NATIONAL RECOVERY PLAN FOR THE

MacDonnell Ranges Cycad

Macrozamia macdonnellii

McDonnell Range Cycad. Photo: © C. Nano

Ripe female cone. Photo: © C. Nano

Australian Government

Northern Territory Government

Threatened Species Officer
Biodiversity Conservation unit
NRETAS
PO Box 1120
ALICE SPRINGS NT 0871.

This recovery plan sets out the actions necessary to stop the decline of, and support the recovery of, the listed threatened species or ecological community. The Australian Government is committed to acting in accordance with the plan and to implementing the plan as it applies to Commonwealth areas.

The plan has been developed with the involvement and cooperation of a broad range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

This plan should be cited as follows: Nano, C. and Pavey, C. R. (2008) National Recovery Plan for the McDonnell Ranges cycad, *Macrozamia macdonnellii*. Department of Natural Resources, Environment, The Arts and Sport, Northern Territory.

Copies of the plan are available at:

http://www.environment.gov.au/biodiversity/threatened/recovery-list-common.html

Table of Contents

Abbreviations **4**

Summary **5**

Species Information **6**

Distribution 6

Important populations 7

Habitat critical to survival 7

Threats **8**

Recovery Information **13**

Objectives 13

Criteria 13

Details of recovery actions 17

Costs 29

Management practices 30

Biodiversity benefits 30

Affected interests 31

Social and economic impacts 31

International obligations 32

References **33**

	Abbreviations
APS	Australian Plant Society, a non-profit, independent, incorporated community organisation with members throughout Australia that encourages the growing, propagating, preservation and conservation of Australian plants.
CLC	Central Land Council, a statutory authority representing Aboriginal people in the southern Northern Territory under the *Aboriginal Land Rights (Northern Territory) Act 1976*. It also has functions under the *Native Title Act 1993* and the *Pastoral Land Act 1992*
CLMA	Central Land Management Association
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*, Commonwealth Government Legislation
NP	National Park
NRETAS	Department of Natural Resources, Environment, The Arts and Sport (formerly Department of Infrastructure, Planning and Environment) of the Northern Territory; includes the Parks and Wildlife Service
NT	Northern Territory
OPBG	Olive Pink Botanic Garden, a 16 ha arid zone gardens in Alice Springs that displays over 300 species of central Australian plants and is administered by a voluntary Board of Trustees.
PACSOA	Palm and Cycad Societies of Australia
PWSNT	Parks and Wildlife Service, Alice Springs, Northern Territory, a service within NRETAS
TSN	The Threatened Species Network is a joint initiative of the Australian Government and WWF- Australia. The TSN is a national network developed to involve the community in conservation programs for threatened species

SUMMARY

This Recovery Plan covers the MacDonnell Ranges cycad *Macrozamia macdonnellii* (F.Muell. ex Miq.) A.DC. (syn. *Encephalartos macdonnellii* F.Muell ex Miq.) which belongs to the family Zamiaceae. This species is classified as Vulnerable under the *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act).

Macrozamia macdonnellii is endemic to the arid southern region of the Northern Territory of Australia. This cycad is almost wholly restricted to the MacDonnell Ranges Bioregion where it occurs up to 200 km east and west of Alice Springs. It is the only cycad occurring in central Australia, and is situated 1400 km from any other member of the genus.

This species is strongly associated with steep south-facing ridge slopes and protected gorges, gullies and river edges. It sometimes occurs on exposed slopes where highly flammable spinifex (*Triodia* spp.) grasses are abundant.

Known and potential threats include: loss of genetic variation, pollinators and seed dispersers; fire; weed invasion; climate change; and removal of seeds from the wild.

This plan outlines identified threats and the actions required to help maintain or eventually improve the conservation status of the species.

