National Multi-species Recovery Plan for the cycads, *Cycas megacarpa, Cycas ophiolitica, Macrozamia cranei, Macrozamia lomandroides, Macrozamia pauli-guilielmi* and *Macrozamia platyrhachis*

Prepared by the Queensland Herbarium, Environmental Protection Agency, Brisbane

Cycas megacarpa male
(photo: P.I. Forster)

Macrozamia cranei male
(photo: P.I. Forster)

Macrozamia lomandroides female
(photo: G. Leiper)

Macrozamia platyrhachis male
(photo: P.I. Forster)

Cycas ophiolitica female
(photo: G.W. Wilson)

Macrozamia pauli-guilielmi male and female growing together (photo: G. Leiper)

Australian Government

Queensland Government
Environmental Protection Agency
Queensland Parks and Wildlife Service

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Contents

Executive summary

Species

The species covered by this plan include two species belonging to the family Cycadaceae (*Cycas megacarpa* and *C. ophiolitica*) and four species belonging to the family Zamiaceae (*Macrozamia cranei, M. lomandroides, M. pauli-guilielmi,* and *M. platyrhachis*) all of which are endemic to Queensland.

Current species status

All six species are listed as 'Endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Schedules of the Queensland *Nature Conservation Act 1992* (NCA). All six species are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II, and variously under the IUCN Red List Category and Criteria, version 3.1 (2001) (Table 3).

Habitat and distribution summary

C. megacarpa is endemic to central Queensland, occurring from Bouldercombe in the north, to near Woolooga in the south, in woodland or open woodland dominated by eucalypts.

C. ophiolitica is endemic to central Queensland where the known populations are concentrated in two areas, around Marlborough and Rockhampton, in woodland or open woodland dominated by eucalypts, often on serpentinite substrates.

M. cranei is restricted to a small area of rugged terrain near Texas in the Darling Downs district of south-east Queensland, in shallow, skeletal soil or on alluvium along seasonal watercourses in woodland dominated by *Callitris glaucophylla* and *Eucalyptus* species.

M. lomandroides has a limited distribution south of Bundaberg, south-east Queensland, between the Elliot and Isis Rivers, in banksia or eucalypt dominated woodland (wallum) or open forest on the coastal plain on flats and gently inclined hill slopes.

M. pauli-guilielmi is found in the Wide Bay district, south-east Queensland, from near the Isis River in the north, to near Wolvi in the south, in lowland open forest or woodland (wallum) dominated by banksias or eucalypts, often on stabilised sand dunes.

M. platyrhachis has a restricted distribution on the Blackdown Tableland, central Queensland, in eucalypt woodland or open forest on deep sandy soils derived from sandstone.

Threats summary

3.2.1 Destruction of habitat and individuals due to land clearing.
3.2.2 Legal harvesting and commercial salvage.
3.2.3 Illegal destruction and harvesting.
3.2.4 Loss of genetic variation and insect pollinators.
3.2.5 Land management practices.

Recovery Objectives

- To prevent further loss of individuals, populations, pollinator species and habitat critical to the species survival.
- To recover existing populations to normal reproductive capacity to ensure viability in the long-term, prevent extinction, maintain genetic viability, and improve conservation status.

Evaluation and review

This plan will be reviewed and revised annually by the recovery team and at least two external referees. This plan will be reviewed within five years of being adopted.

1. General information

1.1 Background information

The cycads are woody gymnosperms of the families Cycadaceae and Zamiaceae (Hill *et al.* 2003). They have a perennial trunk, either above or below ground, and leaves that are shed and renewed over a period of several years. Individual plants are either male or female. The group is of ancient lineage, often referred to as the ‘dinosaurs of the plant world’ and the ancestors of the current-day species were contemporaneous with dinosaurs (Norstog and Nicholls 1997).

There are approximately 300 currently existing species occurring in the tropics and subtropics (Hill *et al.* 2004). Major centres for diversity are southern Africa, Central America and Australia. More than 35 percent of the currently recognised species in the world were described during the last decade, reflecting the current high level of international interest in the group. Four genera of cycads: *Bowenia, Cycas, Lepidozamia* and *Macrozamia* occur in Australia, 74 species overall. Queensland is a major centre of diversity, with 13 percent of the world’s cycad flora. This includes 41 species and three subspecies across all four genera (Forster 2004; Hill *et al.* 2004). Of these species, 39 are found only in Queensland. At the present time, 47 percent of Queensland cycad species are considered threatened (‘Endangered’ or ‘Vulnerable’), slightly less than the world average of 52 percent (Donaldson 2004).

Technical terms and phrases unique to either conservation biology or cycads are defined in a **Glossary of Terms** at the end of this report. For further background information, see Forster (2005).

1.2 Conservation status

Five of the species have at least one significant population conserved in a national park or state forest. *Macrozamia cranei* currently only occurs on freehold land (Table 1).

All six species are listed as ‘Endangered’ under the EPBC Act.

In Queensland, all six species are listed as ‘Endangered’ under the NCA (Table 3). The *Nature Conservation (Protected Plants) Conservation Plan 2000 and Nature Conservation (Wildlife Management) Regulation 2005* contain the management framework for the take and use of protected plants, including threatened species and others listed as Type B restricted plants. Under the *Nature Conservation (Protected Plants) Conservation Plan 2000* (Division 6 “Declaration of Harvest Period”) taking of whole plants for commercial purposes ceased on 31 December 2005, except for taking stock plants under salvage or taking protected plants as a bio-prospecting activity.

Table 1. Number of populations per known land tenure (number of significant populations in brackets)

Species	National park (NP)	State forest (SF)	Vacant crown land (VCL)	Grazing homestead perpetual lease (GHPL)	Road reserve (RR)	Free hold title (FHT)	Forest reserve (FR)	Military land (ML)
Cycas megacarpa	4	12 (3)	2	3	3	19 (3)	1	
Cycas ophiolitica	2 (1)	1			2	9 (3)		2
Macrozamia cranei						6(2)		
Macrozamia lomandroides	8 (5)	12 (10)	1		1			
Macrozamia pauli-guilielmi	3	19(4)	1			4		
Macrozamia platyrhachis	6(6)	1(1)		5(5)				

The purpose of the *Vegetation Management Act 1999* (VMA) is to regulate the clearing of remnant vegetation and conserve all remnant regional ecosystems. Regional ecosystem maps are available on the web at www.epa.qld.gov.au/REMAPS.

The *Vegetation Management and other Legislation Amendment Act 2005* provides a framework for the phasing out of broad scale clearing of remnant vegetation by the end of 2006 under a transitional cap. Details of the framework are available at www.legislation.qld.gov.au. All six cycad species covered under this recovery plan have significant populations occurring in remnant vegetation.

Table 2. Significant populations occurring in remnant vegetation as defined by the *Vegetation Management Act 1999*.

Species	Endangered	Of concern	Not of concern	Non-remnant
Cycas megacarpa	3	12 (1)	23 (6)	8
Cycas ophiolitica		2	8 (3)	6
Macrozamia cranei		4 (2)	1	1
Macrozamia lomandroides	5 (3)	13 (10)	1	3 (3)
Macrozamia pauli-guilielmi		17 (3)	2	8 (1)
Macrozamia platyrhachis			12 (12)	

1.3 International obligations

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List includes five of the six species (*M. platyrhachis* is not listed) and the current categories and criteria for these species (version 3.1) are given in Table 3. Details of the categories and criteria are available at www.redlist.org.

