

RECOVERY PLAN FOR THE THREATENED PLANTS OF THE TIWI ISLANDS IN THE NORTHERN TERRITORY OF AUSTRALIA 2008 – 2013



Typhonium jonesii (Photo D.T. Liddle)



Natural Heritage Trust

Helping Communities Helping Australia

A Commonwealth Government Initiative

Recovery plan for the threatened plants of the Tiwi Islands in the Northern Territory of Australia 2008 - 2013

A recovery plan prepared under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

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SUMMARY

The aim of this recovery plan is to improve the long-term conservation status of the 19 threatened plant species and their habitats occurring on the Tiwi Islands. Six of these species are listed as threatened under the *Environmental Protection and Biodiversity Conservation Act* and all 19 listed under the *Territory Parks and Wildlife Conservation Act*. Six species are endemic to the Northern Territory, of which 5 are restricted entirely to the Tiwi Islands.

The objectives of the recovery plan are:

1. To achieve stabilised or increasing populations of these 19 species in the wild in a collaborative management environment with adequate expertise, community understanding and community support.
2. To improve management of the species by providing adequate knowledge of the species, their habitats and population response to threats to guide and evaluate management decisions.
3. To achieve stabilised or increasing wild plant populations through the management of threatening processes at a landscape scale.
4. To ensure against long-term loss of species by providing a reserve of genetic material through *ex situ* conservation.
5. To provide ongoing refinement of management of the species through timely evaluation of this recovery plan.

The recommended recovery actions include:

- involve the Tiwi people in the implementation and ongoing refinement of this recovery plan;
- establish a recovery team to guide implementation of this recovery plan;
- conduct further field surveys and expand long-term plant population monitoring;
- eradicate the exotic Gamba Grass from the Tiwi Islands;
- control the exotic Guinea Grass and Perennial Mission Grass on the Tiwi Islands;
- manage fire adjacent to rainforest habitat, particularly in the first two years post cyclone;
- act to ensure an adequate and ongoing spring-fed water supply to maintain rainforests;
- eradicate feral pigs on Melville Island; and
- collect propagation material and establish *ex-situ* populations of selected species in the George Brown Darwin Botanic Gardens.

Implementation of this plan will also have benefits to 15 threatened terrestrial animals known from the Tiwi Islands. More generally, there will be widespread biodiversity benefits on the Tiwi Islands through the control or eradication of weeds and feral animals, along with the protection of rainforest communities via recommendations for appropriate fire regimes and maintenance of spring-fed water supplies.

INTRODUCTION

Location of the Tiwi Islands

The Tiwi Islands comprise Melville and Bathurst Islands, along with a few scattered much smaller nearby islands. Melville Island is Australia's second largest island, being smaller than Tasmania, and has a land area of 5788 km². Bathurst Island is Australia's fifth largest island with an area of 1693 km².

The islands lie just to the north of Darwin (Fig. 1), separated from the Northern Territory (NT) mainland by 25 km of the narrow Clarence Strait. Clarence Strait connects the Beagle Gulf to the west and van Diemen Gulf to the east and contains the small Vernon Islands group. Clarence Strait and the Beagle Gulf are relatively shallow, such that a sea level fall of 30 m would result in connection of the Tiwi Islands to the mainland. The Tiwi Islands constitute about 60% of the Tiwi-Cobourg bioregion.

The Islands are recognised to hold particularly important value for biodiversity conservation, in part due to their large size, isolation and relatively low level of previous modification. Further, the Islands have by far the highest rainfall in north-western Australia, and are in relatively close proximity to Indonesian islands to the north. These factors give rise to a high degree of endemism, the occurrence of species otherwise found only in areas beyond Australia, and considerable richness of mesic rainforests and rainforest-associated species.

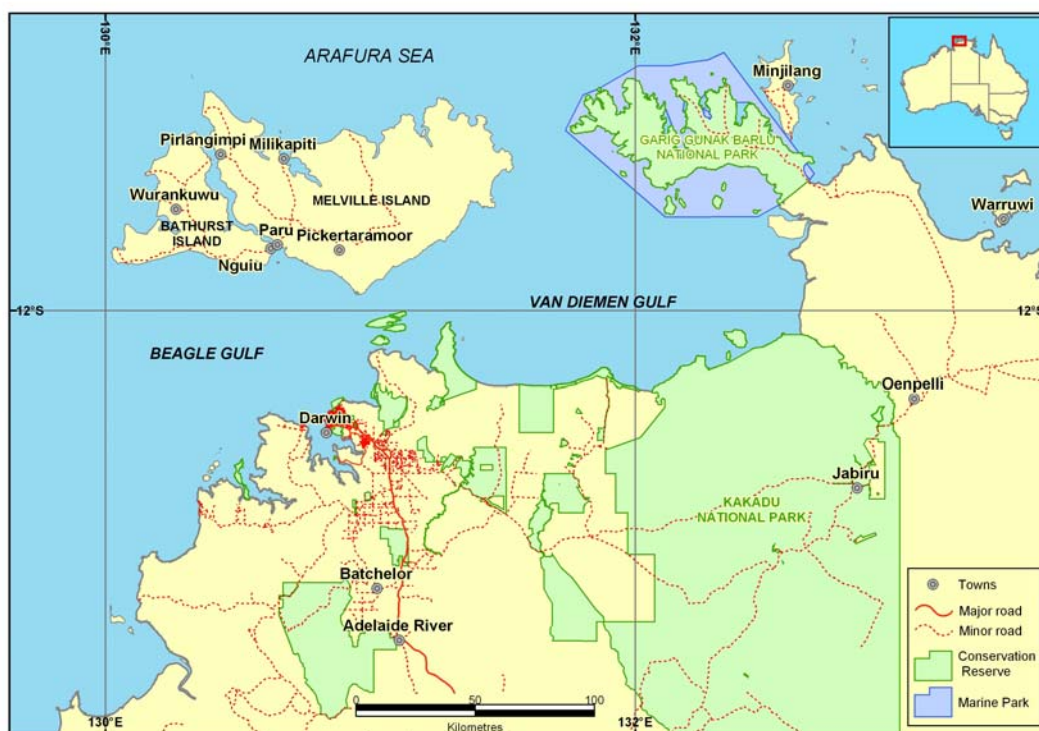


Figure 1. General location of the Tiwi Islands, comprised of Bathurst and Melville Islands, along with locations of communities and main track networks.

Species subject to management

This recovery plan is for 19 plant species found on the Tiwi Islands that are listed as threatened under Australian Government and/or Northern Territory Government (NTG) legislation (Table 1). The IUCN (2001) criteria for listing of each species are provided in Table 1. A small population size and restricted area of occupancy are the most prevalent criteria for listing, though with a few species there is evidence of population decline.

Species taxonomy, distribution, ecology and NT reservation status

Taxonomic, distributional and ecological details for each threatened plant species have been adapted from Woinarski *et al.* (2007) and are provided in a background paper to this recovery plan (Liddle *et al.*, 2008). Six of these species are endemic to the NT, of which 5 naturally occur only on the Tiwi Islands. Sixteen species are not known from any conservation reserve in the NT. Two species are known from only one reserve on the mainland, with *Luisia teretifolia* recorded in Black Jungle Conservation Reserve and *Freycinetia excelsa* recorded in Kakadu National Park. One species, *Cycas armstrongii*, is known from 10 conservation reserves, all of which are located on the mainland.

Legislation and international obligations

Australian Government

Six of the taxa are listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* (Table 1). Four are listed as endangered and two as vulnerable (Table 1). *Xylopia monosperma* is listed as *Xylopia* sp. Melville Island (J.Russell-Smith 2148) NT Herbarium and *Mitrella tiwiensis* as *Mitrella* sp. Melville Island (C.R.Dunlop 6556) NT Herbarium. The *EPBC Act* provides for the development of conservation advice and recovery plans for listed species. Proposed developments that may have a significant impact on populations of listed species should be referred to the Australian Government Minister for Environment, Heritage and Arts to decide if the proposal needs to be assessed under the *EPBC Act*. A permit is required for the export of listed threatened species.

