tailed Bat	lowland woodlands	<5
Golden-backed Tree-rat	stone country; lowland woodlands, rainforests	<5
Northern Quoll	stone country; lowland woodlands	5
Ghost Bat	stone country; lowland woodlands	<5
Arnhem Rock-rat	stone country, rainforests	50
Golden Bandicoot	stone country	<5
Northern Hopping-mouse	?stone country	<5
Nabarlek	stone country	30
Arnhem Leaf-nosed Bat	stone country, rainforests	70
Northern Leaf-nosed Bat	stone country	10
Water Mouse	coastal; wetlands; floodplains	<5

In addition to the taxa listed as threatened in Table 8.1, a further nine mammal species occurring in Kakadu are listed as Near Threatened under Northern Territory legislation and/or are considered Near Threatened in the most recent national review (Woinarski et al. 2013a) (Table 8.3). It is likely that some of these species will be added to national or Northern Territory threatened species lists over the next decade.

Table 8.3 Terrestrial mammal species (additional to those listed in Table 8.1) considered near threatened or data deficient under Northern Territory legislation and/or in the most recent national review (Woinarski *et al*. 2013a). NT=Near Threatened; DD=Data Deficient; LC=Least Concern

Common name	Scientific name	Status in Northern Territory	National review (Woinarski *et al*. 2013a)
Kakadu Dunnart	*Sminthopsis bindi*	DD	NT
Red-cheeked Dunnart	*Sminthopsis virginiae*	DD	LC
Northern Brown Bandicoot	*Isoodon macrourus*	NT	LC
Spectacled Hare-wallaby	*Lagorchestes conspicillatus*	NT	NT
Northern Nailtail Wallaby	*Onychogalea unguifera*	NT	LC
Black Wallaroo	*Macropus bernardus*	DD	NT
Kakadu Pebble-mouse	*Pseudomys calabyi*	NT	NT
Western Chestnut Mouse	*Pseudomys nanus*	NT	LC
Orange Leaf-nosed Bat	*Rhinonicteris aurantia*	NT	LC
Arnhem Sheath-tailed Bat	*Taphozous kapalgensis*	NT	LC

8.2 The status and trends of threatened terrestrial mammals in Kakadu

Compared with other groups of threatened species, there is a reasonably good information on population trends for many of the threatened mammal species in Kakadu, due to a 20–30 history of mammal survey and research, and some now relatively long-standing monitoring programs.

The persistence of four threatened mammal species in Kakadu is uncertain, because there have been no recent confirmed records, notwithstanding much survey effort. The last confirmed record in Kakadu for Golden-backed Tree-rat was in 1969 (Deaf Adder Gorge: Parker 1973), with a previous (1903) record from Nellie Creek; however there has been a recent unconfirmed record from the nearby Warddeken IPA (M. Ziembicki pers comm). The last confirmed record in Kakadu for the Golden Bandicoot was from Goodparla in 1967 (although this specimen may merit closer scrutiny), with previous records from 'South Alligator River' in 1902-03 (Woinarski 2004a). The last (indeed, only) confirmed record in Kakadu for the Water Mouse was in 1903 'from the coastal plain and tidal section of the South Alligator' (Parker 1973). The Northern Hopping-mouse is known from Kakadu only from a recent subfossil deposit at Anbangbang shelter in the stone country (Foley 1985), however there is a 1973 record from the nearby Warddeken area (Woinarski et al. 1999). Given information on trends in the mainland Top End, it is likely that the Golden-backed Tree-rat, Northern Hopping-mouse and Golden Bandicoot no longer occur in Kakadu. There has been relatively little targeted sampling for the Water Mouse in Kakadu or elsewhere in the Top End (Woinarski et al. 2000), and this species may be elusive, so it is plausible that it is still present in Kakadu.

The Brush-tailed Rabbit-rat may also no longer persist in Kakadu, with the last known subpopulation in the Park (at Mardugal campground) disappearing between 2002 and 2009 (Firth 2010), although there have been a few subsequent unconfirmed records.

The Park's main biodiversity monitoring program, based on 136 fixed 'fire plots' sampled at c. 5 year intervals, provides robust information on trends for several of the threatened mammal species, albeit with now low rates of reporting compromising the ability of this sampling to detect current and future trends for decrease for many species. For the most recently reported monitoring period, the abundance of Northern Brush-tailed Possum, Fawn Antechinus, Pale Field-rat, Northern Quoll and Arnhem Rock-rat has declined severely (by >50%) (Woinarski et al. 2010) (Table 4). This follows previous studies documenting severe decline (in the Kapalga area) for the period from 1985–87 to 1999 (and/or the period 1989–93 to 1999) for the Fawn Antechinus, Northern Quoll, Northern Brush-tailed Possum, Black-footed Tree-rat and Pale Field-rat (Woinarski et al. 2001). There are too few records in the monitoring programs to demonstrate trends for the Northern Brush-tailed Phascogale and Nabarlek, but there is strong anecdotal evidence of a decline over the last 1-2 decades for both species (Pearson 2012, Woinarski et al. 2013a). There is no monitoring of bat species, and the population status of the four threatened bat species currently cannot be assessed reliably.

Table 8.4 Change in abundance of threatened terrestrial mammal species recorded from baseline (2001–04) to subsequent (2007-09) sampling at 136 fire plots in Kakadu. Note that % change is reported only for species recorded from at least five plots (otherwise n/a).

Common name	Abundance 2001-04	Abundance 2007-09	% change	No. plots
Northern Brush-tailed Phascogale	0.02	0	n/a	2
Fawn Antechinus	0.40	0.04	-90%	16
Northern Brush-tailed Possum	0.07	0.01	-86%	6
Brush-tailed Rabbit-rat	0	0.01	n/a	1
Black-footed Tree-rat	0.01	0	n/a	1
Pale Field-rat	0.70	0.04	-94%	22
Northern Quoll	0.49	0.02	-96%	29
Arnhem Rock-rat	0.19	0.09	-53%	12

8.3 Management requirements and current management

Compared with the information available for threatened taxa in other groups, there is relatively substantial existing knowledge of the ecology, threats and management requirements for many of the threatened mammal taxa (largely summarised in Woinarski (2004a), Woinarski et al. (2007) and Woinarski et al. (2013a).

Excluding the probably now Kakadu-extinct Golden-backed Tree-rat, Golden Bandicoot and Northern Hopping-mouse, fire is the main or a major threat for most of the species: Northern Brush-tailed Phascogale, Fawn Antechinus, Northern Brush-tailed Possum, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Arnhem Rock-rat, and may also be implicated in the decline of the Northern Quoll and Nabarlek. These species are all detrimentally affected by frequent extensive and high intensity fire. Because of

association with large hollow-bearing trees and/or shrubby understories, the habitat suitability for Northern Brush-tailed Possum, Northern Brush-tailed Phascogale, Fawn Antechinus and Black-footed Tree-rat is highest in woodlands that have been relatively long-unburnt (i.e. >5 years) (e.g. Kerle 1985, Friend 1985, 1987, Friend & Taylor 1985). For the Brush-tailed Rabbit-rat, patchy fires and fewer late dry season fires are preferred (Firth et al. 2010). In the stone country, the Arnhem Rock-rat is associated mostly with rainforest thickets, with these being diminished by frequent and/or high intensity fire (Begg 1981, Begg et al. 1981). Frequent, extensive and high intensity fire may also increase the impacts of predation for all species (e.g. Oakwood 2000).