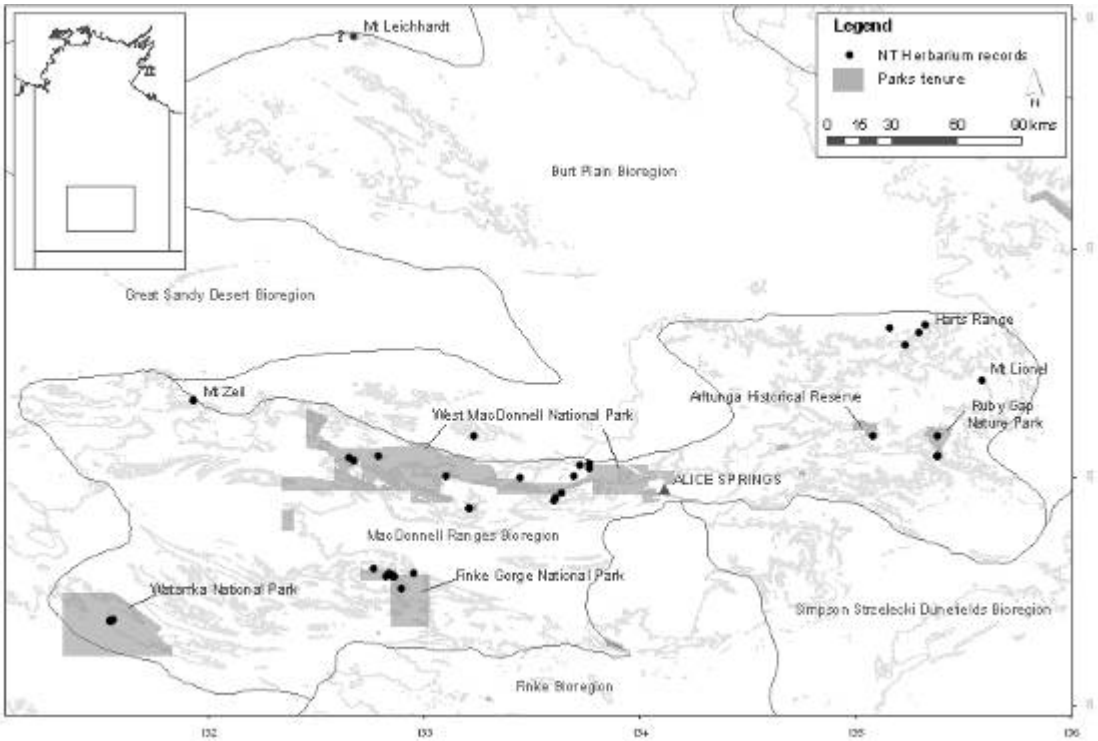
SPECIES INFORMATION

Distribution

This cycad is almost wholly restricted to the MacDonnell Ranges Bioregion where it occurs up to 200 km east and west of Alice Springs on the Krichauff, George Gill, Harts and MacDonnell Ranges (Figure 1). Two outlier populations have also been recorded in the neighboring Burt Bioregion: one from Mount Hay (Hamilton Downs Station) and the other from Mt Leichhardt (Mt Barkley Station). The latter requires verification.

The latitudinal range of this species is 140 km and the longitudinal range is 370 km (Kerrigan *et al*. 2006). It has its north-eastern limit on the Harts Range (Mt Riddock Station) and its southwestern limit at Watarrka National Park. The Mt Leichhardt record would represent its northern extreme. The occurrence of isolated plants at the extremities of its current range is suggestive of a once wider distribution (Mound & Terry 2001). The full extent of occurrence of this species is approximately 40,000 square kilometres.

Figure 1: Distribution of the McDonnell Ranges cycad.



Important Populations

The majority (approximately 70 percent) of MacDonnell Ranges cycad records are from the Northern Territory Parks estate in the following reserves: West MacDonnell NP, Finke Gorge NP, Watarrka NP, Alice Springs Telegraph Station Historic Reserve, Arltunga Historic Reserve, and Ruby Gap Nature Park. The remaining records are from Aboriginal land trusts (Haasts Bluff ALT, Standley Chasm on Iwupataka ALT, Ntaria ALT, Roulpmaulpma ALT) or pastoral leases (Hamilton Downs, Mt Riddock, Ambalindum, Loves Creek, Owen Springs, Mt Barkley).

The locations with the largest populations are Finke Gorge NP and Watarrka NP. The species' distribution within Finke Gorge NP is restricted to the north of the park with the main population located at Palm Valley and estimated to contain at least a few thousand plants (D. Matthews pers. comm.) Large (n = >100 individuals) populations also occur at Hugh River Gorge and at Giles Springs (Preece 2005). The population at Standley Chasm is relatively large and supports a resident pollinator population of thrips *Cycadothrips albrechti* (Mound & Terry 2001). This stand has undergone recent recruitment (C. Nano pers. obs. Feb 2007) (Figure 2) and therefore seems viable. These populations are considered to be important for the long term survival of this species.

Populations elsewhere characteristically have very few (often <100) individuals and may not be viable in the long term is they are too small to support a population of this species' specialised insect pollinator *Cycadothrips albrechti*.

Habitat critical to survival

Macrozamia macdonnellii is a relict of a once more mesic environment, now persisting in a narrow ecological niche in a matrix of otherwise unsuitable habitat (Parks and Wildlife Commission of the Northern Territory 1997). Its present range is characterised by a mean annual rainfall of less than 300mm – substantially more arid than typical cycad habitat (Norstog & Nicholls 1997; Preece 2005).

This species has a strong association with steep south-facing ridge slopes and protected gorges, gullies and river edges (Jones 1993, Hill & Osborne 2001, Preece 2005). These shady habitats provide for increased humidity and lower ambient temperatures (Jones 1993, Mound & Terry 2001, Preece 2005). Other important

habitat characteristic may include frost shelter, water availability and good drainage. This species is less commonly found on exposed hills or mountain tops (Jones 1993; 1997).

It is likely that *M*. *macdonnellii* has a requirement for habitat with low fire-return intervals. While this species is known from sites with a high fire hazard (Parks and Wildlife Commission of the Northern Territory 1997; Preece 2005), the largest populations occur in fire protected habitat characterized by substantial rock outcropping. Habitat with a relatively low fire frequency is critical to the long term survival of this species because seeds and seedlings (and possibly the thrip pollinator) are intolerant of fire exposure. It is possible therefore, that stands that are currently exposed to high frequency firing may not be viable in the long term due to repeated pollination and recruitment failure.

Based on current knowledge, *M*. *macdonnellii* has specialised requirements for shady habitats with relatively lower temperatures, higher humidity and shorter fire-return intervals. Sheltered sites with low grass-fuel loads are therefore critical to the long term survival of this species. However, it is considered that there is currently insufficient information to accurately map habitat critical to survival.

THREATS

Cycads experience the same threats as many other plant species but their biology makes them more vulnerable to human induced disturbance (IUCN 2003). They are generally understood to be more susceptible to extinction than most other plant groups because they have low fecundity, low rates of seed and seedling survival, slow population growth rates, and an intrinsically low capacity to recover from population collapse and respond to climate change (Donaldson 1995; Golding & Hurter 2003; Snow & Walter 2007). Cycads are also more prone to decline because they typically have narrow distributions and exhibit some degree of habitat specialization (Golding & Hurter 2003).