Table 1. Threatened plants recorded from the Tiwi Islands, based on regulations of the *Environment Protection and Biodiversity Conservation Act 1999* (“EPBC status”) and those of the *Territory Parks and Wildlife Conservation Act 2000* (“NT status”). **E** denotes species that are endemic to the Northern Territory. Status codes: CR = critically endangered; EN = endangered; VU = vulnerable. Source: adapted from Woinarski *et al.*, 2007).

Scientific name	Family	NT status and criteria for listing	EPBC status	Life form	Habitat
<i>Elaeocarpus miegei</i>	Elaeocarpaceae	CR: criterion D (very small population size)	Not listed	tree	rainforest
<i>Burmanna</i> sp Bathurst Island (R.J.Fensham 1021) E	Burmanniaceae	EN: criteria B1ab(iii)+2ab(iii); C2b (small extent of occurrence, small area of occupancy, small number of locations and decline in habitat; small population size, population decline and fluctuations in number)	EN	forb	rainforest
<i>Cephalomanes obscurum</i>	Hymenophyllaceae	EN: criterion D (very small population size)	Not listed	fern	rainforest
<i>Garcinia warrenii</i>	Clusiaceae	EN: criterion D (very small population size)	Not listed	tree	rainforest
<i>Tarennoidea wallichii</i>	Rubiaceae	EN: criterion D (very small population size)	Not listed	tree	rainforest
<i>Typhonium jonesii</i> E	Araceae	EN: criteria B1ab(iii)+2ab(iii); D (small extent of occurrence, small area of occupancy, small number of locations and decline in habitat; very small population size)	EN	forb	eucalypt open forest
<i>Typhonium mirabile</i> E	Araceae	EN: criteria B1ab(iii)+2ab(iii); D (small extent of occurrence, small area of occupancy, small number of locations and decline in habitat; very small population size)	EN	forb	eucalypt open forest
<i>Xylopia monosperma</i>	Annonaceae	EN: criterion D (very small population size)	EN	tree	rainforest
<i>Calochilus caeruleus</i>	Orchidaceae	VU: criteria D1+2 (very small population and very restricted area of occupancy)	Not listed	forb	paperbark swamp
<i>Cycas armstrongii</i> E	Cycadaceae	VU: criterion A4ce (decline in area of occupancy, decline in habitat quality and effects of introduced taxa)	Not listed	cycad	eucalypt open forest
<i>Dendromyza reinwardtiana</i>	Santalaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	parasitic vine	rainforest
<i>Endiandra limnophila</i>	Lauraceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	tree	rainforest
<i>Freycinetia excelsa</i>	Pandanaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	climber	rainforest
<i>Freycinetia percostata</i>	Pandanaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	climber	rainforest

Table 1 contd. Threatened plants recorded from the Tiwi Islands.

Scientific name	Family	NT status and criteria for listing	EPBC status	Life form	Habitat
<i>Hoya australis</i> subsp <i>oramicola</i> E	Asclepiadaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	VU	vine	rainforest
<i>Luisia teretifolia</i>	Orchidaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	epiphyte	rainforest
<i>Mapania macrocephala</i>	Cyperaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	sedge	rainforest
<i>Mitrella tiwiensis</i> E	Annonaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	VU	vine	rainforest
<i>Thrixspermum congestum</i>	Orchidaceae	VU: criteria D1+2 (very small population size and very restricted area of occupancy)	Not listed	epiphyte	rainforest

Northern Territory

Nineteen Tiwi Island plant species are listed as threatened under the *TPWC Act*. One is listed as critically endangered, seven as endangered, and 11 as vulnerable to extinction (Table 1). The criteria for listing are based upon IUCN Red List version 3.1 (IUCN, 2001) and the Regional Red List Algorithm (Gärdenfors *et al.* 2001). Along with other cycads in the NT, the management of *Cycas armstrongii* is addressed under a management program approved under the *TPWC Act* (PWCNT, 1997).

Listed threatened species are protected wildlife under the *Territory Wildlife Regulations* and under section 66 of the *TPWC Act* a permit is required to take or interfere with these species. Provision exists under the section 32 of the *TPWC Act* to formulate and implement management programs for the protection, conservation, sustainable use, control and management of wildlife. Co-operative management agreements for the management of wildlife may be made under section 35. Under section 37, areas of land may be declared as essential habitat.

Other States and Territories

Eleven species also occur in other states: *Calochilus caeruleus* in Queensland and Western Australia; *Cephalomanes obscurum* in Queensland and New South Wales; and *Dendromyza reinwardtiana*, *Endiandra limnophila*, *Freycinetia excelsa*, *Freycinetia percostata*, *Garcinia warrenii*, *Luisia teretifolia*, *Mapania macrocephala*, *Thrixspermum congestum* and *Xylopia monosperma* in Queensland. None of these species are listed as threatened in the other states in which they occur.

International

Eleven species are also found beyond Australai: *Cephalomanes obscurum* in Sri Lanka, southern India to Taiwan, Malesia, Solomon Islands and Vanuatu; *Dendromyza reinwardtiana* in Sumatra, Luzon to Papua New Guinea; *Elaeocarpus miegei* in New Guinea, Malesia and the Solomon Islands; *Freycinetia percostata* in New Guinea and the Solomon Islands; *Luisia teretifolia* in New Guinea, Indonesia and Malaysia; *Mapania macrocephala* in Sulawesi, Maluka, Nusa Tenggara, Philippines, and New Guinea; *Tarennoidea wallichii* is widespread in Malesia, extending as far as India; and *Calochilus caeruleus*, *Thrixspermum congestum*, *Freycinetia excelsa*, *Garcinia warrenii* in New Guinea. None of these species are listed as threatened in the other countries where they occur.

Cycas armstrongii is a listed species under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In recognition of this listing, export of plants or plant products other than seed, requires an export permit issued by the Department of the Environment, Water, Heritage and the Arts under the *EPBC Act*. International trade in seed is not restricted.

Indigenous people

The Tiwi Islands support a population of around 2800 people, overwhelmingly comprising traditional Aboriginal owners, the Tiwi people. The population mostly resides in the towns of Nguiu and Wurankuwu on Bathurst Island; and Milikapiti (also known as Snake Bay) and Pirlangimpi (also known as Pularumpi and Garden Point) on Melville Island. In addition there are a number of smaller scattered settlements and outstations. The entire area is Aboriginal freehold land held under the Tiwi Aboriginal Land Trust, with access managed by the Tiwi Land Council (TLC). The track network is best developed on Bathurst Island and the western side of Melville Island. Much of the eastern half of Melville Island is inaccessible by road. More detailed information on the history and people of the Tiwi Islands is given in Forrest (1998). The TLC has been involved in developing this recovery plan and the active participation of Tiwi people is essential to the successful implementation of this plan.

In excess of 200 native plants are known to be used traditionally by Tiwi people for foods and construction material. Most of these plants are associated with rainforest and eucalypt open forests, but there are many utilised plants in all main habitats (Puruntatameri *et al.*, 2001). Two of the species included under this plan are recorded as being used by the Tiwi people. The seeds of *Cycas armstrongii* can be eaten after a long preparation process to remove toxins. Although widely eaten in the past, cycad seeds are now very rarely consumed. In addition, the base of young soft *Cycas armstrongii* fronds may be chewed raw. The tubers of *Typhonium jonesii* are dug up and cooked, then pounded and eaten (Puruntatameri *et al.*, 2001), but this is no longer common usage.

Tiwi people have traditionally used fire as a hunting tool, burning in May to mid-June in isolated patches. These fires were: typically of low intensity and were used primarily to remove speargrass from an area and aid regeneration of native flora.

Such burning had limited impact on rainforest boundaries (Fensham and Woinarski, 1992; Chabra, 1993).

Social and economic impacts

Since 1986, the Tiwi people have sought to achieve economic independence through the development of the Island's natural resources. Plantation based forestry is seen as providing significant economic and social benefits to the Tiwi people.