Currently, there is little information on population-level impacts of predation (notably by feral cats) on the threatened mammal species, but predation by feral cats may be the or a major threat for Northern Brush-tailed Phascogale, Fawn Antechinus, Northern Brush-tailed Possum, Brush-tailed Rabbit-rat, Black-footed Tree-rat, Pale Field-rat, Arnhem Rock-rat and Nabarlek, and may also be implicated in the decline of the Northern Quoll. The relative impacts of fire and predation as factors driving the current decline of this set of threatened species are not yet resolved, and may vary between species. However, it is likely that both factors are significant threats (Woinarski et al. 2011).

Poisoning by Cane Toads has been demonstrated to be the principal factor that caused the recent decline of Northern Quolls in Kakadu (e.g. Oakwood 2004), and may also be implicated in the decline of the Northern Brush-tailed Phascogale and Fawn Antechinus.

The impacts, if any, of disease(s) as a factor contributing to the current decline is unknown. Weeds (particularly invasive pasture grasses) are likely to be a threat to most threatened mammals, mostly operating indirectly through their impacts on fire regimes.

There is little information on threats to the Water Mouse, Arnhem Leaf-nosed Bat, Northern Leaf-nosed Bat, Ghost Bat or Bare-rumped Sheath-tailed Bat, although at least Ghost Bat and Arnhem Leaf-nosed Bat may suffer local detriment from disturbance at roost sites.

To date, there has been relatively little management in Kakadu specifically targeting the conservation of threatened mammal species, other than survey and monitoring activities. In this regard, it is notable that the preference of many of the threatened mammal species for long-unburnt lowland woodlands has been recognised for about 30 years, but there is little evidence that such requirement has been incorporated into fire management planning (Woinarski 2004b). A recent project examined the incidence of disease in populations of the introduced Black Rats *Rattus rattus* in and around Kakadu (Jackson et al. 2010). A current project is assessing the extent to which aversion-training can increase the success of reintroduction of Northern Quolls (Webb et al. 2012). A forthcoming project will consider the response of some mammal species to local exclusion of feral cats (J. Woinarski, G. Gillespie, A. Fisher). Previous research has examined the responses of mammal species to experimental fire regimes (operating over a five-year period) at Kapalga (Corbett et al. 2003, Pardon et al. 2003).

Recovery Plans provide prioritised research and management actions and a strategic framework for the conservation of Australia's threatened species. On Commonwealth lands (such as Kakadu), these plans must be implemented. There are existing Recovery Plans for the Northern Hopping-mouse (Woinarski 2004c), Golden Bandicoot (Palmer et al. 2003), Golden-backed Tree-rat (Palmer et al. 2003), Northern Quoll (Hill & Ward 2010), Water Mouse (DERM 2010) and Bare-rumped Sheath-tailed Bat (Schulz & Thomson 2007); and near-final draft Recovery Plans for the Nabarlek (Pearson 2012)

and Brush-tailed Rabbit-rat (Woinarski et al. 2013b). The actions described in those plans are summarised in Table 8.5. There has been little implementation of these actions in Kakadu (or elsewhere).

Table 8.5 Summary of actions stipulated in Recovery Plans for threatened mammal species occurring in Kakadu. Note that some actions unrelated to occurrence in Kakadu are not included.

Recovery Plan	Actions			
	General	**Research**	**Management**	**Monitoring**
Nabalerk	increase public awareness; involve Indigenous groups in survey and management; establish a recovery team	survey distribution, status and genetic diversity; refine existing and develop new predator control techniques; undertake genetic studies to clarify taxonomy; undertake landscape-scale fire and predator impact study; assess impacts of disease	minimise the impacts of fire	monitor the effectiveness of introduced animal control; develop new monitoring techniques;
Brush-tailed Rabbit-rat	consider options for reintroduction	undertake targeted sampling in response to any ad hoc sightings; undertake experimental re-introduction trial	maintain or enhance low intensity low frequency fire regime; enhance control of invasive grasses	maintain existing monitoring program; review any reintroduction
Northern Quoll	implement a public awareness campaign on quolls, toads and cats	determine factors affecting survival and recovery in areas with toads; identify potential refuge areas where quolls may persist with toads; investigate factors affecting susceptibility of quolls to toads; assess efficacy of toad control measures; increase knowledge and monitoring of disease; assess impacts of feral predators	reduce impacts of feral predators	
Water Mouse	collaborate with Indigenous landholders about knowledge; increase public awareness	survey distribution; consolidate distributional data base; model distribution; assess genetic differences between regions; examine reproductive biology; investigate ecology; assess threats	develop and implement a threat management plan	establish a monitoring program related to assessment of management effectiveness
Bare-rumped Sheath-tailed Bat	increase public awareness	obtain voucher echolocation calls; conduct targeted surveys; determine roosting requirements; identify diet; undertake a genetic study to clarify taxonomy	protect all roosts	establish sites for bi-annual monitoring
Golden Bandicoot	establish multi-species recovery group; increase public awareness	identify factors causing decline		
Golden-backed	establish multi-species recovery	sample sites of historic records; identify factors		

Tree-rat	group; increase public awareness	causing decline	
Northern Hopping-mouse	establish and operate a Recovery Team	enhance sampling protocols; refine knowledge of distribution; undertake detailed ecological study;	maintain or enhanceestablish a monitoring low intensity lowprogram related to frequency fire regime;assessment of minimise impacts ofmanagement feral cats effectiveness

8.4. Priorities for management

Based in part on recommendations from the existing Recovery Plans (where available) (Table 8.5), and on prioritisation based on the proportion of the taxon's range within Kakadu (Table 8.2), priority actions for research, management and monitoring of the threatened terrestrial mammals are summarised in Table 8.6.

Table 8.6 Recommended and prioritised research, management and monitoring actions for threatened terrestrial mammals occurring in Kakadu. High priority actions are marked in bold.