All six species are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II, under the families Cycadaceae and Zamiaceae. Information on CITES is available at www.environment.gov.au/biodiversity/trade_use/cites/index.html and www.cites.org.

This plan is consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993. Details of the Convention are available at www.biodiv.org/convention

Table 3. Conservation codes under the schedules of the NCA and the EPBC Act, and categories and criteria of the IUCN guidelines and CITES.

Species	NCA	EPBC Act	IUCN	CITES
Cycas megacarpa	Endangered	Endangered	EN A2c	Appendix II
Cycas ophiolitica	Endangered	Endangered	NT	Appendix II
Macrozamia cranei	Endangered	Endangered	VU D2	Appendix II
Macrozamia lomandroides	Endangered	Endangered	VU A2c	Appendix II
Macrozamia pauli-guilielmi	Endangered	Endangered	EN A2c	Appendix II
Macrozamia platyrhachis	Endangered	Endangered	Not listed	Appendix II

1.4 Affected interests

Most existing populations occur on Queensland Government owned or controlled land. Therefore the following Queensland Government organisations may have major responsibility for these species and the threats identified by this plan:

Queensland Environmental Protection Agency (EPA)

Queensland Parks and Wildlife Service (QPWS)

Queensland Department of Natural Resources, Mines and Water

Queensland Department of Primary Industries and Fisheries

Queensland Department of Main Roads

The following organisations may also have significant affected interest:

Local councils in affected areas.

The owners of the freehold title on which populations exist.

1.5 Consultation with Indigenous people

A note on the label of a specimen (MEL278110) written by botanist Walter Hill (undated but probably 1860-1870), states "The nuts of this plant are the only food the natives put in store for their use". This is the only reference to indicate that *M. pauli-guilielmi* was once used as a food source. The toxic nature of the material and possible long-term health effects mean that this possible food source has long been abandoned. Indigenous representative groups in the areas where populations occur have been consulted in the development of this plan and participation in the implementation of recovery actions will be encouraged.

1.6 Benefits to other species or communities

Cycads can be considered ‘flagship species’ for conservation biology (Meffe and Carroll 1997), as they have unusual life histories that are interesting to many people, and are restricted in distribution, with over 50 percent of species threatened globally (Donaldson 2003). Nearly all of the 41 species of cycads occurring in Queensland are endemic to the state, a major centre of diversity for these plants.

There is increasing awareness of the dependence of these plants on various insects for pollination, and, conversely, dependence of various insects on the cycads to enable completion of their life cycles (Donaldson 1995). Disruption of these relationships may ultimately result in extinction of the plants and/or the insects (Bond 1994). At least two invertebrates, the butterfly *Theclinesthes onycha* and the beetle *Lilioceris nigripes* are known to predate on cycads (Forster and Machin 1994) but much remains to be discovered about their roles.

The symbiosis between cycads and nitrogen fixing cyanobacteria occurring in the coralloid roots is well documented (Lindblad *et al*. 1991; Lindblad and Costa 2002). This symbiosis results in significant nitrogen fixing and consequent enhancement of soil fertility. Cycads are also known to have mycorrhiza fungi, the vesicular-arbuscula type, and may have significant benefits to soil fertility in the ecosystem (Muthukumar and Udaiyan 2002).

Cycas ophiolitica occurs in areas of serpentinite vegetation in the northern end of its range. Serpentinite vegetation is known to include other endemic rare species such as *Bursaria reevsii, Stackhousia tryonii* and *Macrozamia serpentina. M. lomandroides* grows with the ‘Vulnerable’ *Eucalyptus hallii.*

Where remnant vegetation (as defined in the VMA) and/or for other species overlap, these areas and species are further protected as outlined. See maps Appendix 2. This information is also available on www.epa.qld.gov.au/ecoaccess/ecomaps.

1.7 Social and economic impacts

It is not anticipated that this plan will have significant economic or social impacts in the short or long-term. Five of the six species have at least one significant population in an area managed for conservation e.g. national park or state forest reserves. Recovery actions include negotiating voluntary conservation agreements where appropriate. On-going consultation with land holders will seek to minimise any adverse social or economic impacts.

2. Biological information

2.1 Species and community descriptions

2.1.1 Cycas species

Cycas species are distinguished from *Macrozamia* species by the leaflets, which have a prominent midvein, but lack lateral veins, and by the presence of short spikes along the length of the rachis. Cycas species lack the characteristic pale callous spots at the leaflet base that distinguishes the genus *Macrozamia*.

Cycas megacarpa

Trunked cycad grows to 5m tall, and the trunk to 8–14cm in diameter. The leaves are 70–110cm long, with 120–170 leaflets. New growth is green, densely hairy with orange-brown hairs that later fall off. The seeds are ovoid, green becoming yellowish, pinkish or purplish as they mature, 38-50mm long, 35–45mm diameter. For full description, keys and illustrations see Hill 1992,1998.

C. megacarpa is endemic to south-east Queensland from Bouldercombe in the north, to near Woolooga in the south, in woodland or open woodland dominated by eucalypts, usually on rocky substrate. See map Appendix 2.

C. megacarpa is distinguished from *C. ophiolitica* by the green new growth and larger seeds. The two species do not overlap in distribution.

The degree of relationship between *C. megacarpa* and *C. ophiolitica* especially at the northern end of the range of forms is not known. Systematic and genetic studies would be required to accurately determine species boundaries.

Cycas ophiolitica

Trunked cycad grows to 2m tall, rarely to 4m, and the trunk to 4–20cm diameter. The leaves are 95–140cm long, with 170–220 leaflets. New growth is bluish-green, densely hairy with grey-white and some pale orange-brown hairs that persist. The seeds are ovoid, green becoming yellowish, with a whitish bloom, 29–33mm long, and 28–32mm diameter. For full description, keys and illustration, see Hill 1992, 1998.

C. ophiolitica occurs from Marlborough in the north, to the Fitzroy River near Rockhampton in the south, in woodland or open woodland dominated by eucalypts, often on serpentinite substrates. See map Appendix 2.

C. ophiolitica is distinguished from *C. megacarpa* by its blue-green new growth and smaller seeds.

The degree of genetic continuity within and between populations of this species, especially between the bluish northern and greenish southern forms, is not known.

2.1.2 Macrozamia species

Many *Macrozamia* species lack a visible trunk (it is underground) and are distinguished from *Cycas* species by the leaflets that lack a midrib but which have several longitudinal lateral veins, as well as pale callous spots at the leaflet base. The four species described here all belong to section *Parazamia,* which are all small cycads with 1–15 leaves in the crown and thick, raised veins on the *lower surface of the leaflets and twisted leaf rachis.*

Macrozamia cranei

The mature leaves number 1–5 in the crown, are erect, and 70–90cm long. The leaflets are 7–30cm long, 2–7mm across. The upper surface is dark green, shiny and hairless, the lower surface is whitish and waxy, the leaflet tips yellow and often drooping. The male cones are cylindrical, 8-22cm long, 2.5–5cm wide. The female cones are 8–13cm long and 4.5–5.5cm wide, erect and green. The seeds are oval shaped, 2–2.5cm long, and orange to red when ripe. For a full description and illustration, see Jones and Forster 1994, Hill 1998.