A proposal for plantation forestry prompted the TLC to commission a study on biodiversity conservation on the Tiwi Islands between 1999 and 2002. The study identified a number of steps for conservation design (see Woinarski *et al.*, 2000) that have been, in part, incorporated into a Biodiversity Protection Zone. The Zone includes retention of: (1) all rainforest patches; (2) a 400 m and 200 m native vegetation buffer around wet and other rainforest patches respectively; (3) a native vegetation buffer around all wetlands and river systems; (4) a 250 m native vegetation buffer around known locations of *Calochilus caeruleus*, *Typhonium jonesii* and *Typhonium mirabile* (TLC, 2000). The Biodiversity Protection Zone has been incorporated into a Plantation Forestry Strategic Plan that defined plantation forestry lease areas as land outside this exclusion zone. The Strategic Plan also involves the establishment of an environmental monitoring program with various components including weeds, groundwater and fire to be integrated with existing and proposed plantation establishment (TLC, 2000).

To date, about 26,000 ha of *Acacia mangium* plantations have been established. Existing approvals for land clearing have been provided in the knowledge of the occurrence of *Cycas armstrongii* within the plantation area. This recovery plan includes provision for survey and identification of key *Cycas armstrongii* populations to be incorporated into the Biodiversity Protection Zone. While the existence of a Biodiversity Protection Zone that incorporates retention of habitat of threatened species has an opportunity cost by influencing the land available for plantation forestry, the existence of this Zone provides a mechanism to address environmental concerns and allow forestry to proceed in adjoining areas. In plantation development over the last decade, the Biodiversity Protection Zone has generally been excluded from clearing or development.

Collaboration between Tiwi people holding traditional knowledge and non-Aboriginal people with a background in western science provides an opportunity for mutual cultural exchange and increased understanding. Proposed actions under this recovery plan include introduction of some threatened species to cultivation at the George Brown Darwin Botanic Gardens and provides an opportunity to promote Aboriginal culture at the gardens. At a pragmatic level, external funds sourced to implement this program provide resources that contribute to the employment and training of Tiwi people.

Affected interests

The Tiwi Islands are owned by the Tiwi Aboriginal people, represented by the TLC. Involvement of the TLC is an essential component of the implementation of this

recovery plan. The Tiwi Islands present a particularly complex and unusual situation where around 5% of the native eucalypt forest has been cleared in the last decade in an attempt to bring an improvement in social and economic well-being to the Tiwi people. The Tiwi people have a rich culture and diversity reflected in 8 recognised clan groups. In addition, the Islands are biologically rich and diverse. This recovery plan addresses 19 plant species that occur in a range of habitats. Not surprisingly, this same landscape supports an array of threatened animal species. Other important collaborators in administering and managing this landscape include forestry and mining operators and various levels of government.

Sylvatech Australia Pty Ltd became involved in plantation forestry on the Tiwi Islands in 1995 with trial plantings of *Acacia mangium* commencing in 1997. The current proposal is for the establishment of 31,200 ha of commercial forestry plantation, primarily on Melville Island, that will be completed in 2008. In 2005 the Sylvatech forestry interests were taken over by Great Southern Limited (GSL).

GSL support a Tiwi Land and Sea Management Program that employs 10 Tiwi Island Rangers. In addition, WWF Australia through the Threatened Species Network currently fund a Tiwi based mentor for the TLC Land Management Program. While the focus of the TLC Land Management Program is broader than threatened plant species, the collaboration of the Tiwi people through the TLC, private industry, a high profile environmental organisation and government provides a great opportunity for positive social and environmental outcomes through implementation of this recovery plan.

Given the forestry development may affect a matter of national environmental significance, the Australian Government has been responsible for the approval of forestry proposals. Since the current development was approved a bilateral agreement has been signed and both the Australian Government and NTG play a role in ongoing administration of the development. More generally, both levels of government have obligations towards the administration of activities impacting on threatened species under respective legislation. Successful implementation of this recovery plan will require a high level of biological knowledge and technical expertise and collaboration with the NTG through participation of scientists from NRETA is an integral part of establishing the plant survey and population monitoring proposed under this plan.

Benefits to other species or ecological communities

As 75% of the Tiwi threatened plant species occur in rainforest habitat, their survival depends upon the retention of the network of rainforest patches on the Islands. The monitoring program proposed under this recovery plan will provide detailed ecological information on the rainforest network and its component species. The monitoring program will provide feedback that will help prevent any further reduction in the extent of populations of these rainforest species. More generally, the maintenance of habitat to support populations of threatened plants will provide a biodiversity benefit in whatever vegetation community the particular threatened species occurs (Table 1).

Maintenance of habitat is expected to benefit 15 threatened terrestrial animals known from the Tiwi Islands. For example, vegetation change associated with altered fire regimes, weeds and/or feral animals has been identified as a process threatening Butler's Dunnart, *Sminthopsis butleri*, and the Northern brush-tailed phascogale, *Phascogale pirata*. Both of these species occur in open forest habitat. The threatened land snail *Trochomorpha melvillensis* and Cognate land snail, *Amphidromus cognatus*, both occur in rainforest habitat which is a habitat targeted for management under this recovery plan.

THREATENING PROCESSES

Identification of threats

Weeds

The exotic species Gamba Grass, *Andropogon gayanus*, and Perennial Mission Grass, *Pennisetum polystachion*, have been introduced as pasture species in northern Australia. Both species are present in open forests on the Tiwi Islands and have the potential to extend over much of the Islands. These robust grasses out-compete many native species, giving rise to changes in nutrient flows, soil conditions and fuel loads (Douglas *et al.*, 2004). An increase in fuel load gives rise to increased fire intensity (Rossiter *et al.*, 2003) and the presence of Perennial Mission Grass has been implicated in the decline of rainforests around Darwin due to altered fire regimes (Panton, 1993).

Acacia mangium trial plantings were first established during forestry operations on the Tiwi Islands through the 1960s to 1980s. From these and more recent plantings, wildlings have spread from plantation areas to nearby native forests. Invasion has occurred into both open forest and rainforest communities. In addition to changing the species composition of the respective communities, potential exists for hybridisation with *Acacia auriculiformis* which occurs naturally on the Tiwi Islands (TLC 2000). The impact from introduction of a fast growing robust over-story tree on the listed threatened species is unconfirmed, but is likely to include direct effects such as competition for resources or indirect effects through changed habitat conditions.

Altered fire regimes

There is a potential threat to species due to a possible increase in fire intensity and frequency. A change from the more traditional early dry season, low intensity fires to late dry, high intensity fires may particularly impact on wet rainforests. These rainforest patches are of small size, are dependent upon continuous availability of water, and are embedded within a highly flammable open forest landscape. In a study across the Top End of the NT, Russell-Smith and Bowman (1992) found 38% of wet and 25% of dry rainforests to be severely disturbed by fire. Rainforests from the Tiwi Islands formed part of the study which not only found that severe fire impact was

widespread, but also that the level of impact was not correlated with land tenure or geographic locality. The generality of the results suggest that fire is likely to be a major disturbance factor impinging upon rainforests on the Tiwi Islands.

The threat from an increase in fire intensity is not restricted to rainforest species, as illustrated by *Cycas armstrongii*. Population modelling based on an experiment conducted near Darwin has shown this species to be resilient to a broad range of fire frequencies under ambient fuel loads and relatively low intensity fire. In contrast, an increase in fuel load to the level encountered with the invasion of Gamba Grass or Perennial Mission Grass, which is equivalent to an intense fire once in five years or less, resulted in population decline. Exposure to fire resulted in a severe reduction in seed viability and intense fire gave rise to the loss of 60% of adult stems over two fire events, compared with no loss of adult stems under less intense fire (Liddle, 2004).

The re-introduction of a forestry industry on the Tiwi Islands has led to a reduction in late dry season fires around plantations, in part through application of early dry season burning, and instigation of a Tiwi Islands fire management planning process.