Common name	**Priorities**		
	Research	**Management**	**Monitoring**
Northern Brush-tailed Phascogale	**develop effective detection methodology (high); assess abundance, distribution and threats (high)**	**increase extent of long-unburnt lowland woodlands (high); reduce abundance of cats (high); minimise distribution and abundance of gamba and mission grasses (high)**	**establish and implement specific monitoring program (high)**
Fawn Antechinus		**increase extent of long-unburnt lowland woodlands (high); reduce abundance of cats (high); minimise distribution and abundance of gamba and mission grasses (high)**	maintain fire-plot monitoring (medium)
Northern Brush-tailed Possum		**increase extent of long-unburnt lowland woodlands (high); reduce abundance of cats (high); minimise distribution and abundance of gamba and mission grasses (high)**	**establish and implement specific monitoring program (high)**
Brush-tailed Rabbit-rat		**experimentally reintroduce to a site at which threats are intensively managed (high)**	
Black-footed Tree-rat		**increase extent of long-unburnt lowland woodlands (high); reduce abundance of cats (high); minimise distribution and abundance of gamba and mission grasses (high)**	**establish and implement specific monitoring program (high)**
Pale Field-rat		increase extent of long-unburnt lowland woodlands (high); **reduce abundance of cats (high);** minimise distribution and abundance of gamba and mission grasses (high)	maintain fire-plot monitoring (medium)
Bare-rumped Sheath-tailed Bat	assess abundance, distribution and threats (medium)		

Golden-backed Tree-rat		experimentally reintroduce to a site at which threats are intensively managed (low)	
Northern Quoll	maintain existing program to assess impacts of aversion-training (medium)		**establish and implement specific monitoring program (high)**
Ghost Bat	assess abundance, distribution and threats (medium)		establish and implement specific monitoring program (medium)
Arnhem Rock-rat		**reduce fire severity and/or frequency in stone country (high)**	**establish and implement specific monitoring program (high)**
Golden Bandicoot		experimentally reintroduce to a site at which threats are intensively managed (low)	
Northern Hopping-mouse		experimentally reintroduce to a site at which threats are intensively managed (low)	
Nabarlek	**assess abundance, distribution and threats (high)**	reduce fire severity and/or frequency in stone country (medium); **reduce abundance of cats (high)**	**establish and implement specific monitoring program (high)**
Arnhem Leaf-nosed Bat	**assess abundance, distribution and threats (high)**		**establish and implement specific monitoring program (high)**
Northern Leaf-nosed Bat	assess abundance, distribution and threats (medium)		establish and implement specific monitoring program (medium)
Water Mouse	develop effective detection methodology (medium); assess abundance, distribution and threats (medium)		establish and implement specific monitoring program (medium)

These actions fall into several clear clusters. For species whose status in Kakadu is poorly resolved, there is a priority to clarify that status (particularly in relation to threats and their management). For most lowland and some stone country species, there is a high priority across species to manage fire in a manner that more effectively targets increased retention of longer-unburnt woodlands. For most lowland and some stone country species, there is a high priority to control feral cats. For many species, there is a high priority to establish and implement a tightly-focused monitoring program, linked particularly to assessment of the effectiveness of management.

The targeted management of fire and feral cats for the conservation of threatened mammal species will be challenging, and may be most effectively undertaken at localised sites recognised to hold significant populations of particular threatened species.

In addition to these taxon-specific actions, we note that integration of actions across species, and ongoing review and refinement of conservation efforts, would be

substantially facilitated by the establishment of a Recovery Team or analogous advisory group.

We also recognise that the declining status of this mammal fauna is not an affliction of Kakadu alone, but that similar trends are apparent in at least some other parts of the Top End. Accordingly, conservation management responses for these species will be more effective if they are also coordinated with management actions undertaken at a broader regional level.

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9 Captive Breeding – is there a role in species conservation?

D Wedd[1]

9.1 Introduction

Captive breeding has long been touted as a panacea for species facing the risk of extinction at least regionally if not globally. Many zoos and wildlife parks around the world are involved in different species recovery programs that invariably involve some level of captive population management and breeding. Does captive breeding have a role in species conservation? The cases for and against using captive breeding for species' recovery is as diverse as the number of species requiring intervention. In the Top End of the Northern Territory, species diversity, including mammals, birds and reptiles, is declining at an alarming rate. Over the past decade, targeted surveys have been undertaken to determine the extent of this decline and the results are not at all encouraging (Woinarski et al. 2010). The number of species listed as threatened is increasing faster than the progression of our understanding as to why.

Captive breeding has a role in species conservation, but it does face limitations that restrict its success on many species. Snyder et al. (1996) indicates that captive breeding should only be employed when all other viable conservation alternatives are either exhausted or unavailable and it should not be employed as a long term solution. These and other limitations will be discussed here with relevance to Top End specific examples.

9.2 Threatened species in the Top End

Excluding migratory wading birds, the Top End has a depressing suite of threatened species classed as either, critically endangered, endangered or vulnerable. The list below is comprised of mammals, birds and reptiles that could potentially benefit from ex-situ captive management or a targeted breeding program. I have not included fish, invertebrates or plants in this discussion, but captive breeding/propagation may play an important role in their conservation. It is worth mentioning however, that of the 15 plant species listed as threatened within Kakadu National Park, only one, Acacia Graveside Gorge, is held in the George Brown Darwin Botanical Gardens as seed stock.

The table below lists the species of major concern.

The question managers are faced with is, of the 34 species noted, which ones would be considered suitable for a recovery program where captive breeding plays a major role?

[1] Territory Wildlife Park, Darwin NT

Table 9.1 The Top End's most threatened terrestrial mammal, reptile and bird species (Territory Parks and Wildlife Conservation Act, review of threatened species list 2011). http://www.lrm.nt.gov.au/plants-and-animals/home/specieslist

Order	Critically Endangered	Endangered	Vulnerable
Mammalia	Northern Quoll	Fawn Antechinus	Black footed Tree-rat
	Golden backed Tree-rat	Golden Bandicoot	Northern Hopping-mouse
	Carpentaria Rock- rat	Brush-tailed Rabbit-rat	Narbarlek
		Northern Brush-tailed Phascogale	Pale Field-rat
			Arnhem Rock-rat
			Butlers Dunnart
Reptilia		Arnhemland skink	Plains Death Adder
		Arafura snake eyed skink	VRD Black Soil Ctenotus
			Yellow-snouted Gecko
			Mitchell's Monitor
			Merten's Water monitor
			Floodplain Monitor
Aves	Tiwi Hooded Robin	Carpentarian Grasswren	White-throated Grasswren
		Tiwi Masked Owl	Red Goshawk
		Yellow Chat	Grey Falcon
			Gouldian Finch
			Partridge pigeon
			Painted Honeyeater
			Masked Owl
			Horsfield's Bushlark
			Purple-crowned Fairy-wren
Total	**4**	9	**21**

9.3 What is Captive breeding?

Simply put, captive breeding involves collecting animals from the wild, acclimatising them into a captive situation and hopefully breeding them to produce genetically robust offspring, ultimately for reintroduction into the wild.

There are many reasons why captive breeding might be considered as an option for threatened species. The main one for the purposes of this article is that when a species population is declining and the causes of the decline are unknown or unlikely to be solved in the short to medium term, the consequence of inactivity would most likely be extinction. If this is the case, conservation groups concerned with species extinction

would be likely to recommend establishing a captive population. Whether or not this captive population or offspring from it, are likely to be reintroduced into the wild, the premise of removal from the wild and then maintaining it in captivity is that the species has been saved from extinction. But has it? If a species is extinct in the wild but maintained in captivity, is it still considered extant? Ecological extinction occurs when a population is no longer able to persist in the wild, but is maintained as a viable population in captivity. Aquarists and aviculturists can provide many examples such as some Lake Victorian Cichlids (Fiumera et al. 2000).