M. cranei is restricted to a small area of rugged terrain near Texas in the Darling Downs district of south-east Queensland, in *Callitris-Eucalyptus* woodland on shallow soils or Semi-Evergreen Vine Thickets.

It is similar to *M.occidua,* which occurs nearby in the vicinity of Sundown National Park. *M.occidua* has shorter broader leaflets, 6–20mm long and 4–10mm wide. *M. cranei* has narrower, glossier leaflets.

M. cranei, M.occidua and *M. machinii* are part of a species complex in the area. Systematic and genetic studies would be needed to determine accurate species boundaries.

Macrozamia lomandroides

The mature leaves number 2–6 in the crown, are erect, and are 30–80cm long. The leaflets are 2.3-4mm wide, dull green on the upper surface and paler below. The apex has 1–6 sharp teeth on one side and 1–2 teeth on the other side. The male cones are cylindrical, 12–15cm long, 4–5cm wide, and become curved with age. The female cones are oval in shape, 12–18cm long and 7–9cm wide. The seeds are 2.2–2.6cm long and 1.8–2.2cm wide and orange to red when ripe. For more detailed descriptions, illustrations and keys see Jones 1991, Hill 1998.

M. lomandroides occurs south of Bundaberg between the Elliot and Isis Rivers, in banksia or eucalypt dominated woodlands (wallum) or open forest, on coastal plains or hill slopes in sandy and loamy soil. See map Appendix 2.

M. lomandroides is distinguished from all other Queensland species by several small sharp teeth at the apex of the leaflets (similar to the leaves of some *Lomandra* species).

The degree of genetic continuity within and between populations of this species is not known.

Macrozamia pauli-guilielmi

Mature leaves number 2–8 in the crown, are erect, and 50–100cm long. The leaflets are thick textured, 2.3–4mm wide, and dull green on both surfaces. Male cones are 8–14cm long, 3.5–5cm wide, and straight. Female cones are oval shaped, 9–14cm long and 4–6.5cm wide. Seeds are 17-25mm long and 13–20mm wide, and red when ripe. For full description and key, see Hill 1998.

M. pauli-guilielmi is only found in the Wide Bay district between the Isis River in the north, and Wolvi in the south, occurring in coastal lowland open forest or woodland dominated by banksias and eucalypts (wallum) on sandy and loamy soils. See map Appendix 2.

M. pauli-guilielmi, along with the closely related *M. parcifolia,* is distinguished from all other species in the area by the narrow leaflets (1–4mm wide). *M. parcifolia* has more thin-textured darker green leaflets, a wispy untidy appearance and is restricted to basalt-derived loams on ridges.

M. pauli-guilielmi, M. parcifolia and *M. lomandroides* are part of a species complex. Systematic and genetic studies would be needed to determine accurate species boundaries.

Macrozamia platyrhachis

Mature leaves number 2–8 in the crown, are erect, or reclining with the ends ascending, 45-80cm long. The leaf stalk is 9–13mm wide at the top (at first leaflet). Leaflets are usually 10–20mm wide, mid-green and glossy above, paler green beneath. Male cones are quadrangular in cross section, 10–23cm long, 2.7–4.5cm diameter, and straight or slightly curved with age. Female cones are oval-shaped, 12–17cm long, 8–9cm wide, and mid-green. Seeds are 22–28mm long, 18–25mm wide, and red when ripe. For more detailed description and key see Hill 1998.

M. platyrhachis is restricted to the Blackdown Tableland / Planet Downs area of the Dawson Range in central Queensland, in eucalypt woodland or open forest on sandy soil. See map Appendix 2.

M. platyrhachis is distinguished from other species in the area by the broad leaflets (10–20mm wide), and short broad leaf stalks. The degree of genetic continuity within and between populations of this species is not known.

2.2 Life history and ecology

2.2.1 Response to fire

Most cycads are both fire-dependant for successful reproduction and fire-sensitive for mortality of seeds and seedlings. Understanding the effects of fire frequency, intensity and time of burn on the reproductive capacity of each species and its pollinators is essential for long-term management of populations.

Cycas species

C. megacarpa and *C. ophiolitica* occur in habitats that are subjected to periodic fires of varying intensities. As with other cycads, adult plants are resistant to most fires, although the foliage may be destroyed and some scarring of the stems may occur. Fires probably kill any small seedlings or seed that is either on the plant or locally dispersed.

Macrozamia species

Adult *Macrozamia* plants have an underground stem and are able to resprout after loss of above-ground foliage from fire. Seedlings and unburied seeds are usually killed by fire. Synchronous cone formation (masting) often follows fire, with a small percentage of individuals coning in the first year following the fire, and a high percentage of individuals coning in the second year. This pattern has been found in many species of *Macrozamia.*

The habitat of *M. cranei* is rarely burnt due to low fuel loads that are a result of the skeletal soils, grazing by sheep and goats, and frequent droughts.

M. lomandroides occurs in habitats that are subject to regular controlled burns in the national park and state forest reserves. Uncontrolled fires also impact on the species.

The habitats of *M. platyrhachis* and *M. pauli-guilielmi* are extremely fire-prone and are burnt irregularly on two year, or longer, intervals. The fires are often intense, uncontrolled and may be started by lightning or burning off on adjacent pastoral land, state forests or national parks.

2.2.2 Pollination ecology

Effective pollination is critical for long-term survival in the wild. Very little information is known about the pollinators, their roles and conservation needs. Detailed research on pollination ecology of these species is a high priority.

Cycas species

There is no published information on the pollination ecology of *C. megacarpa* or *C. ophiolitica*, although beetles from the genera *Hapalips* and *Ulomoides* have been recorded from the male cones of *C. megacarpa* (Forster *et al.* 1994). Preliminary work by J.Hall indicates that *C. ophiolitica* is also beetle pollinated (Hall pers. comm. 2005)

Macrozamia species

The pollinator of *M. lomandroides* is a species of *Tranes* weevil (Forster *et al.* 1994). The pollinators of *M. cranei* and *M. pauli-guilielmi* are still unknown, but are likely to also be species of *Tranes* weevil.

It is likely that the pollination ecology involves a mutualism between the pollinating insect and the cycad (Terry *et al.* 2004, 2005). Female cones of these three species are receptive to pollinators in November and the male cones release volatile fragrances that attract pollinators.

For *M. cranei*, there was little evidence of recent coning or successful, recent seed formation in the four populations that were surveyed in November 2003, perhaps indicating failure of cycad-insect pollination relationships.

For *M. lomandroides*, there was evidence of recent coning and recent successful seed formation in several populations that were surveyed in November 2003, indicating that cycad-insect pollination relationships are operating successfully in this species.

M. platyrhachis is unusual in being pollinated by *Cycadothrips* thrips in a mutualistic relationship, a trait shared with *M. fearnsidei.* All other taxa in the section appear to be *Tranes* beetle pollinated (Forster *et al.* 1994; Terry *et al.* 2004, 2005).

2.2.3 Seed development

Cycas species

Seed of both species becomes ripe from March onwards when they drop from the megasporophylls. The seeds are not ready to germinate for at least nine months due to the delayed fertilisation unique to cycads (Norstog and Nicholls 1997).