<u>Loss of genetic variation, pollinators and seed dispersers</u>

This potential threat is the result of continuing isolation and fragmentation of populations and the loss of its pollinators and seed dispersers. It is widely accepted that small, fragmented subpopulations are more susceptible to declines than are

larger subpopulations (Soulé 1986, Golding & Hurter 2003). As much as 60 percent of cycads have a total wild count of less than 10 000 mature individuals and many of these occur in small fragmented colonies (Osborne 1995). While the total number of *M*. *macdonnellii* likely exceeds 10 000 mature individuals (Kerrigan *et al*. 2006), the highly fragmented distribution of this species exacerbates the extinction risks associated with its biology. This is because the effective population size of small dioecious populations is often less than half the number of mature plants in the population (CITES 2003). Further, it is now understood that because cycads are K-strategists, they have the capacity to persist in small subpopulations, even in highly transformed habitats, for long periods of time (Donaldson 1995). Therefore it is possible for fragmented species such as *M*. *macdonnellii* to be undergoing decline that is not overtly apparent i.e. the presence of long-lived adult plants may mask the effects of threatening processes operating at other life stages (Golding & Hurter 2003).

Poor seed dispersal contributes to low levels of genetic exchange in fragmented populations (Wilson & Traveset 2000). It is probable that the primary seed dispersers of *M*. *macdonnellii* were among the suite of now extinct megafaunal species that disappeared during the late Pleistocene (e.g. see Snow & Walter 2007). Further, a number of other potential seed dispersers have become extinct from the area (e.g. western quoll) or undergone severe reductions in range and abundance (e.g. common brushtail possum) during the past 100 years. The black-footed rock wallaby is often cited as a dispersal agent for this species, though field observation suggests that this species commonly consumes the fleshy sarcotesta and deposits the seed *in situ* at the base of the mother plant (Figures 3 & 4).

Pollinator extinction is a major threat to small fragmented plant populations (Golding & Hurter 2003; Vamosi & Vamosi 2005). As individuals become more isolated, insect pollinator behaviour becomes altered and their abundance diminished. This leads to a reduced number of pollination events and ultimately, lower seed set (Vamosi & Vamosi 2005). Plant-pollinator mutualisms are assumed to be particularly sensitive to the effects of fragmentation (Bond 1994; Terry *et al*. 2005; Queensland Herbarium 2005). Research has shown that *M*. *macdonnellii* is involved in a highly specialised dependent mutualism with its thrip pollinator *Cycadothrips albrechti* (Mound & Terry 2001). This means that the long-term health and genetic diversity of this cycad

ultimately depend on the viability of its pollinator and *vice versa* (Terry *et al*. 2005). In central Australia, fire regimes are tending towards infrequent large events. Increased fragmentation of *M*. *macdonnellii* populations due to catastrophic fire effects could therefore heighten the chances of seed crop failure through pollinator loss.

Fire

The impact of fire on the MacDonnell Ranges cycad is unknown; however, fire has potential deleterious effects on early life-stages. No specific fire management strategy exists for *M*. *macdonnellii* and in 2002 many populations were exposed to high intensity wildfires that swept through core habitat areas in the West MacDonnell and Watarrka National Parks. Field observation suggests that the incidence of adult *M*. *macdonnellii* death from this event was low (e.g. A. Schubert pers. comm.); suggesting fire is not a threat to this species (Kerrigan *et al*. 2006). However, this assessment takes no account of the contrasting effects of fire on the different life stages of cycads. Both seeds and seedlings are killed by fire (Hill 2003). Therefore heightened fire frequency could be a critical factor in diminishing the long-term viability of *M*. *macdonnellii* populations, especially given that this species does not establish a persistent seed bank. It has been demonstrated that adults of other supposedly fire tolerant cycad species (e.g. *C*. *armstrongii*) vary greatly in their survival response according to fire intensity (Liddle 2004). While no such data exist for *M*. *macdonnellii*, it is assumed that unfavourable fire regimes would represent a considerable threat to this species given their demonstrated detrimental effects on other cycads with similar life histories and adult fire tolerance (Liddle 2004; Queensland Herbarium 2005).

Weed invasion

The introduction of the highly invasive perennial grasses buffel grass (*Cenchrus ciliaris*) and couch grass (*Cynodon dactylon*) into cycad habitat is viewed as a potential threat to *M*. *macdonnellii.* While neither grass is currently closely associated with cycad habitat, buffel grass, in particular, is often abundant in directly adjacent sites throughout the MacDonnell Ranges and may be further advantaged in the future by processes such as altered fire regimes and climate change. This species has been known to increase both the frequency and the intensity of fire (Butler & Fairfax 2003; Franks, 2002) and could represent a significant threat to cycad populations. Couch

grass also occurs in major drainage lines throughout the MacDonnell Ranges in areas prone to inundation and therefore represents an additional potential threat to *M*. *macdonnellii* populations along creek lines. This species also contributes to increased fuel loads, but to a lesser extent than buffel grass.

Once established, both grass species also have the ability to negatively affect *M*. *macdonnellii* through resource competition. Dioecious species are inherently disadvantaged by seed shadow handicap, meaning they are especially vulnerable to the competitive effects of non-dioecious invasives (Vamosi & Vamosi 2005). Therefore competition from invasive grasses may represent a significant threat to *M*. *macdonnellii* populations (especially those in run-on areas), especially if it constrains seedling recruitment.

Climate change

The threats posed by climate change on *M*. *macdonnellii* are currently poorly understood. Some research suggests that cycads are one of very few groups that stand to benefit from elevated CO_2 levels. Up to three times the current CO_2 levels were present in the atmosphere when cycads evolved (South African National Biodiversity Institute 2007). However climate change does represent a possible future threat given its potential to disrupt the plant-insect pollinator mutualism and its capacity to favour weed invasion and increased fire frequency.

Legal removal

All cycads that are wildlife in the Northern Territory are Protected Plants under sections 45 and 47 of the *Territory Parks and Wildlife Conservation Act 1993*. As a Protected Plant, a permit (non-commercial) or license (commercial) is required to take cycad material, except for non-commercial use by landholders. Up until 2007, *M. macdonnellii* was listed as a Specially Protected Plant in the Northern Territory, and was thereby afforded further protection under sections 50 and 52 of the act, which address the granting of permits or licenses to take, and willful destruction, by a landholder. As a consequence of its recent downgrading to Near Threatened in the Northern Territory, this species is not covered by this additional legislation.