9.3.1. The mechanisms of a captive breeding program

Captive breeding is often undertaken as a result of an assessment of the species' population status in the wild. This assessment is generated from a local concern under the particular relevant conservation legislation i.e. Territory Parks and Wildlife Conservation Act [TPWC] and the Environment Protection and Biodiversity Conservation Act [EPBC]. Because the federal assessment criteria differ from the state or territory assessment, the listed level may also differ. For example, a species may be listed as vulnerable at the state level however, if that species range extends into another state where the threats of extinction are greater, the species may be afforded a high listing such as endangered. Species are also listed internationally by the International Union for the Conservation of Nature [IUCN] and are again categorised differently to state and federal levels. A species listed as endangered under the EPBC Act that has a more global range, for example migratory waders, may be listed as critically endangered by the IUCN.

Often, but not always, listed species have an associated recovery plan, ultimately designed to downgrade the listing or remove it all together. Recovery plans discuss the current population trends, known threats, potential ways to remove or at least alleviate or manage the threats and finally provide a stable robust population that can persist into the future. Captive breeding is a tool used to support a wild population or provide an insurance policy against further population declines in the wild.

Captive breeding relies heavily on the genetic strength of the population that is maintained in captivity. It is assumed that to maintain a self sustaining population in captivity, genetic diversity must be maintained at 95% or higher for at least 25 years to prevent inbreeding depression. In some species this may require several hundred unrelated individuals.

In Australia, breeding programs based in zoological institutions are managed regionally by the Australasian Species Management Plan [ASMP] under the auspices of the Zoo and Aquarium Association [ZAA]. This regional management of a captive breeding program has the effect of sharing the burden of the resource requirements amongst many institutions.

9.4 Captive breeding as a management tool

There are many opinions on the use of *ex-situ* captive breeding or management of dwindling species. Often touted examples such as Balmford et al. (1995) suggest that captive breeding is far more resource intensive than *in-situ* conservation efforts. A result of heavily investing in captive breeding may mean that more valuable, on ground conservation efforts are disregarded in favour of maintaining a captive population. This premise relies on actually knowing and being able to resource activities that remove or lessen the threats causing the decline. If the threats are unknown or current investigation

isn't providing the answers, then captive management should be employed, purely under a precautionary principled approach. For example, Bowkett (2008) cites the recent global amphibian assessment and the associated Amphibian Conservation Action Plan and concludes that given the current rapid decline, captive breeding should be initiated as a matter of urgency to avoid the risk of extinction while monitoring and field studies are being carried out. This refutes Snyder et al. (1996) who claims captive breeding should only be viewed as a last resort in determining strategies for species recovery. It is becoming increasingly acknowledged that under the current decline, Snyder's point may be realised and captive breeding is indeed a last resort. The demise of the Christmas Island Pipistrelle offers a good lesson. A captive breeding program was approved as a last minute solution, but failed to prevent the extinction. Now two species of reptiles that are rapidly declining across their known range on Christmas Island are held in captive populations.

Captive breeding, particularly of the groups of animals discussed above, is relatively straight forward and husbandry techniques are well established for these animals. The use of offspring for targeted reintroductions may have its limitations but the knowledge gained and the offspring produced through a well managed captive breeding program may be of far higher value in understanding the population demise than originally anticipated.

Captive reared offspring can be used as potential test subjects for experiments that help to determine what is causing the demise in the wild. Webb et al. (2011, 2012) describe the use of captive reared Northern Quolls as test subjects for Cane Toad aversion experiments. Their results indicate that 2/3 of the experimental subjects survived in areas where toads were present. Webb et al. (2012) also reported that quolls taught to avoid eating toads had passed this trait onto their offspring.

The use of captive reared animals of known parentage for reintroduction into the wild implies that there exists a wild to reintroduce them to. If the threats to species are not understood and/or not managed, the concept of reintroducing animals, even translocated animals, is unlikely to be ethical or sustainable.

The concept of managed ex-closures has merit for the use of captive reared individuals of many species that we are concerned with here. The removal or manipulation of the threats within the ex-closures has the potential to allow researchers to gain a greater understanding of the effects of the likely threats on particular species. Fire can be managed to produce more fruiting plants, feral predators such as cats and dogs can be removed etc. The use of captive reared individuals for release into these areas allows such experimentation to occur.

Across many reserves in Australia, including some examples in northern Australia, work is currently underway by the Australian Wildlife Conservancy on exactly this idea. Large areas of land have been fenced and feral predators have been removed. For example, at Wongalara Station in the Top End, a cat enclosure experiment using wild-collected and captive bred Long haired Rats has been used to demonstrate the population responses to the presence and absence of non native predators.

9. 5 Limitations of captive breeding

Snyder et al. (1996) elaborates on several points that limit the success of captive breeding and they vary from genetic sustainability to administrative continuity and ultimately state that captive breeding should not replace *in-situ* conservation efforts. While this is holds

true for some species, it should also be understood that where efforts to ameliorate perturbations are unlikely to succeed, then the cost of species extinction should be weighed heavily against the resource implications of a viable and well managed captive breeding program.

9.5.1. Removing individuals of threatened species from wild populations

Until the threats of a declining population are understood, is it sensible to remove persisting individuals of threatened species from the wild to establish an insurance population?

The answer is yes and no and requires a full understanding of why these animals are persisting in the first place. An example is the King Brown Snake. In the Top End, populations of this species have undergone a considerable decline since the arrival of the Cane Toad. Similar to the Northern Quoll in north Queensland, some populations persist in the presence of toads. Is the persistence of the population a result of a preference to avoid toads as a prey item? Have these populations undergone some form of natural aversion to eating toads or are other more desirable prey items placing toads at the bottom of the menu? Has natural selection removed the snakes that preferentially feed on toads, leaving those that don't persisting in the population?

Such theories can be explored by using captive reared snakes that are offspring of parents that have persisted in the presence of a known threat.

The risks associated with removing individuals from remnant populations must be carefully considered and if such action is considered necessary it should be supported under local or federal recovery plans.

9.5.2. The number of founder animals in a captive population and genetic fitness

Self sustaining captive populations may require the injection of new genetic material if the founder population is relatively small. If genetic diversity cannot be maintained through the introduction of new blood lines, it is theoretically impossible to maintain a high level of genetic variation in any population. While this holds true for many species with low fecundity, for those with high fecundity this may not be of such detriment. There are many examples of highly successful releases of introduced species from relatively small founder populations. Most if not all are highly fecund, such as toads or introduced fish or they have high reproductive frequencies, such as rats, mice, pigs etc. The point is that natural selection has favoured particular traits in the initially small population sizes that were released and populations have flourished.

This is where the concept of ex-closures may provide a viable option in the captive breeding puzzle. A small, genetically limited population that is established in an ex-closure that has had all, or most of the known threats removed, now has the potential to be exposed to the natural selective forces that would normally be exerted on a species in a non-compromised environment. This may expose any deleterious alleles and prevent them from being represented in the population. The result will be a population that will either prosper to produce a viable population or will totally fail.