Macrozamia species

Seed of all four species becomes ripe in March to April. As with all *Macrozamia* species, the fresh seed is not ready to germinate for another 12 months, due to the delayed fertilisation process unique to cycads (Norstog and Nicholls 1997).

2.2.4 Dispersal ecology and recruitment

Limited dispersal of ripe seeds from cycad species may occur via mammals such as possums, rodents or fruit bats (Burbidge and Whelan 1982; Ballardie and Whelan 1986; Cox and Sacks 2002; Monson *et al.* 2003). Although cycad seeds are brightly coloured, they are highly toxic (Banack and Cox 2003). Few vertebrate dispersers of seed or fruit of a similar size to cycad seed now exist in Australia (Dennis 2002), although the musky rat-kangaroo, *Hypsiprymnodon moschatus*, has been observed dispersing seed of *Lepidozamia hopei* (Drew and Spencer 1998).

For these six species, as for many cycads, populations can be locally dense in terms of individuals, but the boundaries of populations can be quite sharp, with no apparent change in habitat, indicating dispersal-limited distribution (Primack and Miao 1992). Snow (2003) demonstrated that the distribution of plants within a population of *M. lucida* was strongly clumped and that the bulk of seed dispersal was extremely local and near to the parent plants. A similar situation appears to exist for all six species considered here.

See Appendix 1 for details of population statistics.

Cycas species

There is no information available on dispersal or recruitment for *C. megacarpa* or *C. ophiolitica*.

Macrozamia species

Only limited, local dispersal occurs in populations of *M. cranei.* Recruitment is observed to be minimal to non-existent. In November 2003, few seedlings of any size were present in the four populations surveyed.

Little apparent dispersal of seed occurs for *M. lomandroides*, with localised seedling recruitment, the seedlings often being clumped in close proximity to the parent plants. Seedlings were recorded in all five populations surveyed in November 2003.

There is no information available on dispersal or recruitment for *M. pauli-guilielmi*. Seedling recruitment is localised, the seedlings often being clumped in close proximity to the parent plants.

There is limited information on the dispersal or recruitment levels of *M. platyrhachis*. In November 2003, only four seedlings were seen in one out of 11 populations surveyed. It is assumed that any seedlings existing prior to 2001 have been killed by severe wildfires in 2002 and 2003. While there were thousands of old seeds lying in heaps near the adult plants, these had all been killed by the fires.

2.2.5 Population structure

Population structure in terms of size/age classes is a reliable indicator of levels of attrition and natural recruitment in a population (Schwartz 2003). Where there is a progression of size classes (see Forster 2005), with fewer, large (old) individuals, down to many juveniles, the population can be considered to be adequately replacing itself. However, it is not possible to ascertain a size class structure for the species of *Macrozamia* with subterranean stems. Leaves are highly variable in these species and are influenced by variables of fire history, predation, periodic dormancy and the depth of the underground stem.

Estimates of minimum viable population size give an indication on whether or not a population can survive the effects of inbreeding depression, which leads inevitably to extinction. It is difficult to define what comprises a healthy, viable population of cycads, what might be an ideal minimum viable population size (Soulé 1986; Given 1994) or what number of populations is necessary to maintain a species through time. In the absence of empirical data, 500 individuals for dioecious organisms is often cited (Gilpin and Soulé 1986). See Appendix 1 for population statistics.

Cycas megacarpa

Large and apparently healthy populations of *C. megacarpa* should have a range of individuals from large adults (5-8m in height) through to seedlings. A detailed survey of a small population (number 37) of 181 plants and a large population (number 19) of 530 plants (Appendix 1) found there were 80 percent juveniles (<50cm high) in the larger population (number 19) and only 40 percent juveniles in the smaller population. The size class structure in Population 19 is comparable to those known for *C. armstrongii* (Ornduff 1992; Watkinson and Powell 1997) and *C. media* (Ornduff 1991a) and can be taken as being representative of a long-lived perennial in an undisturbed situation (Schwartz 2003). In the small population surveyed, there is no longer steady replacement recruitment occurring.

Potentially of greater importance is the number of reproductive-age plants, individuals taller than 1m in *C. megacarpa.* In Population 19 there were 14 percent reproductive adults and in Population 37 there were only 11 percent. Based on the two surveyed sites, between 3500 and 4500 plants are a minimum viable population for *C. megacarpa.* Despite the high number of known populations (46) for *C. megacarpa*, only seven of these have more than 3500 plants (Populations 2, 3, 5, 8, 14, 19, 30).

Cycas ophiolitica

There is no detailed information available on population structure for *C. ophiolitica,* although the species does appear to have a similar age class structure of individuals within populations as has been documented for other *Cycas* species (Ornduff 1992; Watkinson and Powell 1997; Ornduff 1991a; Forster 2005). Unlike any of those species, it is rare to encounter individuals of *C.*

ophiolitica that are greater than 4m in height. Of the 16 known populations for *C. ophiolitica*, only five of these (7, 9, 10, 12, 13) have more than 3500 plants, the minimum viable population size for the allied *C. megacarpa* (see above). Most of these large populations of *C. ophiolitica* occur in the southern part of the species range and do not include the bluish forms that are sought after by cycad collectors and that have suffered significant commercial collecting pressure (Hill 1992).

Macrozamia cranei

M. cranei is known from only six populations. These range in size from fewer than 100 adult plants (four populations) to those with at least a thousand individuals (two populations). The four small populations of *M. cranei* show little evidence of insect pollination or seedling recruitment and may already be on the way to extinction.

Macrozamia lomandroides

M. lomandroides is known from 22 populations ranging in size from less than 20 to approximately 8000 individuals, with an area of occupancy from 10sq.m to 2.3ha (Halford 1998). Most of the populations in State Forest 840 and Burrum Coast National Park (13-15, 17-21) could be considered to be part of one or two fragmented metapopulations.

Macrozamia pauli-guilielmi

M. pauli-guilielmi is known from at least 27 populations. These range in size from a single adult plant to at least 3600 individuals. Most of the populations in State Forest 519 could be considered as being part of a single, much fragmented metapopulation. Our lack of knowledge about the biology of this species makes it extremely difficult to estimate a minimum viable population. Most of the populations of *M. pauli-guilielmi* show evidence of insect pollination and seedling recruitment.

Macrozamia platyrhachis

The 12 populations of *M. platyrhachis* have a projected number of individuals between 1000 and 198,000 individuals**.** Adult plants may be densely distributed with a large number of individuals in close proximity to one another, or may consist of solitary individuals. All populations are considered to be viable in the long-term.

2.2.6 Genetics

There is limited information on the population genetics of these six species. Genetic techniques can determine not only the amount of variation that is present, but whether or not individuals within a population originate from that population, or from long-distance dispersal within a greater metapopulation (Cain *et al.* 2000). Several other species of cycads have been shown to have high levels of incipient inbreeding and little genetic flow between disjunct populations (Keppel 2002; Keppel *et al.* 2002; Yang and Meerow 1996; Huang *et al.* 2001).

Limited isoenzyme work has been undertaken on *M. cranei* using samples from a single population (Sharma *et al.* 2004). This work showed that *M. cranei* was most similar to *M.occidua* and *M. machinii,* the two species occurring in adjacent areas, indicating a recent speciation event. There is no published information on the population genetics of *C. megacarpa, C. ophiolitica, M. lomandroides, M. pauli-guilielmi,* or *M. platyrhachis*.