Illegal removal

All cycads are included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) meaning that commercial international trade in specimens is strictly regulated. Despite this, illegal trade in cycads remains a worldwide problem.

M. *macdonnellii* is highly sought after by growers and collectors (www.pascoa.org.au/cycads). It is of interest because of its desirable 'bluish' appearance, its relict status and its interesting provenance (Osbourne 1999). Illegal seed collection for horticultural trade is cited as a threat to this species (White *et al*. 2000). However there are no reliable data on the amount of seed taken or on the effect of seed harvesting on *M*. *macdonnellii* populations. Seeds are reportedly regularly removed by the public from the Standley Chasm population. Other accessible populations (e.g. Palm Valley and Watarrka NPs) would presumably experience similar levels of seed collecting.

RECOVERY INFORMATION

Overall Objective

To improve (or at least maintain) the current conservation status of *M*. *macdonnellii* (currently listed as vulnerable nationally).

Specific Objectives

- Fill gaps in knowledge of distribution.
- Maintain or increase habitat quality and extent.
- Understand critical ecological attributes including the fire response, life history characteristics, and reproductive and seed biology.
- Implement *ex-situ* conservation measures that ensure the long-term preservation of representative samples of this species' genetic diversity.
- Undertake a population genetic study to determine connectivity and mode of seed dispersal and to guide seed collection protocols.
- Engage with Indigenous people to enable the incorporation of traditional ecological knowledge and management practice into recovery plans.
- Inform and involve the community and all stakeholders into the recovery plan process.

Performance Criteria

- The distribution limits and number of populations of *M. macdonnellii* is understood.
- Habitat quality and extent is maintained or increased.
- Adequate knowledge of the influence of fire and other ecological processes on *M.macdonnellii* persistence is available.
- Seeds from populations of *M. macdonnellii* are held in properly maintained *ex-situ* storage facilities (potential long term goal).
- The connectivity between *M. macdonnellii* populations is better understood and genetic tracking system is in place.

- Indigenous knowledge relating to phenology, distribution, and cultural significance is properly incorporated into recovery programs.
- Community and stakeholder based networks are maintained and enhanced.

Evaluation

The performance of the plan will be evaluated by an independent consultant within five years from adoption as a national recovery plan.

Table 1: Relationships between specific objectives, performance criteria and actions.

Specific objectives		Performance criteria		Actions
Fill gaps in knowledge of distribution.	⇔	The distribution limits and number of populations is understood.	⇔	1. Carry out targeted surveys for additional populations within the MacDonnell Ranges & resurvey Mt Leichhardt with an intensified sampling effort. 2. Mapping of *M*. *macdonnellii* populations.
Maintain or increase habitat quality and extent.	⇔	Habitat quality and extent is maintained or increased.	⇔	3. Negotiate conservation agreements to secure significant populations on leasehold and land trust properties. 4. Carry out population and habitat monitoring at selected sites. 5. Implement management strategies for key threatening processes as required.
Understand critical ecological attributes including fire response, life history characteristics, and reproductive and seed biology	⇔	Adequate knowledge of the influence of fire and other ecological processes on the persistence of this species is available.	⇔	6. Undertake research on fire ecology, reproductive biology, and seed storage potential.
Implement *ex-situ* conservation measures that ensure representative sampling of this species' genetic diversity.	⇔	*Ex-situ* collections in botanic gardens are sourced from widely dispersed populations.	⇔	7. (pending progress towards 6) Store seeds from many different populations in seed-banks.

Specific objectives		Performance criteria		Actions
Collate information on intraspecific genetic variation.	⇔	.Understand connectivity and mode of seed dispersal	⇔	8. Determine the degree of intra-specific population differentiation exhibited by *M. macdonnellii* using molecular techniques.
Incorporate traditional ecological knowledge and management practice into recovery process.	⇔	Cycad management is informed by traditional ecological knowledge.	⇔	9. Engage traditional ecologists to provide advice on biological aspects, threatening processes and the cultural and economic significance of this species.
Inform and involve the community and all stakeholders in the recovery process.	⇔	Community and stakeholder based networks are maintained and enhanced.	⇔	10. Community and stakeholder education and information.

Details of Recovery Actions

Action 1. Carry out targeted surveys for additional populations of *M. macdonnellii* in the MacDonnell Ranges Bioregion and at Mt Leichhardt.

Aim

To search for additional populations of *M*. *macdonnellii* and determine the extent of its latitudinal range (northern-most limit).

Justification

Information from long-isolated outlier populations is required to take full account of the level of intra-specific genetic variation in *M*. *macdonnellii*. The anecdotal reports of a highly disjunct population at Mt Leichhardt are from a reliable source and therefore warrant further investigation. Further sampling within the core habitat area (Macdonnell Ranges Bioregion) will allow for better-informed assessment of total wild counts and of threatening processes.

Methods

Additional surveys for *M. macdonnellii* will be carried out by experienced field biologists in the MacDonnell bioregion and at Mt Leichhardt. Use of a helicopter will be required to access certain areas and the use of aerial survey methods will be investigated.

Stakeholders

NRETAS, CLC, CLMA, Iwupataka Land Trustees, Mt Barkley Station lease holders

Costs ($1000s)

One 4-5 day survey in planned for each of year 2 and 3.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
	25.0	25.0			50.0

Action 2. Mapping of *M. macdonnellii* populations with inclusion of risk assessment.

Aim

To produce maps of *M*. *macdonnellii* distribution with related spatial information on population density and fire and weed risk assessments.

Justification

Time and resource constraints preclude the active management of all *M*. *macdonnellii* populations. Delineation of *M*. *macdonnellii* mapping polygons that are attributed with density estimates and fire and weed threat ratings will help prioritise management effort. In addition, broad-scale mapping will provide information on connectivity of populations.