9.5.3. Behavioural fitness or domestication

Domestication stems from the previous point concerning genetic fitness. In a captive situation the survival of individuals in a population, when all other controllable factors

are considered, is determined by genetics. Simply put, individuals that persist to pass on their genetic material to their offspring are selected as the ones most suited to captivity. Several authors (Kohane & Parsons 1988, Allendorf 1993) have reported the adaptive forces that prevail in captive populations. As an example, characteristics that lead to a greater risk of exposure to predators or predator naivety, is a major concern when releasing multi-generational captive bred animals into the wild.

Domestication is something that is well understood in modern zoos and most reintroduction programs involving offspring that have been in captivity for several generations should undergo a soft release process. This technique gradually reduces the individual's reliance on human interference for survival.

Further, captive reared animals that are raised with as little human interference as possible show greater adaptability when released into the wild. The work done on Northern Quolls at the Territory Wildlife Park supports this hypothesis.

9.5.4. Resourcing

A critical determining factor in all captive breeding programs is the level and duration of resourcing required. This varies greatly and is highly dependent on the species involved. A program for a Siberian Tiger for example is going to cost more than a program for Blue-tailed Skinks. Derrickson and Snyder, (1992)-indicate that captive breeding programs can cost upwards of $500,000/year per species to operate and maintain.

Resource implications to consider when establishing a captive breeding program extend well beyond infrastructure, staff costs and animal food. Collection of founder animals, particularly the groups discussed above, may be very expensive. Considering the remoteness and scarcity of some of these species, mounting a successful collecting expedition would be costly. Once the animals are in captivity, quarantine resources need to be considered. When a population is established in a zoo or wildlife park, holding spaces for large numbers of individuals that are valuable to the population need to be sourced. The facilities that are used for this come at the expense of displaying something else that might increase gate takings.

The allocation of resources in many instances is driven by the potential for cost recovery. Many zoos rely on species that are of particular interest to the public, work as a drawcard and are likely to increase revenue. Therefore there is less interest in zoos holding or being involved in breeding programs of less enigmatic animals that are at the risk of extinction without intervention.

It is worth noting that in Australia, most Government funded zoos are required to allocate a portion of their funding to captive breeding and species recovery programs. To this end facilities are provided to reach this milestone. The success of captive breeding programs is reported through the estimates committee each year. Governments have recognised an obligation to the community to support species recovery. It is leveraging this support through community advocacy that is an important part of the resourcing picture.

9.5.5. The conflict of resource allocation

With relevance to the paragraph above, captive breeding and the supposed merits that surround the technique can get tangled in bureaucracy. Governments with limited resources to allocate to the environment often rely on the outdated benefits associated with captive breeding. Long term, more sustainable solutions to population declines may

be more politically difficult to handle, whereas captive breeding is seen as a proactive response with supposed virtues that are easily expounded to the voting public. It is assumed by the general public and governments alike that if a species is in captive care it is safe from extinction.

However, Durrell and Mallinson (1987) provide examples where the likelihood of improved habitat protection increases as a result of raised public awareness when people learn about captive breeding coupled with *in-situ* conservation to help recognise and reduce the threats to wild populations.

Where captive breeding has succeeded in zoos and the results of a project or rehabilitation program have been encouraging in the short term, the increase in public awareness through various media is a powerful advocate for stimulating thought and leveraging government support to direct resources into slowing the rate of species decline.

9.5.6. Administrative Continuity

Captive breeding programs or species recovery programs are implicitly long term projects. Administrators of such projects must ensure ongoing continuity through the life of the project. This rarely happens: project leaders leave, investigators graduate, zoological management changes, even government priorities change. This is seen as a big problem when rationalising a captive breeding program and is often ignored completely (Clark et al. 1994).

9.6. Where to from here?

We are fortunate in this country to be able to afford to worry about conserving our threatened species. Many people in far more compromised environments than ours don't have this luxury. We are currently facing a serious decline in our biodiversity and it seems there is little being done to slow it or reverse it. People can make a difference and governments can help in the hotly contested resource arena. Advocacy is the key to public awareness about the environmental issues we face and only from a need from the voting public will resources be allocated to help solve some of the concerns we are facing.

We recognise that our environment is under threat; we assume that the obvious things such as fire, feral animals and plants, and maybe diseases are contributing to the demise of our wildlife. What are we doing to solve the issues that we know about? What are we doing to investigate the issues we don't know about? This is where captive breeding may play a crucial role. As with Northern Quolls, the consequence of any breeding program is surplus offspring. These offspring can be used in controlled experiments that manipulate variables associated with the requirements that all living things need; food, shelter, predator avoidance etc. By doing this we can start to understand what is happening in the wild and provide advice to governments on the best way to start effectively managing our environment.

There are many authors who have experienced the lack of success of captive breeding for reintroduction and have written about it. Like anything there are advocates for and against it. I believe captive breeding for species recovery is a developing science and that useful lessons can be learned through either success or failure. A sensible approach to the concept is needed, now more than ever, given the current rate of species decline.

The IUCN publish the Global Re-introductions Perspectives (Soorae 2011) which details the successes and failures of recent global species recovery programs. The list is comprehensive, easy to read and makes sound recommendations about the future of these programs and is assessed by the IUCN's Species Recovery Group. This publication lists many successful species' reintroductions as a result of well managed captive breeding programs. The science is improving, and the time is right to commence sensible recovery programs.

Zoos have a crucial role to play in the conservation of native species. Governments have an obligation to support conservation efforts for the species under their custodianship. Zoos should use their inherent powers of advocacy to educate the community about the current state of the environment and its inhabitants by ensuring critically endangered animals are represented in their collections for research and education. Further, zoos that are involved with *ex-situ* captive breeding of threatened species are often involved with *in-situ* conservation efforts. When coupled and well advocated, the increase in public awareness about declining threatened species increases exponentially. Zoos and wildlife parks then have the ability to leverage government support and ultimately, resource allocation.

Community advocacy programs work, but apart from Landcare and the RSPCA, you rarely see any community awareness raising about the environment and the animals and plants that are under threat. It is my belief that this needs to change. It seems to be a sad fact that doing nothing is cheap in terms of resourcing. The question is what price Governments place on the loss of biodiversity through species extinction.

9.6.1. Recommendations

- Establish threatened species recovery teams. These teams should comprise individuals that have a good understanding of the ecological requirements of the taxa they are concerned with. They provide advice and recommendations to the decision makers in terms of potential techniques that can be adapted to facilitate species recovery and play a key role in determining the allocation of resources.
- Recognise that we have a compromised environment that isn't improving. We must improve the training offered to our land managers that will increase their understanding of the known threatening processes and work collaboratively to reduce or remove those threats.
- Reduce the reliance on traditional indigenous land management. The landscape is no longer what it was before non-indigenous people introduced weeds and feral animals. This has greatly changed the landscape and traditional land management hasn't advanced with these changes. A fresh collaborative approach is needed that addresses the key threats in a strategic and logical manner.
- Improve the experience in Kakadu National Park. People are not coming to the park because the experience they receive when they get there has been devalued and the cost of visiting has increased dramatically. Creating experiences that highlight the issues of the escarpment country will help protect it. Locking people out will do the opposite. Park Managers need to decide what they want Kakadu National Park to become. It is an important and diverse ecological system with huge drawcards that are dwindled away each year. The result is a reduction in visitor numbers and satisfaction which in turn stimulates a reduction in government support at a critical time.