2.2.7 Predation

Both the beetle (*Lilioceris nigripes*) and the lycaenid butterfly (*Theclinesthes onycha*) have been recorded on the foliage of *C. megacarpa* and *C. ophiolitica*. The impact on new foliage can be devastating, particularly when fire synchronises with new leaf emergence for the entire population (J.Hall pers. comm. 2005). These insects may have implications for fire regime management.

Foliage of *M. cranei, M. lomandroides* and *M. pauli-guilielmi* also exhibit evidence of grazing by invertebrates, most likely the same butterfly and beetle as for the *Cycas* species (Forster and Machin 1994). Although neither of these insects has been collected on *Macrozamia,* adults and larva of the lycaenid butterfly were commonly observed in attendance on new and expanding foliage of *M. platyrhachis* in November 2003 (Paul Forster pers. comm. 2005).

2.3 Distribution and habitat

Cycad species are sought after by specialist collectors. Consequently, illegal collection is a major threat to these six species. Therefore, details of exact locations are not given in this plan. This information is available from the Queensland Herbarium, EPA. See Appendix 2 for distribution maps.

2.3.1 Distribution

Cycas megacarpa

C. megacarpa is the most southerly occurring species of the genus and has an estimated minimum area of occupancy of 2527ha in 46 populations, with a projected total number of adult individuals greater than 372,964. It occurs from Bouldercombe in the north, to near Woolooga in the south, with a latitudinal - longitudinal range of about 250 x 150km. There is an historical, more southerly record from near Kilkivan (no longer extant) (cited in Hill 1992). The decline in area of occupancy for *C. megacarpa* in the 20th century is due to land clearing and habitat degradation for agriculture, and selective poisoning of plants on pastoral land. Keys (1886) noted that the species (as *C. media*) was "gradually disappearing from the [Mt Perry] district" and in 2003, this species was rare and only present in very small populations in that area. Whitelock (2002) stated "without doubt, thousands of plants have been destroyed in past years to protect stock animals from eating the leaves. This fact is easily confirmed when one notes the large numbers of plants along the roadside in their habitat, whereas on the other side of the stock fences there are none to be seen".

Cycas ophiolitica

C. ophiolitica is endemic to central Queensland where it is found from Marlborough in the north, to the Fitzroy River near Rockhampton in the south. The known populations are concentrated in two areas, around Marlborough and Rockhampton respectively, with an apparently natural disjunction between them. The species has an estimated area of occupancy of at least 2080ha within a latitudinal – longitudinal range of about 120 x 40km in 16 extant populations, although in reality Populations 9, 10, 12 and 13 are probably one large and diffuse metapopulation centred on Mt Archer. The estimated total number of adult plants is 364,988, however, detailed survey data is not available.

Ma*crozamia cranei*

M. cranei is restricted to a small area of rugged terrain near Texas in the Darling Downs district of south-east Queensland. It is currently known from six populations that all occur on private freehold title. It is probable that Populations 3 and 4 are part of a single much fragmented population.

Macrozamia lomandroides

M. lomandroides has a limited distribution south of Bundaberg between the Elliot and Isis Rivers over a latitudinal – longitudinal range of about 35 x 30km. It is currently known from 22 populations with a minimum area of occupancy of at least 10ha within an overall area of about 1000sq.km (Halford 1998). Twenty populations occur on national park and state forest reserves.

Macrozamia pauli-guilielmi

M. pauli-guilielmi is endemic to south-east Queensland where it is found in the Wide Bay district, from near the Isis River in the north, to near Wolvi in the south. Hill's (1998) statement that it occurs in the Burnett, Darling Downs and Western Moreton districts is incorrect. *M. pauli-guilielmi* occurs over a latitudinal – longitudinal range of about 120 x 40km in at least 27 populations with an estimated area of occupancy of at least 35ha, and with at least 13,131 adult individuals.

Macrozamia platyrhachis

M. platyrhachis has a restricted distribution in the Blackdown Tableland – Planet Downs area of the Dawson Range in central Queensland. There are also historical records from the Ceres Holding southeast of Springsure (1973) and from Spring Creek (1972), but these populations have not yet been relocated. The total area of occupancy is estimated to be less than 400ha**.** It is found in at least 12 populations within a latitudinal – longitudinal range of about 40 x 40km and is both more widespread and more common than previously thought (Whitelock 2002).

2.3.2 Habitat

General habitat descriptions are given here. Major regional ecosystems and remnant vegetation status under the VMA are listed in the tables in Appendix 1. Descriptions of regional ecosystems can be found on www.epa.qld.gov.au/REDD and maps of remnant vegetation can be obtained at www.epa.qld.gov.au/REMAPS

Cycas megacarpa

C. megacarpa occurs within an altitudinal range of 40–680m, in woodland or open woodland dominated by eucalypts, particularly *Corymbia citriodora* and *Eucalyptus crebra,* but also *Corymbia erythrophloia, E. melanophloia* and *Lophostemon confertus.* The substrate is usually rocky and derived from acid volcanics, ironstone or mudstone, rarely from alluvium.

Cycas ophiolitica

C. ophiolitica occurs within an altitudinal range of 80-400m, in woodland or open woodland dominated by eucalypts, often on serpentinite substrates (with *Corymbia dallachiana, C. erythrophloia, C. xanthope, Eucalyptus fibrosa*), but also on mudstone (with *Corymbia dallachiana, C. erythrophloia* and *Eucalyptus crebra*) and on alluvial loams (with *Corymbia intermedia, Eucalyptus drepanophylla* and *E. tereticornis*). The species may co-occur with either *Macrozamia serpentina* (serpentinites) or *M. miquelii* (mudstone or alluvial loams). Other rare and endemic species are associated with the serpentinite communities in which *C. ophiolitica* occurs.

Macrozamia cranei

Plants of *M. cranei* occur at altitudes of 400–600m on steep ridges (‘traprock’) in shallow, skeletal soil or on alluvium along ephemeral watercourses. Both soil types are associated with limestone outcrops. The vegetation is woodland dominated by *Callitris glaucophylla* and *Eucalyptus* species (*E. caleyi, E. dealbata, E. melanophloia, E. terrica*), usually with a dense understorey (commonly *Acacia semilunata, Beyeria viscosa, Dodonaea viscosa, Leptospermum brevipes, Olearia elliptica*) or fragmented semi-evergreen vine thicket (dominants *Alectryon connatus, Backhousia angustifolia, Elaeodendron australe, Geijera parviflora, Notelaea microcarpa*).