Methodology

Standard Park mapping procedure will be followed as part of the existing broader NT Parks mapping project currently being undertaken by NRETAS staff.

Responsibilities

NRETAS

Costs ($1000s)

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
12.0	15.0				27.0

Action 3. Negotiate conservation agreements to secure significant populations on leasehold and land trust properties.

Aim

To ensure that significant populations of *M*. *macdonnellii* that occur outside the NT parks estate are adequately protected.

Justification

A large proportion of the total *M*. *macdonnellii* population is currently reserved in the East and West MacDonnell National Parks and at Watarrka NP. However some significant populations do not occur on reserved tenure and are therefore priorities for off-park protection measures. The population at Standley Chasm is large and is positioned at a very popular tourist destination in close proximity to Alice Springs. This provides much opportunity for scientific research and population monitoring but it also means that the population is exposed to the negative aspects of tourism such as trampling and seed poaching. As stated above, outlier populations of *M*. *macdonnellii* on Mt Hay and (potentially) at Mt Leichhardt have intrinsic genetic value and may require management as separate entities. Conservation agreements with these landholders should therefore be pursued.

Methods

Avenues for effective protection of off-park populations of *M. macdonnellii* should be pursued by NRETAS with the assistance of relevant non NT government agencies (specifically CLMA and CLC). Some cycad conservation work has already been undertaken at Standley Chasm by the current managers with the aid of the Green Corps organisation. The managers may be willing to work with NRETAS to further ensure adequate long-term protection of this population. Facilitation of research, increased signage, upgrades on paths and non-intrusive fencing and fire and weed management are some obvious avenues to pursue in this case. In the NT, provision exists for the NT government, after consultation with the relevant landowner, to declare areas of essential habitat under section 37 of the *Territory Parks and Wildlife Conservation Act 2000*. Section 73 of the Act allows the NT government to assist, cooperate in or enter into agreements relating to the management of Aboriginal land for wildlife conservation.

Conservation agreements with Hamilton Downs and potentially Mt Barkley Station leaseholders should have a strong fire-management emphasis.

Stakeholders

NRETAS, Iwupataka Land Trustees, Hamilton Downs and Mt Barkley Station leaseholders, CLMA and CLC.

Costs ($1000s)

$5K per year is estimated to cover costs of consultation and liaison for one population.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
		15.0	15.0		30.0

Action 4. Carry out population and habitat monitoring at selected sites.

Aim

To ensure that significant populations of *M*. *macdonnellii* are regularly monitored on a long-term basis to detect any declines in population size, extent or condition, and in habitat quality.

Justification

MacDonnell Range cycads are long-lived with slow population turnover. This means that fragmented populations may be undergoing decline that is not overtly apparent. It also means that their response to conservation actions may be slow. An effective long-term (at least 20 years) monitoring program is needed to ensure that declines in selected populations do not occur. As part of the adaptive management approach adopted in this plan, monitoring and research (see below) will in turn guide future management practice.

Methods

Monitoring should be designed to enable an assessment of:

- population size, extent and age-structure dynamics
- fire responses of seed, seedling and adult life-stages
- coning events: including location, numbers, and assessment of between-population dynamics

- pollinator activity
- seed production
- seedling establishment and attrition
- insect predation
- habitat condition especially in relation to weed abundance
- presence of threatening processes.

All information will need to be analysed in the context of prevailing environmental conditions including rainfall, drought and fire events as well as the degree of isolation from other populations.

Monitoring should include the following sites to cover the range of tenures:

- Finke Gorge National Park (at the two sites surveyed in June 1993)
- Standley Chasm on Iwupataka Aboriginal Land Trust
- Hamilton Downs pastoral leasehold (Mt Hay population).

Monitoring will need to involve the establishment of replicate permanent sampling quadrats within each population. All individuals of the species within the quadrats will be marked. Monitoring will be carried out three times per year at times coinciding with winter, spring/autumn and summer conditions, or in response to a fire or rainfall event.

Potential stakeholders

NRETAS, CLMA and pastoral leaseholders, CLC and traditional owners, TSN, APS, relevant university researchers.

Costs ($1000s)

Four sites will be monitored under this action with an expected cost of $7.5K per site/year giving an estimated annual cost of $30K per year. These costs include salary, vehicle use, and equipment.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
30.0	30.0	30.0	30.0	30.0	150.0

Action 5. Implement management strategies for key threatening processes as required.

Aim

To manage populations of *M*. *macdonnellii* using an adaptive management approach that enables a response to threats as each is identified.

Justification

Effective management of *M*. *macdonnellii* requires a thorough understanding of the ecology and threats faced by this species. Action 5 (below) has been developed to provide this information. Until such data are available, it is important to carry out adequate monitoring and to develop the capacity to respond to changes in existing conditions.

Methods

Management strategies will be developed and implemented following the outcomes of action 6. In particular, an understanding of the role of fire in the reproductive ecology of this species is essential before adequate fire management strategies can be developed and implemented.

Stakeholders

NRETAS, CLMA, CLC

Costs ($1000s)

These are indicative costs only. As stated above, the details of the management actions will not be known until the completion of action 5.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
		25.0	25.0	25.0	75.0

Action 6. Undertake research on fire ecology, reproductive biology, and seed storage potential.

Aim

To progress understanding of the fire response, pollination ecology, seed dispersal mechanisms, reproductive biology, recruitment constraints and seed storage potential of *M*. *macdonnellii*.

Justification

Detailed ecological research is a prerequisite for the effective management of this species. The research program detailed below is designed to assist the formulation of species management strategies especially in relation to fire use and the amelioration of threatening processes associated with small fragmented populations. Five main avenues of research are suggested and detailed below.