- Advocate environmental issues through empathy for species undergoing decline. Work closely with zoos locally and regionally to highlight the plight of threatened species through education (including within the current school curriculum) and interpretation that is graphic and well directed at initiating behavioural change.
- Critically assess the current threatened species and establish well managed and resourced captive populations as a matter of urgency. These populations should be well represented in zoos and wildlife parks locally and regionally and be used as ambassadors for public awareness about their plight. If they are successfully bred in captivity, offspring should be offered as research subjects to graduate students and researchers working specifically on species decline.
- Free up the processes involved with working or collecting animals in Kakadu.

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10. Threatened species of Kakadu National Park: synthesis and conclusion

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10.1. Introduction

Kakadu National Park (KNP) is one of the largest and most diverse national parks in Australia. Its objectives include obligations to deliver cultural outcomes for its traditional landowners; requirements to provide satisfying experiences, infrastructure and safety for very many visitors; and biodiversity conservation. There are many challenges to the achievement of these diverse objectives, and many specific challenges for the biodiversity objectives, relating in part to limited access for management and the substantial array and near intractability of threatening factors. These factors include legacy impacts of historic mining, current mining within the Park environs, climate change, tourism, inappropriate fire regimes, weeds, vertebrate and invertebrate pests, and diseases and pathogens. Within this complex setting, the conservation of Kakadu's very many threatened species (possibly more than any other conservation reserve in Australia) is a management priority. The size and complexity of this complement of threatened species is influenced in part by the vast extent of Kakadu, its co-occurrence with an area of particular richness for endemism, and its substantial range of environments.

The effectiveness of the management of Kakadu's threatened species is constrained by a series of factors:

(i) *Inadequacy of status assessment*. Lists of threatened species are fluid, and there may be substantial delays between when species merit listing and when they become listed. Given that Kakadu's Plans of Management may typically operate over 5–10 year cycles, this may mean that there may be critical delays between signs of a species' decline and its explicit inclusion as a management priority within Kakadu's planning process. Furthermore, as indicated in the invertebrate chapter in this volume (Andersen et al. Chapter 4), it is almost certain that many currently unknown or little known invertebrate species may merit listing as threatened, but cannot because of information deficiencies. This may also be the case for plant species, although this is less likely because Kakadu's plant species have been far more comprehensively inventoried than its invertebrate species (Cowie & Liddle Chapter 3), and because all plant (and vertebrate) species known from the Northern Territory have their conservation status scrutinised at c. 5 year intervals through the Northern Territory threatened species process.

Given fluidity in lists and delays between information acquisition and consequences for listing, there may also be some cases where currently listed species that may be management priorities in Kakadu should no longer be listed or prioritised. Based on recent assessment of conservation status, this may be the case for Red Goshawk and Northern Shrike-tit (Woinarski & Garnett Chapter 7).

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(ii) *Inadequacy of knowledge about listed threatened species*. Management will be most effective when it is based on robust and comprehensive information. For almost all of the threatened species occurring in Kakadu, there are major information gaps that currently impede good management.

These deficiencies relate to locations occupied within KNP, population size and trends, habitat (and food) requirements, life history attributes, the relative impacts of current and projected threats (i.e. which threats are most detrimental and are currently driving status change), and responses to management interventions. The extent of knowledge gaps varies appreciably amongst threatened species, with relatively more information for some terrestrial mammal and bird species, and less information for some invertebrate, plant and marine species. However, for even some terrestrial mammal species (such as the Northern Brush-tailed Phascogale *Phascogale pirata*) the information base is particularly threadbare and inadequate. Such information inadequacy compromises the ability of managers to answer such fundamental conservation questions as: In what areas should management attention be focused?; What threats are the most important to manage?; How do we best manage those threats? How do we document management effectiveness? Which species merit most immediate attention?

But there will always be some information shortcomings, and KNP has had many decades of substantial environmental research. For many species there is sufficient information to provide preliminary management advice, or at least to provide some advice that is likely to be more effective than no advice. As described in (vii) below, if resulting actions are set within an adaptive management framework, this advice can then be subject to continuing iterative testing and refinement. But some information gaps may be particularly critical; and a strategic program that focuses on research to fill these gaps may be necessary to ground management that aims to achieve adequate conservation outcomes.

(iii) *Inadequacy of knowledge about threats*. The incidence, extent and history of many factors that may affect threatened species in KNP are poorly known. This is so particularly for relatively covert threats such as disease and pathogens, but there is also very little useful information for some other threats likely to be causing major impacts, such as predation by feral cats. Furthermore, little is known about the manner in which different threats may interact, and result in potentially multiplicative impacts.

(iv) *Limited ability to control some threats*. Even in cases where the major factor affecting a threatened species is well known, it may be impossible or prohibitively expensive to eradicate or even effectively control that threat in a manner sufficient to allow the recovery of the threatened species. Many of the main threatening factors affecting threatened species in KNP may fall into this category: these may include climate change and consequential saltwater intrusion, cane toads, feral cats, feral pigs and some weeds. However, in such cases, some conservation outcomes may be achievable through captive (*ex situ*) breeding, localised intensive threat abatement activity at particular sites that are significant for the threatened species, or manipulation of the genetic or behavioural features of the threatened species to allow it to avoid or cope better with the uncontrollable threat (e.g. toad aversion training for Northern Quolls: O'Donnell et al. 2010).

(v) *Limited target-setting and specific objectives*. Management may be doomed to be ineffective and arbitrary if it is not positioned within a clear framework that provides explicit justification for actions, or is not directed strategically towards the achievement of an

explicit, realistic and worthwhile set of targets and objectives. For the conservation of threatened species in KNP, the existing Plan of Management has been criticised for this shortcoming (Parr et al. 2009). In the absence of well-defined targets, it is difficult to assess the extent of management success or failure. Furthermore, in the absence of a robust framework for management, there is little or no accountability for failure or recognition of achievement for success.

(vi) *Uncertainty about prioritisation*. As described in earlier chapters in this symposium, there are very many threatened species in KNP, many additional species of cultural or other concern, and many other issues that drive management attention and action. Without some explicit and rational justification mechanism, it is difficult to ensure that adequate resources are directed towards the most urgent and effective actions for the conservation of threatened species, to ensure that other management activities are not detrimental to threatened species, and to prioritise activities amongst different threatened species. For conservation management in KNP, an unusually explicit prioritisation factor is the responsibility mandated in the *Environment Protection and Biodiversity Conservation Act 1999* (s 269(1) that 'the Commonwealth must implement a recovery plan or threat abatement plan to the extent to which it applies in Commonwealth areas'. Hence, such actions should be locked in as essential components of the Park's management program.