Macrozamia lomandroides

M. lomandroides occurs in banksia or eucalypt dominated woodland (wallum) or open forest on the coastal plain on flats and gently inclined hill slopes at elevations of 10–50m above sea level. The soils are well-drained, dark greyish yellow, greyish yellow to dark reddish brown, clayey sands to sandy clay loams with a pH of 4.8–5.6. The geology is mostly deeply weathered sedimentary rock with some quaternary alluvia. The common canopy species are *Corymbia trachyphloia, C. intermedia, Eucalyptus hallii* and *E. latisinensis.* Other tree species include *Eucalyptus racemosa, Angophora leiocarpa* and *Syncarpia glomulifera.*

Macrozamia pauli-guilielmi

M. pauli-guilielmi occurs in lowland (5–230m altitude) open forest or woodland (wallum) dominated by banksias or eucalypts, or in shrub land or heath land, generally on stabilised sand dunes. It has rarely been recorded from clay loams (usually overlying sandstone substrates) or sedimentary substrates. Dominant canopy species associations that are recorded from the habitats of this cycad include *Angophora leiocarpa* with *Leptospermum* species; *Eucalyptus racemosa; Angophora leiocarpa, Corymbia intermedia*, *Eucalyptus pilularis, E. racemosa; Corymbia intermedia,* *Eucalyptus microcorys, Lophostemon confertus*, various rainforest elements; *Angophora leiocarpa, Corymbia citriodora* subsp. *variegata,* and *Eucalyptus fibrosa* subsp. *fibrosa*.

Macrozamia platyrhachis

Populations of *M. platyrhachis* are found in eucalypt woodland or open forest. Dominants include *Angophora leiocarpa, Corymbia bunites, C. citriodora* subsp. *citriodora, C. hendersonii, C. watsoniana, Eucalyptus baileyana, E. cloeziana, E. crebra, E. melanoleuca, E. suffulgens, Lophostemon suaveolens* and *Lysicarpus angustifolius* on deep sandy soils derived from sandstone at altitudes between 300 and 780m. The mid- and under-stories of the vegetation may be quite dense, but this is variable depending on fire history.

2.4 Habitat critical to survival

Habitat where the remaining viable populations occur is considered to be critical to survival. For these six species, estimates of viability are based on population size and evidence of replacement by age structure where these are known – see discussion above under "Population Structure".

Appendix 1 lists all populations reliably known to exist at the present time, including those estimated to be viable in the long-term. These are discussed below under "Important Populations".

Potential habitats where re-introduction might be carried out are not known, but are likely to be in close proximity of existing populations where the habitat is similar, for example, in the same or similar regional ecosystem, with similar soil and understorey elements. Identification of these areas, followed by artificial introduction or translocation from small nearby populations under immediate threat, may be a critical step in the recovery of these species in the context of providing further subpopulations in the metapopulation mosaic. It is also important to ensure that suitable pollinators exist in the new area, and to consider re-introduction of the insect pollinators where these have been lost.

All species are considered to be easy to propagate (Whitelock 2002; S.Walkley, pers. comm.). Re-colonisation into adjacent areas is likely to be very slow due to the very limited seed dispersal (see discussion under 2.2.4 "Dispersal, Ecology and Recruitment").

Translocation of cycads from threatened habitats has been practised for some time in South Africa (Boyd 1995) and has been successfully carried out for *C. megacarpa* (Forster 2005), *C. ophiolitica* (Rowe and Rowe 1995) and *M. lomandroides* (Baillie1999). General guidelines for translocation are given by Vallee *et al.* (2004).

2.5 Important populations

Important populations are those considered to be viable in the long-term (see discussion under 2.2.5 Population Structure). While very small populations may not be viable in the long-term, they may represent significant genetic variation across the range of the species. Therefore, all populations should be considered to be worth preserving or, where appropriate, translocating into suitable habitat.

Detailed information of the locations of these populations is not provided here, but is available from the Queensland Herbarium EPA.

Cycas megacarpa

Seven populations are currently considered to be viable in the long-term. Three populations are conserved in state forests: Population 8 (Biloela), Population 19 (Kroombit) and Population 30 (Wonbah). These three populations are particularly significant for the conservation of the species due to their large number of plants and natural disposition of size classes. Population 2 occurs in a recreational reserve at Bouldercombe. Populations 3,5 and 14 occur on freehold land on remnant 'Not of concern' vegetation at Mt Morgan, Dee Range and Biloela respectively. See Appendix 1, Table A for population statistics.

Cycas ophiolitica

Five populations are currently considered to be viable in the long-term. Of these, 9, 10, 12 and 13 are likely to be one large diffuse metapopulation centred on Mt Archer. Populations 10 and 12 are already conserved in national park estate, while Populations 7, 9 and 13 occur on freehold land and adjacent road reserves. Population 7 (Glen Geddes) occurs in remnant vegetation but Population 9 and 13 occur in an area considered to be non-remnant. Note that none of the "bluish" northern populations are known to occur in reserves. Population surveys for this species is particularly poor. Further survey work is critical to establish extent and numbers, especially for populations occurring in non-remnant vegetation and at risk of clearing for development. See Appendix 1, Table B for population statistics.

Macrozamia cranei

Two populations of *M. cranei* are currently considered to be viable in the long-term: Populations 3 and 4 near Texas. However, it is probable that these two populations are part of a single, fragmented metapopulation. In the decade since initial discovery, while there has not been an obvious loss of adult plants, little or no recruitment of seedlings has occurred. Both occur on freehold land in remnant 'Of concern' vegetation. See Appendix 1, Table C for population statistics.

Macrozamia lomandroides

Fourteen populations are currently considered to be potentially viable in the long-term, although detailed survey information is lacking for Populations 17, 18, 19, 20, 21, 22. All of these populations are located in State Forest 840 near Bundaberg (Populations 3,4,5,7,8,9,10,11, 12, 22) or in Burrum Coast National Park (17, 18, 19, 20, 21). These 14 populations are probably parts of a large metapopulation, or perhaps two, now significantly fragmented. Population 8 occurs in non-remnant vegetation in state forest, and Populations 11 and 12 occur in pine plantations. The remainder occur in remnant vegetation. See Appendix 1, Table D for population statistics.

Macrozamia pauli-guilielmi

Only four populations are currently considered to be viable in the long-term. Populations 8, 14 and 17 occurring in Tuan State Forest are considered to be part of a single, significantly fragmented metapopulation. Population 8 occurs in an area of pine plantations, while Populations 14, 17, and 19 (Toolara) occur in remnant vegetation. Most of the remaining populations of *M. pauli-guilielmi* show evidence of insect pollination and seedling recruitment, an indication of viability at least in the short term. See Appendix 1, Table E for population statistics.

Macrozamia platyrhachis

All of the 12 known populations of *M. platyrhachis* are currently considered to be viable in the long-term. Populations 7,8, 9,10 and 11 occur in Blackdown Tableland National Park or state forest area (Population 11). The others occur on grazing homestead perpetual lease in the vicinity of Duaringa. It is not known whether these populations represent fragments of one or possibly two much larger metapopulations. All occur in remnant 'Not of concern' vegetation. See Appendix 1, Table F for population statistics.

3. Threats

3.1. Biology and ecology relevant to threats

Cycads as a group are considered to be in global decline. Norstog and Nicholls (1997) stated that almost all human interaction…[with cycads]…has been deleterious" and that "the most realistic conservation efforts should involve attempts to provide well-protected cycad habitat reserves".

Most species of cycads occur in unconnected local populations persisting in a mosaic of habitat (regional ensemble model of Freckleton and Watkinson 2002). There is little evidence of gene flow between populations and incipient inbreeding is common (Sharma *et al.* 1998, 1999, 2004). Seed death is high due to predation and fire. Shallow burial, rather than no burial, is more likely to result in successful germination (Snow 2003). Dispersal of seeds is localised (less than 100m from the parent), rather than long-distance (in the sense of Cain *et al.* 2000). Many seedlings are destroyed by fire, competition or predation. Cycads are also generally absent from areas of disturbance where quick establishment and competitive growth is an advantage (Bond 1989). Low levels of dispersal and recruitment, slow seedling growth and specialist pollination requirements mean that cycads are generally restricted to areas of periodic dryness and low fertility.