Fire response studies

Currently it is assumed that *M*. *macdonnellii* is capable of vegetative regeneration following wildfire events but that seeds and seedlings are killed by fire. No attempts have been made though to properly quantify these fire responses. Research should therefore focus on determining the influence of fire frequency, intensity and season on the long term persistence of *M*. *macdonnellii* in the wild. This will help determine the optimum fire regime for long-term survival.

Coning phenology.

Coning in *M*. *macdonnellii* has been recorded in all months including February (C. Nano & C. Pavey pers. obs.) however little is known about the actual cues for cone initiation in this species. Research should focus on the extent to which seed production varies among populations according to fire incidence and severity. The role of other environmental factors such as rainfall, drought and temperature should also be examined to assist prediction of the effects of climate change on the reproductive output of this species.

Pollinator studies

An understanding of the dynamics of the mutualism between *M*. *macdonnellii* and its thrip pollinator is essential for the effective management of this species. Research

should be undertaken to determine recruitment of pollinators, to monitor pollinator abundance and movements, and to assess the presence/absence of pollinator populations at small and isolated *M*. *macdonnellii* stands. This will help determine minimal viable population size for this cycad. There should also be a focus on gauging pollinator effectiveness, especially in relation to the minimum pollinator numbers required to obtain full seed set (erry *et al*. 2005). *In situ* conservation efforts need to conserve not only the cycad but also its thrip pollinator. Very little is known about the conservation needs of this thrip. Fire experiments should be designed to assess the impact of fire season and intensity on this species.

Seed dispersal.

An understanding of the vectors involved in seed dispersal is vital for the proper management of this species. This will help provide estimates of the level of inter-population seed exchange and of the potential for this species to colonise areas of suitable habitat without the aid of human intervention. Information is also needed on retention of seed, seedling establishment and population structure (to indirectly assess dispersal).

Conservation of recalcitrant seeds

The seeds of *M*. *macdonnellii* are desiccation-sensitive (recalcitrant) meaning that it is extremely difficult to conserve them in *ex situ* seed banks. Research is needed to determine the effect of variables such as temperature, drying- cooling- and warming-rates, water-content and storage-time on seed viability retention in *M*. *macdonnellii*. The potential for other *ex situ* conservation methods such as germplasm cryopreservation could also be explored.

Methods

The seed biology research outlined above would be carried out as part of the NRETAS-Kew Gardens collaborative Millennium Seed Bank Project (MSBP). The MSBP is an international collaborative plant conservation initiative staffed by the Seed Conservation Department of the Royal Botanic Gardens, Kew. A major goal of the MSBP is the development of an effective *ex situ* conservation program for plant biodiversity. The Biodiversity Conservation section of NRETAS is the Northern Territory MSBP partner. Research will involve experimental investigations of factors

affecting the viability *M*. *macdonnellii* seed in the field and under varying storage conditions.

Information relating to the fire response of each of the life stages of this species would be obtained through a monitoring program involving opportunistic recordings of responses to uncontrolled wildfire events. Experimental burning of some adult populations is also justifiable given the large numbers of individuals and the expected low mortality rates. Likewise, field- and lab-based seed and seedling fire-exposure experiments should also be undertaken to help gauge current rates of attrition.

Research on coning cues, pollinator dynamics and dispersal vectors will be undertaken in collaboration with researchers at the University of Queensland (Dr G. H. Walter and associates).

Stakeholders

NRETAS, MSBP, University of Queensland.

Costs ($1000s)

The predicted cost of each of these actions is $15K.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
15.0	15.0	15.0	15.0	15.0	75.0

Action 7. Collect seeds from core and outlying populations and store them in seed-banks.

Aim

The *ex-situ* conservation of *M*. *macdonnellii* seeds such that a source of material for re-introduction or supplementation of wild populations is available should the conservation status of this species decline.

Justification

This species is at risk of extinction from fire effects and from stochastic processes as a consequence of its highly fragmented population. It is therefore important to have a secure source of genetic material in the form of a seed bank. The seed bank may be needed in future for re-introduction or population enhancement.

Methods

Pending the development of an effective seed storage methodology for this species (see Action 6), the joint NRETAS-Kew MSBP project provides an opportunity to establish a verified and well-documented seed collection of *M*. *macdonnellii* as an insurance against extinction in the wild.

Stakeholders

MSBP, NRETAS

Costs ($1000s)

These costs are for the collection, preparation and maintenance of all seed in the MSBP.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
2.0	2.0	2.0	2.0	2.0	10.0

Action 8. Determined the degree of intraspecific genetic differentiation exhibited by *M. macdonnellii.*

Aim

To understand the degree of genetic variation between and within populations in order to understand dispersal and degree of connectivity of populations.

Justification

Molecular analysis of genetic variation in *M. macdonnellii* is necessary to determine whether or not populations should be treated as separated management units. Evidence of significant population differentiation will have important ramifications for the management of this species.

Methods

Samples of individuals from outlying and core populations (including the eastern and western extremities) and from different topographic positions (upslope/downslope) within populations will be collected in the field. Molecular analysis will be carried out in the laboratory.

Stakeholders

Relevant researches at Australian Universities, NRETAS

Costs ($1000s)

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
		20.0	20.0		40.0

Action 9. Engage indigenous ecologists to provide advice on biological aspects, threatening processes and the cultural and economic significance of this species.

Aim

To incorporate indigenous ecological knowledge and management practice into the recovery process.

Justification

M. *macdonnellii* features prominently in Arrernte mythology. Engagement of Aboriginal people with knowledge of this species will enable the incorporation of traditional ecological knowledge and management practice into the recovery process.

Methods

Indigenous people with knowledge of *M*. *macdonnellii* will be contracted to help ensure that traditional knowledge is properly incorporated into the management strategy of this species. Where appropriate, this properly referenced information would be made accessible to indigenous communities and to the wider public.