Feral animals

Wild populations of introduced horses, buffalo and pigs occur in substantial numbers on the Tiwi Islands. Of these, pigs pose the most acute threat to the listed plant species. Feral pigs are suspected of impacting on populations of *Burmanna* DNA 61177 Bathurst Island. While this species seems to have a disturbance requirement, it is probable that pigs are excavating *Burmanna* D61177 Bathurst Island in their search for food (Fensham, 1993). In addition, both pigs and buffalo have the potential to affect recruitment of the rainforest species *Elaeocarpus miegei*, *Endiandra limnophila*, *Freycinetia excelsa*, *Freycinetia percostata*, *Mapania macrocephala*, *Mitrella tiwiensis*, *Tarennoidea wallichii* and *Xylopiya monosperma*, through either grazing of juveniles, trampling or rooting (Russell-Smith and Bowman, 1992; Woinarski *et al.*, 2007). *Calochilus caeruleus* occurs in wet areas and hence may be affected by pigs either directly by consumption of the tuber or indirectly by rooting. *Typhonium jonesii* and *Typhonium mirabile* occur in drier sites but their tubers may be eaten by pigs.

The threat from feral animals has increased with the recent (2003) introduction of pigs to Melville Island. At present, this newly established population appears to be restricted to around the Rangini area in the north-west of Melville Island. This north-western portion of Melville Island supports a high concentration of threatened plant species. Initial assessment has indicated a possible population of 100-200 animals. In the absence of effective control it is highly likely pigs will spread across Melville Island. An outcome of such spread would be a significant expansion of the threat to many of the plant species that are the focus of this recovery plan. Many of the species are restricted to rainforest habitat, an environment that is heavily utilised by pigs elsewhere in the monsoonal tropics of the Top End of the NT (Russell-Smith and Bowman, 1992).

Stochastic events

The small population size and very restricted distribution of the majority of threatened species makes them vulnerable to stochastic events such as cyclone. The arboreal parasite *Dendromyza reinwardtiana* and epiphytes *Luisia teretifolia* and *Thrixspermum congestum*, may be particularly vulnerable to cyclonic events through either direct impact or loss of habitat trees. This threat may increase in the future, given projections that the frequency of severe cyclones is likely to increase in coastal northern Australia in the next few decades due to global warming.

Changes in hydrology

The expansion of plantation forestry using the fast growing species *Acacia mangium* may result in increased demand for soil water. There is thus the potential to reduce groundwater recharge resulting in a reduced flow from springs in the dry season (ForSci, 1999). Such an effect would have most impact on rainforest species restricted to spring-fed wet rainforests. In addition to direct moisture stress on threatened species, these forests are more susceptible to fire following a reduction in water availability. Such a change provides a plausible explanation for the decline of an endangered palm in spring-fed rainforests on the mainland near Darwin (Liddle *et al.* 2006).

Clearing

The majority of land clearing on the Tiwi Islands has been undertaken for forestry. Existing older plantations (>20 yrs old), are typically of *Callitris intratropica* and *Pinus caribaea*. Plantations that are more recent have been predominantly of *Acacia mangium*, with some smaller areas of other *Acacia* spp. and *Eucalyptus* spp. For a history of the plantation forestry see: Haines (1986); ForSci (1999); and TLC (2000). Land clearing for the expansion of plantation forestry has the potential to directly threaten the three species found in eucalypt open forest: *Cycas armstrongii*, *Typhonium jonesii* and *Typhonium mirabile*. Should clearing affect hydrologic function, clearing may indirectly affect those threatened species occurring in rainforest patches interspersed within plantation areas.

Clearing for other developments such as road and mine infrastructure also has the potential to impact on threatened species. The vine *Hoya australis* subsp *oramicola* has been recorded on coastal dunes in proximity to dry rainforests in an area subject to a mining exploration licence on the south coast of Bathurst Island.

Disruption to the mosaic of rainforest habitat patches

Rainforests in the Top End of the NT occur as a network of small patches. Mobile fauna play an important role in the long-term maintenance of the rainforests as

populations of many of its constituent plants depend upon birds and bats for the transfer of pollen and seeds between patches. In turn, these mobile fauna rely upon the rainforest patches as well as adjacent open forest communities for food and shelter. Loss of patches from the mosaic is predicted to result in a disproportionately large decline in the abundance of frugivorous birds (Price *et al.*, 1999). Such loss of mobile fauna would be likely to have a flow-on effect on plant populations. Loss of rainforest patches could arise from a range of threats discussed above or loss of mobile fauna could arise from other factors such as disease, habitat modification or competition from exotic species. Long-term conservation of threatened rainforest plants on the Tiwi Islands will require the maintenance of a mosaic of rainforest patches, their associated fauna and sympathetic management of adjacent open forests.

Climate change

Climate change may have both direct impacts such as changes in temperature or rainfall affecting plant growth, or indirect impacts such as changes in fire regime. While climate change is expected to have significant effects on the vegetation of northern Australia, the likely impact on populations of specific threatened species on the Tiwi islands is largely unknown. In the absence of knowledge for particular species a watching brief should be maintained and management response developed as information on the threat to plant populations becomes apparent.

AIM, OBJECTIVES, PERFORMANCE CRITERIA AND ACTIONS

Aim

The aim of this recovery plan is to improve the long-term conservation status of the 19 threatened plant species and their habitats occurring on the Tiwi Islands.

Objective 1: To achieve stabilised or increasing populations of these 19 species in the wild in a collaborative management environment with adequate expertise, community understanding and community support.

Action 1.1 Ensure a framework for the flow of information and advice is in place and operational.

Performance criterion: Recovery team operational with free and open flow of information and advice between collaborating parties.

Sub-actions and timeline:

- 1.1.1 Establish a recovery team which has Tiwi representation by the end of the first year of the recovery plan.
- 1.1.2 Ensure the recovery team is functioning with a minimum of an annual meeting.

- 1.1.3 Negotiate data sharing arrangements and ensure an up to date database of threatened plant populations is available to project collaborators by the end of the first year of the recovery plan.
- 1.1.4 Compile information on threatened plant populations on an ongoing basis and provide a minimum of a biennial update of maps and database.
- 1.1.5 Provide advice on threatened plant populations and their management needs as required.

Additional information about each action is provided in a background document to this plan (Liddle *et al.* 2008). The priority for each species within groups of actions is provided in Table 2.

Action 1.2 Consult with and involve Tiwi people in on-ground survey and monitoring.

Performance criterion: Tiwi people and western scientists jointly participating in survey and monitoring activities that provide training opportunities for participants.

Sub-actions and timeline:

- 1.2.1 Involve Tiwi people and western scientists in field programs surveying and monitoring threatened plants on an ongoing basis.
- 1.2.2 Consult with Senior Tiwi custodians with regard to *Typhonium* populations, their monitoring and ongoing management, to be undertaken during the first two years of the recovery plan.
- 1.2.3 Provide ongoing training in on-ground management of threatened plants and their habitats via a mentor to the Tiwi Land Management Officer Program.

Action 1.3 Develop and implement an educational program aimed at the broader community.

Performance criterion: An educational program implemented and extension materials distributed to the broader Tiwi community.

Sub-actions and timeline:

- 1.3.1 Develop and commence delivery of a program to inform the broader Tiwi community about threatened plants on the Tiwi Islands by the end of the third year of the recovery plan.
- 1.3.2 Train and employ a Tiwi person as an extension office focussing on threatened plants by the end of the third year of the recovery plan.
- 1.3.3 Produce a *Typhonium* identikit by the end of the first year of the recovery plan.
- 1.3.4 Produce a threatened plant identikit covering all threatened plants on the Tiwi Islands by the end of the third year of the recovery plan.

Objective 2: To improve management of the species by providing adequate knowledge of the species, their habitats and population response to threats to guide and evaluate management decisions.

Action 2.1 Increase knowledge of the species distribution, abundance, biology, habitat requirements and population response to disturbance.

Performance criterion: An up to date database of threatened plant populations and monitoring data at hand. Baseline data on which to evaluate future population trends available. Publications detailing the ecology and/or population trend of target species.