The minimum viable population size for any cycad species is not known at this time. Healthy viable populations generally are considered to have large numbers of individuals (more than 500 adults), a diversity of individual size classes, and obvious seedling recruitment (see discussion under 2.2.5 Population Structure).

Individual cycads are long-lived. Life spans ranging from decades to several centuries have been given for *Macrozamia* species (Benson and McDougall 1993; Pate 1993). They are resilient to fire and some forms of mechanical disturbance. Many populations of Queensland cycads are very small (less than 100 adults) with little evidence of recruitment. These persistent individuals existing in small numbers are therefore thought to be the last remnants of once healthy populations.

3.2 Identification of threats

3.2.1 Destruction due to land clearing

Broad scale land clearing and habitat degradation over the last 200 years have played a major role in decreasing the area of occupancy of Queensland cycads. Based on historical records (Queensland Herbarium specimen label data 2005), many small extant cycad populations (1-20 individuals), particularly *C. megacarpa* and *C. ophiolitica,* are thought to have been previously much more extensive.

Today, many cycad populations are preserved in national park estate, state forests or reserves, and as part of remnant vegetation preserved under the VMA and subordinate legislation. Broad scale clearing of remnant vegetation was phased out by December 2006. Populations most at risk from land clearing are therefore those present in land that has already been cleared, or is considered to be non-remnant. Populations in areas of remnant vegetation may still be at risk from permitted small-scale clearing or exceptional circumstance such as for a dam or highway construction, and therefore may be salvaged (as defined in the *Nature Conservation (Protected Plants) Conservation Plan 2000*). Under the Integrated Planning Act, areas zoned as urban or future urban are also exempt from needing a clearing permit under the VMA unless the area is mapped as 'Category 1' under the VMA (essentially 'Endangered' regional ecosystems).

Destruction of individuals and habitat from land clearing activities is still considered as the greatest risk to these species. Populations for which the survey and mapping information is minimal or absent may not be protected under existing planning and permitting processes.

Specific threats from land clearing activities include:

- ***Cycas ophiolitica*****:** proposed road corridors in the vicinity of Rockhampton, Glen Geddes and Marlborough, and throughout Livingstone Shire; housing development in the vicinity of Rockhampton City; existing mining and quarrying activities.
- ***Macrozamia lomandroides*****:** proposed road and rail corridors, as well as agricultural clearing in the vicinity of Elliot River State Forest 840 and adjacent crown land; housing development proposals in the vicinity of Isis River-Buxton area.
- ***Macrozamia pauli-guilielmi*****:** proposed road corridors in the Poona, Tuan State Forest 915 and Cooloola Way road systems; quarrying in the vicinity of Tuan SF; proposed housing development in the vicinity of Tin Can Bay, Poona, Maryborough, Buxton and Isis River areas.
- ***Macrozamia platyrhachis***: proposed road corridors, and quarrying in the vicinity of Blackdown Tableland National Park, State Forest 28.

3.2.2 Legal harvesting and commercial salvage

All six species have been affected by targeted eradication, harvesting or salvage in the past (Forster 2004). Cycads are poisonous to many animals including insects, birds, fish and mammals, if consumed. In Australia, consumption of the foliage by domestic stock can result in their death or serious injury (Seawright *et al.* 1993). As recently as the early 1990s, the selective destruction of cycads was carried out by the application of power kerosene, arsenic or herbicides to the growing points (Kelly 1967; Vitelli 1993). Populations where these practices have been undertaken, for example for *Cycas megacarpa,* are usually notable for the absence of large mature plants. This selective eradication is illegal under the Regulations and Schedules of the NCA.

Wild harvesting of whole plants for commercial purpose was phased out in December 2005, except for permitted salvage and bio-prospecting (schedule 3 of the *Nature Conservation (Protected Plants) Conservation Plan 2000*). Under this plan permitted salvage can only occur where the taking of a plant or plant part for a commercial purpose is not the reason for the clearing or disturbance. However, for approved clearing or disturbance under another Act, such as for construction of a dam or road, contingent or operational salvage may be permitted.

3.2.3 Illegal harvesting

Whole plants

Cycads continue to be a desirable and collectable commodity worldwide, for use in horticultural landscaping, botanic gardens and private collections. While all the Queensland species are of interest to collectors, thirty have been targeted more so than the remainder (Forster 2004). These include five of the six species considered here (all except *M. cranei*). The demand for both plants and seeds continues to be driven by their availability in overseas nurseries (particularly in the U.S.A.) where prices for adult plants range from USD $200-$1700. Because cycads grow slowly and do not mature for many years, the temptation to illegally remove large mature plants from the field is ever present and the illegal trade in cycads remains a worldwide problem.

Removal of even small numbers of adult plants from a cycad population is thought to have an immediate and long-term deleterious effect on population viability (Raimondo and Donaldson 2003). Species with bluish foliage such as *C. ophiolitica* (northern populations) have a higher horticultural desirability, and are perhaps most at risk (Forster 1999), although there are those collectors that wish to acquire at least one of every known species.

Under the NCA and subsequent provisions and regulations it is illegal to harvest whole plants of any threatened species in Queensland without a permit issued by the EPA.

Seed

Seed harvesting for end use in horticulture has been carried out on a commercial basis for a number of Queensland cycads in the past, including the species considered here (P. Forster pers. comm. 2005). There are no reliable data on the amount of seed taken or the effect of seed harvesting on populations and whether it is sustainable in the long-term. Raimondo and Donaldson (2003) considered that the removal of seeds from wild populations of *Encephalartos* cycads did not have a deleterious effect, at least in the short term, whereas removal of adult plants had a serious, long-term negative effect.

Under the NCA and subsequent provisions and regulations it is illegal to harvest seed of any threatened species in Queensland without a permit issued by the EPA.

3.2.4 Loss of genetic variation and insect pollinators

Genetic variation usually decreases as the numbers of individuals of a species decline (Levin 2000). As yet our knowledge of genetic variation in cycads (not just for Queensland) is minimal. This knowledge is essential for informed and effective conservation of threatened plant species, particularly where gene flow between populations is thought to be minimal, as is the case for these species. Some species of Queensland cycads are extremely local in their area of occupancy with few populations and a relatively small number of individuals (such as *Macrozamia cranei*) whereas others are wide ranging with many disjunct populations of various sizes (such as *C. megacarpa*). Field examination of Queensland cycad populations has indicated that all six species considered here may be suffering from loss of genetic variation (Forster 2004).

There is increasing awareness of the dependence of these plants on various insects for pollination, and conversely dependence of various insects on the cycads to enable completion of their life cycles (Donaldson 1995). Disruption of these mutualistic relationships may ultimately result in extinction of the plants and/or the insects (Bond 1994).