(vii) *Limited application of monitoring and adaptive management*. As foreshadowed under (ii) above, in the absence of perfect knowledge, management may be most effective over longer periods if it is contextualised within an adaptive management framework that embeds monitoring within a cycle of performance assessment, reporting and improvement (Holling 1978). Indeed, monitoring is a particularly critical issue for threatened species, as it is instrumental for the provision of a rational prioritisation of actions within and amongst species, to measure management effectiveness, and to assess conservation status. As described in the previous chapters, there is effective and statistically powerful monitoring for only a small minority of KNP's threatened species. Conversely, some existing more general monitoring programs in KNP are notable for describing population trends over at least several years (e.g. Edwards et al. 2003, Russell-Smith et al. 2009, Woinarski et al. 2010, 2012) and some of these programs have been useful in helping to change management practice.

(viii) *Resource constraints*. All conservation reserves have finite resources. As illustrated in the previous chapters, there are very many threatened species in KNP. Research to fill significant knowledge gaps is required for many species, and this may be expensive and long-term. Many of KNP's threatened species may require considerable investments in management, over long time periods. It is impossible that all research and management actions that are needed to achieve conservation security for all species can be implemented within existing budgets, and implausible that these can all be implemented within any more generous but realistic budget settings. Nonetheless, there may be scope for more effective resourcing efficiencies through better integration of collaborative management of threats amongst regional stakeholders, through investments in research partnerships, through expansion of the conservation budget through competitive funding or philanthropic sources, through more tightly focused management actions, and through management frameworking that works towards threat management that is better integrated amongst threatened species affected by similar threats within the same broad landscale types.

(ix) *Off-site impacts*. KNP may have perfect conservation management for all threatened species occurring within its borders, but the status of many of those species in KNP may

still decline because of off-site impacts. These constitute three main issues: (a) species whose individuals may disperse widely such that Kakadu constitutes only a part of those individuals' range, either seasonally or in parts of their life cycle; (b) species whose habitat or individuals are detrimentally affected by pervasive factors beyond the control of Kakadu management, notably such as through the impacts of global climate change (this issue is considered in more detail in (iv) above); and (c) species that operate in a regional meta-population for which subpopulations occurring in areas around Kakadu may operate as population 'sinks', hence de-stabilising and reducing the long-term viability of subpopulations within Kakadu. This latter issue is mostly a problem in relatively small conservation reserves, but may be a minor concern for a few threatened species in Kakadu that have very large home ranges and relatively small population size (a possible such example may be Red Goshawk *Erythrotriorchis radiatus*).

Many of Kakadu's threatened animal species are not permanent residents in Kakadu, and hence their population trends in KNP may be affected significantly by factors operating outside Kakadu's borders. This is particularly the case for shorebirds (affected particularly by habitat loss and degradation along other parts of their migration route), marine turtles and sharks and sawfish (all affected particularly by targeted take or by-catch within and beyond Australia). The scale of these dispersals varies substantially, from relatively local to global (as for the shorebirds). In all cases, long-term conservation objectives are likely to be realisable only through collaborations involving stakeholders in all parts of the species' range. Nonetheless, appropriate conservation management in KNP may help contribute to the resilience of dispersive species' populations, allowing them some (limited) scope for coping with pressures elsewhere in their range.

Collectively, these factors have led to the undesired outcome that many of KNP's threatened species are now exhibiting declining trends (in some cases severely), notwithstanding some commitment to threatened species' recovery and the application of some threat management. This is a sub-optimal outcome, but one that may well be typical of other conservation reserves in the region.

10.2 The current status of threatened species in Kakadu

In most of the previous chapters the authors were requested to list all threatened species occurring (or formerly occurring) in KNP, to interpret their current status (particularly whether they were increasing, stable or decreasing in abundance), and to provide recommendations for enhanced management. In this section of the paper, we integrate the information on the assemblage of threatened species and on their population trends; in the next section we integrate recommendations for enhanced management.

A clear conclusion is that very many threatened species occur (or occurred) in KNP. The tally is a little indefinite, as it depends upon what list or lists are considered, and the extent to which one includes species for which the few and only records from the KNP area are now historic. There are four mammal species in this latter set (Northern Hopping-mouse *Notomys aquilo*, Golden-backed Tree-rat *Mesembriomys macrurus*, Water Mouse *Xeromys myoides* and Golden Bandicoot *Isoodon auratus*), and these may represent local extinctions (or, more precisely, extirpations) from KNP. However, this conclusion should be qualified by noting that their loss from the area may (or may not) have preceded the establishment of the National Park, and could be qualified also by noting that it is difficult to demonstrate absence and it is just possible that they may persist in the area (with this possibility varying substantially between the 'lost' species). These

losses are more than historical marginalia, as their fate serves as a reminder that some factors threatening the Kakadu biota have operated with significant detrimental impact over many decades: that is, the current decline of many threatened species in KNP is not necessarily a new phenomenon or an indication of the sudden recent imposition of novel threats or management inadequacy.

Table 10.1 summarises the tallies of threatened species in KNP by broad taxonomic group.

Table 10.1 Tallies of threatened species (and threatened ecological communities) by taxonomic group and legislative list

Taxonomic group	No. of EPBC Act listed threatened taxa	No. of Northern Territory listed threatened taxa	No. shared between lists	Total number of different entities listed as threatened
plants	3	14	2	15
invertebrates	0	0	0	0
fish	4	4	4	4
frogs	0	0	0	0
reptiles	8	9	5	12
birds	7	16	6	17
mammals	9	12	6	15
ecological communities	1	0	0	1
total entities	*32*	*55*	*23*	*64*

This Table excludes species recognised internationally as threatened, but not listed as threatened under Northern Territory and Australian legislation, and excludes very many species considered Near Threatened or Data Deficient (noting that neither category is available under the *EPBC Act*). It also excludes many species (particularly invertebrates) about which too little is known to even assign a status. Setting aside such species, the tally of listed species occurring in KNP is very substantial (32 EPBC Act-listed species, and a further 32 species listed under Northern Territory legislation), and may well exceed that for any other conservation reserve in Australia. The conservation management of so many species is a formidable challenge, especially given that their threatened status implies that many may require very considerable threat abatement actions.

One question that this symposium sought to answer was: how are threatened species faring in KNP? In many of the previous chapters, the authors have struggled to answer this question: for most species, trends in KNP are not known, largely because most threatened species are not subject to specific monitoring programs. Notwithstanding the now reasonably long history of Kakadu as a national park, and of the decades of environmental research undertaken, there has generally been little robust or long-term monitoring of threatened species. There are some specific exceptions (such as the long-term monitoring program for breeding Flatback Turtle *Natator depressus* at Field Island: Kyne Chapter 5), some monitoring programs that have been established but not regularly

implemented (notably for some plant species: Cowie & Liddle Chapter 3), and some more general monitoring programs have provided information on trends for some threatened species (notably the fireplot monitoring program, that has demonstrated marked population change for several threatened mammal species: Woinarski et al. 2010).

For threatened species, the clearest picture of trends in KNP is for a set of small- to medium-sized mammal species (such as Brush-tailed Rabbit-rat *Conilurus penicillatus*, Northern Quoll *Dasyurus hallucatus*, Pale Field-rat *Rattus tunneyi*, Black-footed Tree-rat *Mesembriomys gouldii*) that have all exhibited marked decline over the last 1-2 decades. For none of the threatened species occurring in KNP is there any compelling evidence of population increase.