Stakeholders

NRETAS, Indigenous ecologists, CLC.

Costs ($1000s)

Estimated costs are for consultation, project co-ordination and employment of traditional ecologists.

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
25.0					25.0

Action 10. Community education and information.

Aim

To improve the profile of *M*. *macdonnellii* within the community and to ensure that all stakeholders are informed of recovery actions and the results of ongoing research and monitoring.

Justification

Cycads are a high profile charismatic group due to a number of factors including their antiquity, unusual biology, rarity and their suitability for horticulture. They are an ideal group for a range of conservation actions including tourism, sustainable use in nurseries, and inclusion in botanical gardens. For this reason they are often used as 'flagship species' for conservation (IUCN 2003). Improved communication among stakeholders and promotion of this species within the general community will engender an appreciation of the evolutionary, ecological and traditional importance of *M*. *macdonnellii*.

Methods

Information on the ecological, evolutionary and traditional importance of *M*. *macdonnellii* will be promoted in a variety of media and community and landholder extension activities. The co-ordinator of Threatened Species projects in the NT (NRETAS, based at Alice Springs) will ensure that information on research and management projects is disseminated to stakeholders. Information and specimens will continue to be displayed at the Alice Springs Desert Park, the Olive Pink Botanic Gardens and the Darwin Botanical Gardens. In addition, signage on national parks that support large populations of the cycad (e.g. Finke Gorge, West MacDonnell) will also cover these topics.

Stakeholders

NRETAS, TSN, OPBG, APS.

Costs ($1000s)

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
1.0	1.0	1.0	1.0	1.0	5.0

Costs

The total cost of the recovery program is estimated at $487,000 over a period of five years. Action 7 will mostly be funded by the existing MSBP project being undertaken by NRETAS and Kew Gardens. Limited research and management actions currently involve *M. macdonnellii*; however, research partnerships are being developed with institutions currently carrying out significant applied research on cycads (e.g. University of Queensland) as a means to fast-track completion of this work.

Estimated costs of recovery (in $1000s)

Actions	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
1		25	25			50
2	12	15				27
3			15	15		30
4	30	30	30	30	30	150
5			25	25	25	75
6	15	15	15	15	15	75
7	2	2	2	2	2	10
8			20	20		40
9	25					25
10	1	1	1	1	1	5
Total required	85	88	133	108	73	487

Management Practices

The following management practices are necessary to avoid a significant adverse impact on populations of *M*. *macdonnellii*.

1. The recommendations of the Cycad Management Program developed by the Northern Territory government should be followed especially with respect to prescriptions for the management of fire and harvesting.

2. Fire management plans for Northern Territory parks that aim to reduce fire frequency should be implemented.

3. Collection of seeds or plants from wild populations should be strongly discouraged and compliance will be enforced.

Biodiversity Benefits

This plan will help ensure the continued existence of key cycad interactions with its root symbionts, sole pollinator and seed predators/dispersal agents. *M*. *macdonnellii* has a key function in the life history of its sole pollinator the thrip *Cycadothrips albrechti*. This insect shelters, feeds, and completes its life-cycle on the male cones of *M*. *macdonnellii* (Mound & Terry 2001). Disruption of this relationship may result in the extinction of both the plant and the dependent insect fauna. Implementation of this plan will help reduce the threat of pollinator loss. All cycads posses coralloid roots. These roots host vesicular-arbuscula mycorrhiza fungi that in turn fix gaseous nitrogen from the atmosphere and provide essential compounds to the plant. Conservation efforts that benefit *M*. *macdonnellii* would thereby likewise benefit this organism. Certain vertebrates (e.g. the black-footed rock wallaby) also have some reliance on cycad seeds as a food resource and would thereby benefit from conservation measures that enhance seed production. Cycads also have many known non-symbiotic interactions with other organisms. It is possible for example, that other insect species predate on *M*. *macdonnellii* leaves, and are therefore reliant on its continued existence.

Recovery actions for *M*. *macdonnellii* will also benefit a diversity of plant and animal species that do not necessarily interact with this species, but occupy the same habitat. *M*. *macdonnellii* populations regularly occur within botanically important areas that are

known to support various other endemic, rare, or fire sensitive species (White *et al.* 2000). Also, a diverse range of animal species occupy this environment including endangered insects (e.g. desert sand skipper, (*Croitana aestiva*) and rodents. Further, threatened species of land snail may shelter under individual cycads. This means that the implementation of effective fire and weed management within the range of *M. macdonnellii* will have benefits for a diversity of plant and animal species.

Finally, monitoring of *M*. *macdonnellii* population health would provide additional long term biodiversity benefits because of its potential value as an indicator species: due to their inherent sensitivities to external pressures, cycads can provide early warning signs for threats to plant diversity (IUCN 2003).

Interests that will be affected by the Recovery Plan's implementation

The species covered in this Recovery Plan is known from conservation reserves managed by the NT government, pastoral leases and Aboriginal land trusts. All affected interests will be involved in the implementation of this plan to some degree. NT government agencies will be involved in recovery actions and will play an important role in the plan's implementation. Recovery actions undertaken on Aboriginal land will be carried out in consultation with the CLC and other relevant Aboriginal organisations and communities. Employment of traditional owners in recovery actions will be undertaken whenever possible. Recovery actions on pastoral leases will be undertaken in consultation with property managers. Where feasible, pastoralists will be encouraged to play an increased role in management of outlier populations.

Social and economic impacts

The implementation of the recovery plan is unlikely to result in any significant adverse social and economic impacts. Implementation of the actions developed in this plan will be on a small scale that will not significantly alter existing land uses.

Some positive social and economic impacts are likely to arise from implementation of this recovery plan. These include the incorporation of indigenous knowledge into the recovery program, employment opportunities for Aboriginal people, and development

and training of Aboriginal ranger groups, particularly the Tjuwanpa rangers based at Hermannsburg.