Sub-actions and timeline:

- 2.1.1 Report on existing population monitoring protocols and accompanying data by the end of the first year of the recovery plan.
- 2.1.2 Report on the results of *Burmannia* monitoring in 2006 and 2007 by the end of the first year of the recovery plan.
- 2.1.3 Reassess existing *Typhonium* monitoring plots and report the results during the first year of the recovery plan.
- 2.1.4 Establish additional *Typhonium* monitoring plots by the second year of the recovery plan.
- 2.1.5 Reassess existing *Xylopi*a monitoring plots and report the results during the first year of the recovery plan.
- 2.1.6 Develop and trial a survey and monitoring protocol for *Cycas armstrongii* by the end of the second year of the recovery plan.
- 2.1.7 Establish long-term monitoring plots for *Hoya australis* subsp. *oramicola* and produce an initial report of data and protocols by the end of the second year of the recovery plan.
- 2.1.8 Establish long-term monitoring plots for *Cephalmanes obscurum* and produce an initial report of data and protocols by the end of the second year of the recovery plan.
- 2.1.9 Conduct a targeted survey for the critically endangered *Elaeocarpus miegei* by the end of the second year of the recovery plan.
- 2.1.10 Establish long-term monitoring plots for *Elaeocarpus miegei* and produce an initial report of data and protocols by the end of the third year of the recovery plan.
- 2.1.11 Conduct a targeted survey for *Tarennoidea wallichii* by the end of the third year of the recovery plan.
- 2.1.12 Establish long-term monitoring plots for *Tarennoidea wallichii* and produce an initial report of data and protocols by the end of the third year of the recovery plan.
- 2.1.13 Establish long-term monitoring plots for *Garcinia warrenii* and produce an initial report of data and protocols by the end of the third year of the recovery plan.
- 2.1.14 Establish long-term monitoring plots for *Mapania macrocephala* and produce an initial report of data and protocols by the end of the fourth year of the recovery plan.
- 2.1.15 Establish long-term monitoring plots for *Dendromyza reinwardtiana* and produce an initial report of data and protocols by the end of the fourth year of the recovery plan.
- 2.1.16 Establish long-term monitoring plots for *Mitrella* and produce an initial report of data and protocols by the end of the fifth year of the recovery plan.
- 2.1.17 Collect reproductive material of threatened species, particularly *Elaeocarpus miegei*, *Freycinetia* and *Xylopi*a opportunistically by the fifth year of the recovery plan.

- 2.1.18 Collect plant material from the Annonaceae family (*Xylopia* and *Mitrella*) for analysis to determine genetic distinctiveness and clarify taxonomy during the first two years of this recovery plan.
- 2.1.19 Collect information about other threatened, near threatened and data deficient plants and their habitats opportunistically on an ongoing basis.

Objective 3: To achieve stabilised or increasing wild plant populations through the management of threatening processes at a landscape scale.

Action 3.1 Control of introduced weeds with a focus on grassy weeds that lead to increased fire intensity.

Performance criterion: An annual weed control program implemented under the umbrella of a strategic weed management plan for the Tiwi Islands resulting in eradication of Gamba Grass and control of Guinea Grass, Perennial Mission Grass and wildling *Acacia mangium*.

Sub-actions and timeline:

- 3.1.1 Develop a strategic weed management plan for the Tiwi Islands that addresses the conservation of threatened plant populations and provides a framework for an annual control program, by the end of the second year of the recovery plan.
- 3.1.2 Eradicate Gamba Grass from the Tiwi Islands by the fifth year of the recovery plan.
- 3.1.3 Reduce the abundance and/or extent of Guinea Grass on the Tiwi Islands by the fifth year of the recovery plan.
- 3.1.4 Design and implement an ongoing annual program for control of other grassy weeds under the auspices of the TLC in conjunction with relevant land users, with specific requirements to continually reduce the area occupied by and abundance of all exotic grassy weeds.
- 3.1.5 Refine and implement an ongoing program for the effective control of *Acacia mangium* wildlings and hybrids, under the auspices of the TLC in conjunction with GSL.
- 3.1.6 Refine and implement an ongoing annual program for control of other weeds under the auspices of the TLC in conjunction with relevant land users.
- 3.1.7 Encourage the adoption of intra-territory quarantine mechanisms for the transport of freight to the Tiwi Islands from the NT mainland.

Action 3.2 Implement targeted fire management, including a focus on areas adjacent to key rainforest habitat.

Performance criterion: A program of fire management implemented adjacent to rainforest patches with provision for a heightened management response after cyclone and capacity to map and evaluate the burning implemented. A program to manage fire in habitat of non-rainforest threatened species implemented.

Sub-actions and timeline:

- 3.2.1 Identify patches and design a program of fire management to protect priority rainforest patches by the end of the first year of the recovery plan.

- 3.2.2 Undertake an annual program of early dry-season control burning adjacent to key rainforest patches, on an ongoing basis.
- 3.2.3 Implement a program of extensive early dry-season control burning in years where there is an increase in fuel load due to the effect of cyclone, on an ongoing basis.
- 3.2.4 Acquire and process remotely sensed imagery to evaluate the extent of burning adjacent to rainforest patches, on an ongoing basis.
- 3.2.5 Develop, implement and evaluate a program to manage fire, particularly to avoid high intensity fire, in habitat supporting non-rainforest threatened species, by the fifth year of the recovery plan.

Action 3.3 Ensure an adequate and ongoing water supply to spring-fed rainforests.

Performance criterion: An ongoing program for monitoring groundwater levels and spring-flow implemented, with baseline data available to evaluate rainforest response to any changes in water supply.

Sub-actions and timeline:

- 3.3.1 Design and establish an expanded water monitoring program including groundwater levels and spring-flow by the end of the second year of the recovery plan.
- 3.3.2 Implement an ongoing program of water monitoring.
- 3.3.3 Complete vegetation sampling along monitoring transects at 4 rainforests by the end of the first year of the recovery plan.
- 3.3.4 Construct database and enter existing vegetation sampling data by the end of the first year of the recovery plan.
- 3.3.5 Expand vegetation sampling to include 2 additional rainforests on Bathurst Island by the end of the second year of the recovery plan.
- 3.3.6 Develop a preliminary model of water requirements for Tiwi wet rainforests applying data on use of water by wet rainforests near Darwin, by the end of the second year of the recovery plan.

Action 3.4 Manage introduced animals with a focus on eradication of pigs from Melville Island.

Performance criterion: Pigs eradicated from Melville Island and impact of pigs on *Burmattia* on Bathurst Island evaluated.

Sub-actions and timeline:

- 3.4.1 Implementation of an effective program to eradicate pigs on Melville Island on an ongoing basis, until successful.
- 3.4.2 Maintain the fences around the *Burmattia* monitoring plots on Bathurst Island and assess levels of disturbance at least annually.
- 3.4.3 Assess the *Burmattia* plant population in existing monitoring plots and assess the efficacy of pig exclosure in a manner appropriate for refinement of broader-scale management, by the end of the fifth year of the recovery plan.

Action 3.5 Maintain viable populations of threatened species, particularly open forest species, through ensuring adequate numbers of critical populations are retained should further developments proceed in the future.

Performance criterion: Critical plant populations identified and maintained in the landscape, with a focus on open forest species.

Sub-actions and timeline:

- 3.5.1 Develop a survey protocol for *Typhonium* by the end of the first year of the recovery plan.
- 3.5.2 Survey for *Typhonium* in habitat proposed for conversion to other land uses, as required in response to development proposals.
- 3.5.3 Conduct surveys to refine data on the distribution and abundance of *Cycas armstrongii* by the end of the third year of the recovery plan.
- 3.5.4 Work collaboratively with Tiwi people to develop recommendations for priority areas for conservation of *Cycas armstrongii* populations by the end of the third year of the recovery plan.
- 3.5.5 Conduct a targeted survey for *Hoya australis* subsp. *oramicola* by the end of the second year of the recovery plan.
- 3.5.6 Ensure the maintenance of populations of threatened plant species and their habitat is taken into account in evaluating development proposals, on an ongoing basis.
- 3.5.7 Review zoning policy and practice in the light of new information gained, by the end of the fifth year of the recovery plan.