Most of the previous chapters sought not only to address trends in the status of KNP's threatened species, but also to consider the adequacy of knowledge for those species, the extent of conservation management directed towards those species, and the threats that are most influencing current status.

The KNP area has been subject to much research; and successive plans of management and the Kakadu Research Advisory Committee have sought to ensure that much of this research is directed as strategically as possible. However, as documented in previous chapters, there are still formidable knowledge gaps for most threatened species. In terms of conservation management objectives, these knowledge gaps mostly relate to limited information on distribution (and areas of significance for particular species), population size, ecological requirements, the relative impacts of threats, and the response to a range of management options. This is the case particularly for invertebrates (Andersen et al. Chapter 4), plants (Cowie & Liddle Chapter 3), marine species (Kyne Chapter 5) and terrestrial reptiles (Gillespie & Fisher Chapter 6), but also applies for most birds and mammals. In many cases, the inadequacy of knowledge substantially hinders or subverts the application of targeted management. Of course, there are also some notable achievements, whereby substantial research effort has been (or is being) directed at major knowledge gaps concerning threatened species. One notable such example is the current collaborative research program that is considerably advancing (from a previous very sparse base) knowledge of the status of threatened shark and sawfish species in Kakadu (Kyne Chapter 5).

Furthermore, it is likely that knowledge transfer between researchers on one hand and rangers and other park management staff on the other is imperfect, with little information on threatened species readily available on the Park's GIS and other knowledge management systems, and hence little incorporation into day-to-day Park management activities. There is also relatively little knowledge exchange concerning threatened species with the Park's traditional owners, but some of that traditional knowledge is being documented (Winderlich & O'Dea Chapter 2). Nonetheless, there are some notable initiatives in knowledge transfer. Many monitoring and other research activities in KNP are deliberately designed as collaborative exercises with Parks staff and Traditional Owners, and hence allow for on-ground sharing of knowledge. Furthermore, this symposium and its predecessors have been designed to provide a forum for such knowledge exchange, and to seek to ensure the translation of research to management advice.

Much of the Park's management is directed towards the control of fire, weeds and feral animals, and this activity undoubtedly provides some benefit to many of KNP's threatened species and its threatened ecological community. Furthermore, exclusion of

commercial fishing and constraints on recreational fishing, management of some other tourism activities, and regulation or prohibition of mining and other extractive industries also serves to provide general benefit to KNP's biodiversity. But there is relatively little management directed and tailored specifically to meet the explicit needs of threatened species, or to control the most detrimental threatening factors at the sites of most significance to particular species; and to date there has been little attempt to develop and implement a coherent, comprehensive and strategic plan for the recovery and management of any threatened species within KNP. One manifestation of this lack of management focus on threatened species is the low uptake in KNP of actions detailed in Recovery Plans for the minority of KNP's threatened species for which Recovery Plans exist, notwithstanding the legal requirement to implement these Plans on Commonwealth lands. One other manifestation is the relatively low uptake of recommendations given in the Park's two attempts at a threatened species strategy (Roeger & Russell-Smith 1995, Woinarski 2004). But, as with the discussion above concerning knowledge limitations, there are also some recognised achievements. In this regard, the development and implementation of a Stone Country fire management program (Petty et al. 2007) is particularly notable, in that it seeks to curb the threat that is of most concern to the status of very many threatened plant and animal species (and the Park's sole threatened ecological community) in one of the Park's major landscapes; and the implementation of this program appears to be resulting in some benefit to at least some of those species (Cowie & Liddle Chapter 3).

What threats are having the most impact for KNP's threatened species? As described in earlier chapters, this simple question is not necessarily easy to answer: in some cases, threats operating beyond the Park are the most detrimental; in some cases (such as for some highly restricted plant species), the population size of the threatened species may be stable and there are no particular threats; in other cases, the information is simply too insubstantial to ascribe causality or to demonstrate the relative impacts of any particular threat. Furthermore, threats vary in their intensity and impact amongst different landscapes and species. Notwithstanding these caveats, there is a compelling signal that for the Stone Country, fire is the most significant threat for a substantial set of threatened plant and animal species (and for the ecological community): the current regime is characterised by fires that are too frequent, extensive and of high intensity. The same threat is also critical for a smaller set of lowland species, mostly mammals. (As noted within most chapters, this threat is in turn influenced by some weed species, particularly invasive pasture grasses, whose large biomass fuels fires of increased severity.) The evidence is not yet compelling, but there are reasonable grounds for inferring that predation by feral cats is also a major threat for many threatened mammal species (and possibly some threatened bird and reptile species). The other notable threat that has been demonstrated to affect multiple species is poisoning by cane toads, causing recent marked population declines for some threatened mammal and reptile species.

In addition to these main considerations, the previous chapters also noted other threats to particular threatened species; and most recognised that global climate change had substantial potential to cause direct severe impacts, or to amplify some existing threats, on some threatened species, with particular concern for some threatened species occurring in coastal floodplains. Furthermore, any such substantial environmental change is likely to lead to many currently non-threatened species becoming threatened.

10.3. Research and management priorities for threatened species in Kakadu

The workshop, and papers in this symposium, recognised that the general trend for Kakadu's many threatened species is of decline, albeit with some variation amongst species (some species declining particularly severely; other species probably stable; and yet other species for which the information base is too inadequate to determine trends). Workshop participants recognised that this is not an ideal or even satisfactory state, and that substantial changes in management may be required. Most of the preceding chapters offered some recommendations towards enhancement of existing management.

In outline, such changes should include:

1. A much more explicit statement of KNP's objectives for the conservation of threatened species, with clear and measurable targets and commitment to achieving the targets.
2. An explicit prioritisation of research and management activity and investment to those threatened species for which Kakadu is of particular importance, or which may most benefit from management.
3. A strategic program of research that focuses tightly on the key knowledge gaps that most impede the design and delivery of effective conservation management.
4. Tailored monitoring programs for most threatened species, with those monitoring programs designed in such a manner that they can effectively measure population trends and responses to management intervention, are implemented in a timely manner, and are reported within a framework that allows managers to regularly gauge the impacts of their management.
5. A more spatially specific conservation management approach, with a dedicated attempt to identify sites of particular significance for priority species, with such sites providing foci for intensive management actions.
6. Further enhancement of the existing Stone Country fire management program, to seek to continue to reduce fire intensity, frequency and extent.
7. Development of a complementary lowland fire management program, that includes as a key priority and target the imposition of fire regimes that enhance habitat suitability for threatened species, in particular to increase the extent of relatively long-unburnt woodland and forest areas.
8. An integrated research and management program that seeks to implement effective control of feral cats in at least trial areas of the lowlands.
9. The establishment of ex situ conservation measures for priority threatened plant species (and potentially some animal species).
10. Consideration of the reintroduction to protected sites within KNP of some threatened mammal species that are now locally extinct in the Park.
11. The enhancement of collaborative management programs for threatened species with neighbouring land-owners.
12. The establishment of an advisory KNP threatened species Recovery Team that includes relevant researchers and stakeholders.

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