International obligations

This species is listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II. This recovery plan is consistent with Australia's international obligations.

References

Bond, W.J. 1994. Do mutualisms matter? Assessing the impact of pollinator and disperser disruption on plant extinction. *Philosophical Transactions of the Royal Society of London*. Series B, Biological Sciences, **344**: 83-90.

Butler, D. W. and Fairfax, R. J. 2003. Buffel grass and fire in Gidgee and Brigalow woodland; a case study from central Queensland. *Ecological Management and Restoration* **4**: 120-125.

Donaldson, J.S. 1995. Cycad Conservation in South Africa. pp. 8-13 *In* Donaldson, J. S. ed. *Cycad Conservation in South Africa: Issues, Priorities and Actions*. Cycad Society of South Africa, Groenkloof (Pretoria), South Africa.

Franks, A. J. 2002. The ecological consequences of buffel grass *Cenchrus ciliaris* establishment within remnant vegetation of Queensland. *Pacific Conservation Biology* **8**: 99-107.

Golding, J.S. and Hurter, P.J. 2003. A Red List account of Africa's cycads and implications of considering life-history and threats. *Biodiversity and Conservation*, **12**: 507-528.

Hill, K.D. 2003. Regional Overview: Australia. *In* Donaldson, J. S. ed. *Cycads Status Survey and Conservation Action Plan*. IUCN/SSC Cycad Specialist Group. IUCN, Gland, Swizerland and Cambridge, UK.

Hill, K. and Osborne, R. 2001. *Cycads of Australia*. Kangaroo Press, East Roseville, NSW.

Jones, D. L. (1993) *Cycads of the World*. Reed Books, Chatswood, NSW.

Kerrigan, R., Albrecht, D. and Duguid, A. (2006) Macdonnell Ranges Cycad, *Macrozamia macdonnellii*. Threatened Species Profile at http://www.nt.gov.au/NRETAS/wildlife/threatened/pdf/plants/Macrozamia_macdonnell_NT.pdf

Liddle, D.T. 2004. *The ecology of* Cycas armstrongii *and management of fire in Australia's tropical savannas*. Unpublished PhD thesis, Charles Darwin University, Darwin, NT.

Mound, L.A. and Terry, I. 2001. Thrips pollination of the central Australian cycad, *Macrozamia macdonnellii* (Cycadales). *International Journal of Plant Sciences* **162**: 147-154.

Norstog, K. & Nicholls, T.J. 1997. *The Biology of Cycads*. Comstock Pub. Associates, Ithaca, New York

Osborne, R. 1995. The world cycad census and a proposed revision of the threatened species status for cycad taxa. *Biological Conservation*, **71**: 1-12.

Osborne, R. 1999. *Macrozamia macdonnellii*. *Encephalartos* **59**: 4-7.

Preece, L.D. (2005) *Distribution of* Macrozamia macdonnellii *in Central Australia*. Unpublished Honours Thesis, University of Melbourne, Melbourne, Victoria.

Parks and Wildlife Commission of the Northern Territory (1997) *A Management Program for Cycads in the Northern Territory of Australia*. At www.nt.gov.au/NRETAS/wildlife/animals/management.

Queensland Herbarium. 2005. Multi-species Recovery Plan for the cycads, *Cycas megacarpa*, *Cycas ophiolitica*, *Macrozamia cranei*, *Macrozamia lomandroides*, *Macrozamia pauli-guilielmi* and *Macrozamia platyrhachis* 2007-2011. Report to Department of the Environment and Heritage, Canberra. Queensland Parks and Wildlife Service, Brisbane.

Snow E. L. and Walter G. H. (2007) Large seeds, extinct vectors and contemporary ecology: testing dispersal in a locally distributed cycad, *Macrozamia lucida* (Cycadales) *Australian Journal of Botany,* **55***:* 592 – 600.

Soulé, M.E. 1986. (ed.) *Conservation Biology: The Science of Scarcity and Diversity.* Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts.

Terry, I.L., Walter, G.H., Donaldson, J.S., Snow, E., Forster, P.I. and Machin, P.J. 2005. Pollination of Australian *Macrozamia* cycads (Zamiaceae): effectiveness and behaviour of specialist vectors in a dependent mutualism. *American Journal of Botany*, **92**: 931-940.

Vamosi, C. and Vamosi, S.M. 2005. Present day risk of extinction may exacerbate the lower species richness of dioecious clades. *Diversity and Distributions* **11**: 25-32.

Wilson, M.F. and Traveset, A. 2000. The Ecology of Seed dispersal. pp. 85-110 in fenner, M. ed. *Seeds. The Ecology of Regeneration in Plant Communities* (2nd Edition), CABI publishing, Wallingford, UK.

White, M., Albrecht, D., Duguid, A., Latz, P., and Hamilton, M. 2000. *Plant Species and Sites of Botanical Significance in the southern Bioregions of the Northern Territory. Volume 1: Significant vascular plants.* A report to the Australian Heritage Commission. Arid Lands Environment Centre, Alice Springs.

Web addresses

South African National Biodiversity Institute. http://www.sanbi.org/research/co2.htm last viewed March 2007.

CITES. 2003. Review of Significant Trade Cycads. http://www.cites.org/eng/com/pc/14/E-PC14-09-02-02-A1.pdf last viewed March 2007.

IUCN. 2003. Modern Lifestyle threatens oldest seed plants on earth. http://www.iucn.org.press@iucn.org last viewed March 2007.

Figures

Figure 2 Established seedlings (Photo: C. Nano).

Figure 3 Seeds with sarcotesta partially removed (Photo: C. Pavey).

Figure 4 Black-footed rock wallaby feeding on female cone (Photo: Kaij LeFebvre).