Objective 4: To ensure against long-term loss of species by providing a reserve of genetic material through *ex situ* conservation.

Action 4.1 Establish and maintain *ex-situ* populations.

Performance criterion: *Ex-situ* populations established for at least 2 threatened species.

Sub-actions and timeline:

- 4.1.1 Establish *ex-situ* populations for 2 threatened species at George Brown Darwin Botanic Gardens by the end of the third year of the recovery plan.
- 4.1.2 In cooperation with Tiwi people design and install interpretational signage at *ex-situ* populations by the end of the third year of the recovery plan.
- 4.1.3 Maintain *ex-situ* populations at George Brown Darwin Botanic Gardens on an ongoing basis.
- 4.1.4 Investigate other options for conserving the genetic material of threatened plants of the Tiwi Islands, including the Millenium Seed Bank, by the end of the fifth year of the recovery plan.

Objective 5: To provide ongoing refinement of management of the species through timely evaluation of this recovery plan.

Action 5.1 Evaluate and revise this recovery plan.

Performance criterion: Timely evaluation and review of this recovery plan.

Sub-actions and timeline:

- 5.1.1 Complete an evaluation of this recovery plan 6 months prior to the expiry of the plan.
- 5.1.2 Prepare an updated plan ready for public consultation 3 months prior to the expiry of the current plan.

Table 2. Location, foliage and flower times, and priority for each species within a group of management actions for the 19 Tiwi Island threatened species. A dash “-“ indicates not applicable. Note the priority rankings provide a comparison between species within a group of actions rather than a comparison between actions addressing difference objectives.

Species	Locality: Melville Is = M, Bathurst Is = B	Phenology			Priority within groups of actions addressing management objectives						
		Foliage time	Flower time	Fruiting time	Targeted survey	Monitoring plots	Weed control	Rainforest fire management	Maintenance of water supply	Pig control	Ex-situ
<i>Burmannia</i> D61177 Bathurst Island	Big Pig & Ilinga Jungle (B)	leafless	June, Nov.	June	low	High to maintain existing	low	mod	high	high	low
<i>Calochilus caeruleus</i>	Snake Bay Rd (M)	Jan, Feb	Dec – Jan.	Jan.	mod	low to establish	mod	-	unknown	mod	low
<i>Cephalomanes obscurum</i>	Tarracumbie Falls	all year	-	-	mod	high to establish	mod	mod	high	mod	mod
<i>Cycas armstrongii</i>	Widespread	all year	-	Aug – Nov	high	high to establish	high	-	-	high	low
<i>Dendromyza reinwardiana</i>	seven sites, three from B, four from M	all year	?	Jan, Sept, Nov	low	mod to establish	mod	mod	high	low	low
<i>Elaeocarpus miegei</i>	six sites, two from M, four from B	all year	?	Nov	high	mod to establish	high	mod	high	mod	low
<i>Endiandra limnophila</i>	eight sites from B, 17 from M	all year	Dec	?	mod	mod to establish	mod	high	high	mod	low
<i>Freycinetia excelsa</i>	two sites from B, one from M	all year	?	Feb	mod	low to establish	mod	mod	high	mod	mod
<i>Freycinetia percostata</i>	Big Pig Jungle B	all year	?	Nov	mod	low to establish	low	mod	high	-	mod
<i>Garcinia warrenii</i>	Jesse River M	all year	Aug	?	low	mod to establish	low	low	low	mod	mod
<i>Hoya australis</i> subsp. <i>oramicola</i>	two sites on B) one on M	all year	Mar, July	3-4 months after flowering	high	high to establish	mod	-	low	-	low
<i>Luisia teretifolia</i>	nine sites on M	all year	Feb, Nov - Dec	Nov	low	very low to establish	mod	mod	high	low	low
<i>Mapania macrocephala</i>	two sites from B, one from (M)	all year	?	Feb, June, Nov	mod	mod to establish	low	mod	high	-	low
<i>Mitrella tiwiensis</i>	22 sites from B and M	all year	?	June, Sept, Dec	mod	mod to establish	mod	high	high	mod	low
<i>Tarennoidea wallichii</i>	three sites from M	all year	Oct	July, Oct	high	mod to establish	high	high	high	mod	mod
<i>Thrixspermum congestum</i>	four sites from B, four from M	all year	Feb	?	low	very low to establish	mod	mod	high	low	low
<i>Typhonium jonesii</i>	one site from B, two sites from M	Dec	Dec	?Mar	high	high to expand	high	-	-	?high	low
<i>Typhonium mirabile</i>	five sites on M	Oct-Dec	Oct	Dec	high	high to expand	high	-	-	?high	low
<i>Xylopia monosperma</i>	two sites on B, three on M	all year	?	?	mod	mod to expand	high	high	high	mod	low

MANAGEMENT PRACTICES

Weed control

There are seven isolated infestations of Gamba Grass, *Andropogon gayanus*, reported from the Tiwi Islands. Three of the seven occur within community areas at Nguuu, Wurankuwu and Milikapti. Another is associated with native vegetation in a disused borrow pit 12 km south-east of Pirlangimpi and two more adjacent to the road between Pirlangimpi and Maxwell Creek. Following control measures, the roadside population near Maxwell Creek appears to have been eradicated, as has an isolated outbreak at Pickertaramoor. Control of this weed is extremely important as it can build up a large biomass and leads to increased frequency and intensity of fires. This can lead to decreased tree canopy cover and loss of rainforest patches (Wilson and Mudita 2000). Action is being undertaken by the TLC to eradicate all known populations of this exotic pasture species.

The occurrence of Perennial Mission Grass and Guinea Grass is more extensive on the Islands, however, they currently extend over only a small proportion of their potential range and a containment program is being undertaken by the TLC. Should containment be successful, the possibility of eradication should be considered. The containment or eradication of these robust grasses is being approached in an integrated manner with mapping of occurrences, a co-ordinated strategic spraying program with a focus on outlying outbreaks, monitoring the outcome of control activities and follow-up inspections to confirm localised eradication. All weed outbreaks and containment activities are being recorded in a database with the potential to link the data to a geographic information system. This recording facilitates the preparation of annual control programs and the evaluation of progress with implementation of a strategic weed management plan.

These control actions are supported by public awareness activities and signage to minimise spread around the Islands and prevent further introduction of seed from the mainland. The TLC has developed a quarantine policy focussed on the prevention of the transport of weeds to the Tiwi Islands. Strengthening intra-territory quarantine legislative mechanisms would assist in protecting the habitat of threatened plants on the Tiwi Islands. Education and involvement of the Tiwi people is an integral component of controlling these grasses and preventing reinfestation.

Feral animal control

To manage the impact of buffalo and pigs the most appropriate practice is to avoid introduction to islands where they do not currently occur or to implement a timely eradication program where small populations have recently established. Where present and well established, the emphasis under this plan is on monitoring levels of animal disturbance and response of either the threatened plant populations or response of their habitat. This feedback will be used to develop further management recommendations. Control and eradication prescriptions are likely to require a sustained effort implementing an integrated approach, possibly combining baiting, shooting and trapping. An essential element is to include a program of education and

involvement of the Tiwi people to maintain local awareness and support for control activities. The TLC is active in its attempts to eradicate the small population of pigs on the north-west of Melville Island.

The introduction of pigs to Melville Island is unlikely to impact on *Burmanna* sp. Bathurst Island (R.J.Fensham 1021), as to date it has only been found on Bathurst Island, however, ongoing action is required for this species. In late 2006 a series of fenced and unfenced monitoring plots were established and ongoing maintenance of these fences is required. Should significant population decline due to pigs be observed, a control program, possibly combining fencing with other techniques should be instigated around key populations. At this stage, fencing is not considered to be a priority for other rainforest species that may be impacted by feral animals. The need for future action will be considered in the light of the outcomes from further population survey and monitoring.

Fire management

The preferred fire regime in open forest would mimic traditional burning patterns and comprise fine-scale burning in the early to mid-dry season with one-third of every clan estate burnt each year, but with locations burnt varying substantially from year to year (Woinarski *et al.*, 2000). This fire regime will help maintain conservation values and has been endorsed in the Plantation Forestry Strategic Plan for all areas with the exception of a hazard reduction burn zone around plantations. The TLC is currently developing a fire management plan for the whole of the Tiwi Islands. The outcomes of monitoring threatened plant populations will be fed into future refinements of fire management on the Tiwi Islands. A high priority with respect to fire management is to prevent the further introduction or spread of species such as Gamba Grass, Perennial Mission Grass or Guinea Grass which lead to significant increases in fuel load.

Habitat protection

All known occurrences of 17 of the 19 threatened species are within the Biodiversity Protection Zone as set out in the Plantation Forestry Strategic Plan (TLC, 2000). The exceptions are a population of *Typhonium mirabile* and populations of *Cycas armstrongii*. There is a need to incorporate significant populations of *Cycas armstrongii* into the Biodiversity Protection Zone. In addition to the Biodiversity Protection Zone, the adoption of the forestry plan involves investigation of the establishment of a conservation reserve area in the eastern portion of Melville Island. Consequently, no further habitat reservation is considered necessary at this time. Note that this recovery plan should succeed in developing considerably more information (including on status trends, impact of threats and efficacy of management) than was available at the time of the initial recommendations for buffer zoning and other protection, and hence it would be desirable to use this information to review and inform the zoning policy and practice.

DURATION AND COSTS

Duration and costs

An implementation and cost schedule for actions proposed under this recovery plan is provided in Table 3.

Resource allocation

The actions proposed in this recovery plan build upon previous threatened plant survey work undertaken by the NTG (Fensham and Woinarski, 1992; Fensham, 1993; Woinarski *et al.*, 2000; Woinarski *et al.*, 2003) and complement the actions proposed under the Plantation Forestry Strategic Plan (TLC, 2000). The attention to weeds and introduced animals is in accord with concerns raised about the current and potential impact of these exotic organisms on threatened plant populations on the Tiwi Islands. Allocation of resources to the eradication or control of the current relatively small outbreaks of Gamba Grass, Guinea Grass, Perennial Mission Grass and pigs on Melville Island is timely and will avoid significantly greater expense in the future to manage the negative impacts of these exotic species. The proposed actions involve ongoing collaboration between with the Tiwi people, specifically the Aboriginal landholders through the TLC and private industry, a community conservation organisation and government, however, future funding is unsecured. The continuing involvement of the above groups in implementation of the recovery plan will facilitate complementary actions and the efficient use of funds to address recovery of the species.

Table 3: Implementation and cost schedule for the recovery of threatened plant species on the Tiwi Islands. Costs are expressed in \$'000. Long-term importance of action: 1 = crucial to long-term success; 2 = probably crucial to long-term success; and 3 = possibly crucial to long-term success. Immediacy of action: 1 = requires immediate implementation or required to maintain existing management momentum; 2 = requires implementation in near future; and 3 = desirable implementation occurs as soon as practical.

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Collaboration and education	Establish and maintain recovery team (Act 1.1.1, 1.1.2)	1	1	4	4	4	4	4	20
	Negotiate a data sharing agreement and establish an up to date database(Act 1.1.3)	1	2	10					10
	Biennial update of plant population maps and database (Act 1.1.4)	1	2			5		5	10
	Provide advice on management of populations (Act 1.1.5)	1	1	2	2	2	2	2	10
	<i>Sub-total</i>			16	6	11	6	11	50
	Involve Tiwi people and western scientists in field programs (Act 1.2.1)	1	1	Cost in other actions	Cost in other actions	Cost in other actions	Cost in other actions	Cost in other actions	Cost in other actions
	Consult senior custodians regards <i>Typhonium</i> (Act 1.2.2)	1	1	6	6				12
	On-ground training via mentor (Act 1.2.3)	1	1	70	70	70	70	70	350
	<i>Sub-total</i>			76	76	70	70	70	362
	Develop and implement community education program (Act 1.3.1)	1	2		10	10	10	10	40
	Train and support Tiwi extension officer (Act 1.3.2)	2	2		70	70	70	70	280
	Produce <i>Typhonium</i> identikit (Act 1.3.3)	1	1	3					3

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	Produce threatened plant identikit (Act 1.3.4)	2	2			18			18
	<i>Sub-total</i>			3	98	80	80	80	341
Increased knowledge	Report plant monitoring protocols and accompanying data (Act 2.1.1)	2	2	8					8
	Report results of <i>Burmannia</i> monitoring (Act 2.1.2)	2	2	8					8
	Reassess <i>Typhonium</i> monitoring plots and report results (Act 2.1.3)	2	2	13					13
	Establish additional <i>Typhonium</i> monitoring plots (Act 2.1.4)	2	2		19				19
	Reassess <i>Xylopi</i> a monitoring plots and report results (Act 2.1.5)	2	2	19					19
	Develop and trial a survey and monitoring protocol for <i>Cycas armstrongii</i> (Act 2.1.6)	1	1	10	20				30
	Establish <i>Hoya</i> monitoring (Act 2.1.7)	2	2		20				20
	Establish <i>Cephalmanes</i> monitoring (Act 2.1.8)	2	2		20				20
	Targeted survey for <i>Elaeocarpus miegei</i> (Act 2.1.9)	2	2		19				19
	Establish <i>Elaeocarpus miegei</i> monitoring (Act 2.1.10)	2	2		5	15			20
	Targeted survey for <i>Tarennoidea</i> (Act 2.1.11)	2	2		9	9			18
	Establish <i>Tarennoidea</i> monitoring (Act 2.1.12)	2	2			15			15

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	Establish <i>Garcinnia warrenii</i> monitoring (Act 2.1.13)	2	2			12			12
	Establish <i>Mapania macrocephala</i> monitoring (Act 2.1.14)	2	2				20		20
	Establish <i>Dendromyza</i> monitoring (Act 2.1.15)	2	2				20		20
	Establish <i>Mitrella</i> monitoring (Act 2.1.16)	2	2					20	20
	Collect reproductive specimen material (Act 2.1.17)	2	2	1	1	1	1	1	5
	Clarify taxonomy and genetic distinctiveness of Annonaceae (Act 2.1.18)	2	3	1	1				2
	Collect information on other species (Act 2.1.19)	2	2	1	1	1	1	1	5
	<i>Sub-total</i>			61	115	53	42	22	293
Weed control	Develop a strategic weed management plan for the Tiwi Islands (Act 3.1.1)	1	1	10	10				20
	Eradicate Gamba Grass (Act 3.1.2)	1	1	6	6	5	4	3	24
	Control Guinea Grass (Act 3.1.3)	1	1	15	15	15	15	15	75
	Plan and implement an annual program for control of other grassy weeds (Act 3.1.4)	1	1	100	100	100	100	100	500
	Plan and implement program for control of <i>Acacia mangium</i> wildlings and hybrids (Act 3.1.5)	1	1	20	20	20	20	20	100
	Plan and implement annual program for control of other weeds (Act 3.1.6)	2	2	10	10	10	10	10	50

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	Encourage quarantine mechanisms (Act 3.1.7)	1	2	5	5	5	5	5	25
	<i>Sub-total</i>			166	166	155	154	153	794
Fire management	Develop proposal and identify priority rainforest patches for fire management (Act 3.2.1)	2	2	12					12
	Plan and implement annual program of control burning around priority rainforest patches (Act 3.2.2)	2	2	20	20	20	20	20	100
	Plan and implement an extensive program of control burning around rainforest patches in first two years post cyclone (Act 3.2.3)	2	2			20 (year depends upon cyclone)	20 (year depends upon cyclone)		40
	Acquire and process remotely sensed imagery (Act 3.2.4)	2	2	15	15	15	15	15	75
	Develop, implement and evaluate a program to manage fire, particularly to avoid high intensity fire, in habitat supporting non-rainforest threatened species (Act 3.2.5)	2	2		20	20	20	20	80
	<i>Sub-total</i>			47	55	75	75	55	307
Water supply to spring-fed rainforests	Expand water monitoring program (Act 3.3.1)	1	2	30	200				230
	Implement water monitoring program (Act 3.3.2)	1	2			20	20	20	60
	Complete vegetation sampling at 4 rainforests (Act 3.3.3)	2	2	17					17

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	Construct database and enter vegetation data (Act 3.3.4)	2	2	4					4
	Complete vegetation sampling at 2 additional rainforests on Bathurst Island (Act 3.3.5)	2	2		34				34
	Develop a preliminary model of water requirements for Tiwi wet rainforests (Act 3.3.6)	1	2		50				50
	<i>Sub-total</i>			51	284	20	20	20	395
Manage feral animals	Eradicate pigs on Melville Island (Act 3.4.1)	1	1	100	100	100	100	100	500
	Maintain fences around <i>Burmannia</i> plots and assess levels of disturbance (Act 3.4.2)	2	1	4	5	4	5	4	22
	Reassess <i>Burmannia</i> in monitoring plots and analyse results (Act 3.4.3)	2	2				18	11	29
	<i>Sub-total</i>			104	105	104	123	115	551
Maintain critical populations with changes in land use	Develop survey protocol for <i>Typhonium</i> (Act 3.5.1)	1	1	2					2
	Survey for <i>Typhonium</i> in habitat proposed for conversion to other land uses (Act 3.5.2)	1	3	as needed	as needed	as needed	as needed	as needed	as needed
	Broad-scale survey of <i>Cycas armstrongii</i> , establish monitoring sites and identify priority populations (Act 3.5.3, 3.5.4)	1	2		50	20			70
	Targeted survey for <i>Hoya</i> (Act 3.5.5)	2	2		15				15

Objective	Action and performance criteria	Importance	Immediacy	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	Provide input into evaluation of development proposals (Act 3.5.6)	1	1	2	2	2	2	2	10
	Review zoning policy and practice (Act 3.5.7)	1	2					8	8
	<i>Sub-total</i>			4	67	22	2	10	105
<i>Ex-situ</i> populations	Establish <i>ex-situ</i> populations for 2 species (Act 4.1.1)	3	3	3	3	3			9
	Install interpretational signage (Act 4.1.2)	3	3			3			3
	Maintain <i>ex-situ</i> populations (Act 4.1.3)	2	3				1	1	2
	Investigate other options for conserving genetic material (Act 4.1.4)	2	3				2		2
	<i>Sub-total</i>			3	3	6	3	1	16
Evaluation of recovery plan	Evaluate and update recovery plan (Act 5.1.1, 5.1.2)	1	3					14	14
	<i>Sub-total</i>							14	14
Total				531	975	596	575	551	3228

REFERENCES

- Chabra, S.E. (1993) Historical ecology and plantation characteristics of Melville Island. Honours Thesis, Northern Territory University.
- Douglas, M.M., Setterfield, S.A., Rossiter, N., Barratt, J. and Hutley, L.B. (2004) Effects of mission grass (*Pennisetum polystachion* (L.) Schult.) invasion on fuel loads and nitrogen availability in a northern Australian tropical savanna. In *Weed Management Balancing People, Planet, Profit* (eds B.M. Sindel and S.B. Johnson), pp. 179-181. Weed Society of New South Wales, Wagga Wagga.
- Fensham, R.J. (1993) The impact of pig rooting on populations of *Burmannia* sp., a rare rainforest herb on Bathurst Island. *Proceedings of the Royal Society of Queensland*, **103**, 5-12.
- Fensham, R.J. and Woinarski, J.C.Z. (1992) YAWULAMA The ecology and conservation of monsoon forest on the Tiwi Island, Northern Territory. Conservation Commission of the Northern Territory, Darwin.
- Forrest, P. (1998). Culture and history. In *The history and natural resources of the Tiwi Islands, Northern Territory*. pp. 17-52. Parks and Wildlife Commission of the Northern Territory, Darwin.
- ForSci (1999) Environmental impact assessment of fast grown plantations on the Tiwi Islands. ForSci Pty Ltd.
- Gärdenfors, U., Hilton-Taylor, C., Mace, G.M. and Rodriguez, J.P. (2001). The application of IUCN Red List criteria at regional levels. *Conservation Biology* **15**, 1206-1212.
- Haines, M.W. (1986) An outline of the Melville Island plantation forestry project. 86/4. Conservation Commission of the Northern Territory, Darwin.
- IUCN (2001) IUCN red list categories: version 3.1. Prepared by the IUCN Species Survival Commission, Gland, Switzerland and Cambridge, UK. 23p.
- Liddle, D.T. (2004) The ecology of *Cycas armstrongii* and management of fire in Australia's tropical savannas. PhD thesis, Charles Darwin University, Darwin.
- Liddle, D.T., Brook, B., Matthews, J., Taylor, S.M. and Caley, P. (2006). Threat and response: A decade of decline in a regionally endangered rainforest palm affected by fire and introduced animals. *Biological Conservation* **132**, 362-375.
- Liddle, D.T., Gibbons, A. and Taylor, R. (2008). Background to a recovery plan for the threatened plants of the Tiwi Islands in the Northern Territory of Australia 2008-2013. Northern Territory Department of Natural Resources, Environment and the Arts, Darwin.
- Panton, W.J. (1993) Changes in post World War II distribution and status of monsoon rainforests in the Darwin area. *Australian Geographer*, **24**, 50-59.
- Price, O.F., Woinarski, J.C.Z. and Robinson, D. (1999) Very large area requirements for frugivorous birds in monsoon rainforests of the Northern Territory, Australia. *Biological Conservation*, **91**, 169-180.
- Puruntatameri, J., Puruntatameri, R., Pangiraminni, A., Burak, L., Tipuamantymirri, C., Tipakalippa, M., Puruntatameri, J., Puruntatameri, P., Puruntatameri, J.B., Kerinaiuua, R., Tipiloura, D., Orsto, M., Kantilla, B., Kurrupuwu, M., Puruntatameri, P.F., Puruntatameri, T.D., Puruntatameri, L., Kantilla, K., Wilson, J., Cusack, J., Jackson, D. and Wightman, G. (2001) *Tiwi plants and animals. Aboriginal flora and fauna knowledge from Bathurst and Melville*

- Islands, northern Australia.* Parks and Wildlife Commission of the Northern Territory and Northern Land Council.
- PWCNT (1997) A Management Program for Cycads in the Northern Territory of Australia. Parks and Wildlife Commission of the Northern Territory.
- Rossiter, N.A., Setterfield, S.A., Douglas, M.M. and Hutley, L.B. (2003) Testing the grass-fire cycle: alien grass invasion in the tropical savannas of northern Australia. *Diversity and Distributions*, **9**, 169-176.
- Russell-Smith, J. and Bowman, D.M.J.S. (1992) Conservation of monsoon rainforest isolates in the Northern Territory, Australia. *Biological Conservation*, **59**, 51-63.
- TLC (2000) Tiwi Islands plantation forestry strategic plan. Tiwi Land Council, Darwin.
- Wilson, C.G. and Mudita, I.W. (2000). Fire and weeds: interactions and management implications. In *Fire and sustainable agriculture and forestry development in Eastern Indonesia and Northern Australia*. (Eds Russell-Smith, J., Hill, G., Djoeroemana, S. and Myers, B.) ACIAR, Canberra.
- Woinarski, J., Brennan, K., Cowie, I., Kerrigan, R. and Hempel, C. (2003) Biodiversity conservation on the Tiwi Islands, Northern Territory: part 1. Environment and plants. Parks and Wildlife Commission of the Northern Territory, Darwin.
- Woinarski, J., Brennan, K., Hempel, C., Firth, R. and Watt, F. (2000) Biodiversity conservation on the Tiwi Islands: plants, vegetation types and terrestrial vertebrates on Melville Island. Report to the Tiwi Land Council. PWCNT, Darwin.
- Woinarski, J., Pavey, C., Kerrigan, R., Cowie, I. and Ward, S., Ed. (2007) *Lost from our landscape: threatened species of the Northern Territory*. Northern Territory Government, Darwin.