A diverse range of insects is associated with Queensland cycads although much remains to be discovered about their roles (see discussion under 2.2.2 Pollination ecology). In the genus *Macrozamia*, there appear to be three main systems of insect-mediated pollination; those species that are pollinated by *Tranes* beetles, those pollinated by *Cycadothrips* thrips, and those pollinated by a combination of the two (Forster *et al.* 1994; Mound *et al.* 1998; Mound and Terry 2001; Terry 2001; Terry *et al.* 2004; Terry *et al.* 2005). In some isolated populations of cycads (such as *M. cranei*) where little obvious recruitment is occurring, there appears to be no resident populations of pollinators.

Knowledge of the pollination system for *Cycas* species is scant, although it is likely that insects, particularly Coleoptera, are involved (J. Hall, pers. comm. 2004). By contrast, the Fijian species *C. seemanii* was thought to be wind-pollinated (Keppel 2001) although this remains to be proven experimentally.

Conserving the adult plants of any cycad population and the associated pollinators at the same time is vital to the survival of the species. Pollination cycles and pollinator activity are also significant when considering management issues such as fire and timber harvesting at times when the plants are initiating cones or receptive to pollination.

3.2.5 Land management practices

Fire

There are positive and negative effects of fire on cycad survival and life histories. Adult plants of *Cycas* and *Macrozamia* species are quite fire-tolerant, generally resprouting after fires where the foliage has been entirely killed. Cycads with trunks have a fire-resistant layer of old leaf bases that insulate the live tissue, and are resistant to all but the most intense fires, although some species from more mesic environments can be severely affected (Keppel 2002).

There is good observational evidence that irregular fires are required by many species of *Macrozamia* to promote synchronous coning events (Baird 1977; Pate and Dixon 1982; Forster, unpubl.) although this may be affected by drought (Borsboom pers. com. 2005). It is thought that fire may enhance nutrient supplies to cycads, by stimulating the growth of new coralloid roots and their nitrogen-fixing cyanobacteria (Halliday and Pate 1976; Grove *et al.* 1980).

Cycads do not have a long-lived soil seed bank. Viability of most species is from six months to three years. Most fires, but especially those of high intensity, will result in the destruction of any existing seed banks. Fires occurring at the times when seeds are ripe, and especially during synchronous coning or "masting" events, will result in high losses of potential seed.

Fire usually kills small cycad seedlings (Forster, unpubl. obs.) and has been promoted as a pastoral management tool for this purpose in the Northern Territory (Wesley-Smith 1973). However, observations after recent burns in the Mount Archer National Park indicate that seedlings do survive low intensity burns (J.Hall, unpublished data, 2005). Cumulative seedling loss because of fire regimes that are too frequent or too hot will ultimately result in a decline of the number of individuals within a population (Keith 1996).

The effect of fire on some of the insect-plant interactions is unknown, but fire should be avoided at least when the plants are coning and receptive to pollinators. This usually occurs between October and March (Halford 1995).

Cycad populations may appear static in the short-term environment as a result of the long persistence of individuals and poor long-distance dispersal. It is probably unrealistic to manage cycad populations using the general method of mosaic patches of burnt and unburnt vegetation of differing ages (Keith 1996). Cycad populations require individual fire management to maximise recruitment, although this may be difficult to implement.

Timber harvesting

Many Queensland cycads occur in state forests, including pine plantations, where sporadic timber harvesting is carried out using heavy machinery.

This physical damage to cycad stems is similar to that produced from storms, although it has the added stress of soil compaction caused by vehicle tracks. Cycads have demonstrated resilience to this type of disturbance, including the ability to resprout from broken stems (Borsboom and Rudd 2002; Wang and Borsboom 2003). There is often little impact on species with subterranean stems (*Macrozamia*), but for trunked species (*Cycas*), damage may be severe with stems of considerable age broken off. Many plants of *C. megacarpa* that are present in state forests or along roads show evidence of stem damage (either the main stem broken and with new adventitious shoots, or resprouting from the base). Whether the damage was caused by storms or timber-harvesting is unknown. This ability to resprout is an advantage both in rehabilitation of damaged populations or in replanting of salvaged individuals (Rowe and Rowe 1995).

In recent years, forests used for timber harvesting have been managed using criteria that reduce damage from soil compaction, physical destruction of individuals and location of snig tracks, fire trails and log dumps (Halford 1995, Borsboom and Rudd 2002, Wang and Boorsboom 2003). The long-term impacts are not fully understood but appear to be minimal if physical damage to the trunk (above or below ground) is avoided (Forster 2004, Wang and Boorsboom 2003, Wang pers. com. 2005). The impact on insect pollinators is not known.

Populations currently affected by timber harvesting include *M. pauli-guilielmi* in the vicinity of Tuan State Forest 915, *M. lomandroides* in the vicinity of Elliot River State Forest 840. Populations 11 and 12 of *M. lomandroides* and Population 8 of *M. pauli-guilelmi* have existed within exotic pine plantations for approximately 40 years (Jian Wang pers. comm. 2005). The history of management of these plantations over this period of time, including fire and other disturbances, may have useful indications for the development of management guidelines (see Action 4.5).

Drought

The effect of drought (or conversely flood) on cycads is unknown. During prolonged drought in southern Queensland between 2000 and 2003, many small cycad seedlings were observed to disappear from populations; however, it has not been identified whether this was due to death from water deficit, predation or other factors. There is circumstantial evidence that drought may affect coning cycles in some species, even after fire (Borsboom pers. comm. 2005).

3.3 Areas under threat

Areas where significant populations are most at risk are those in and around the major developing townships along the Queensland coast particularly in areas of non-remnant vegetation and those not protected in other ways. Areas under threat are also those where activities such as mining, quarrying, road building or timber harvesting activities are planned in or near known cycad populations.

3.4 Populations under threat

Populations occurring only on areas of non-remnant vegetation not protected in other ways, i.e. those occurring on freehold, vacant crown land, road reserve or state forest pine plantations, are most immediately under threat from land clearing and habitat destruction (see Appendix 1 for population details). These include:

- *C. megacarpa*: Populations 6,18,38 (Mt Larcom, Kroombit and Mt Perry) and Populations 23, 32, 40 (Blackman's Gap and Mt Perry).
- *C. ophiolitica*: Populations 8, 9 and 13 (Bondoola, Mt Arden Hills and Mt Sleipner).
- *M. cranei*: Population 6 (near Texas).
- *M. lomandroides*: Populations 1 (Isis River) and Populations 11,12 (pine plantations near Bundaberg).
- *M. pauli-guilielmi*: Populations 8,15,21 (pine plantations at Poona, Tuan and Tooloora).

See also discussion under 3.2.1 Destruction due to land clearing.

Note that detailed population surveys are required for *Cycas ophiolitica* and *Macrozamia lomandroides* to identify further populations under threat.

Threats summary

Many cycad species are sought after by collectors. As a consequence, illegal collection is a major threat to these six species. Details of exact location and co-ordinates are not given in this plan to protect the species. This information is accessible from the Queensland Herbarium. For location voucher information, population size and land tenure, see Appendix 1. For distribution maps, see Appendix 2.

Type of threat	Populations affected (see Appendix 1)	Current actions to reduce threats	Future actions to reduce threats
3.2.1 Destruction of habitat and individuals due to land clearing • development for housing • road building and maintenance activities • mining, quarrying • permitted land clearing	Mainly populations occurring in non-remnant vegetation, and not protected in other ways	Many populations discovered, surveyed and documented. Broad-scale clearing of remnant vegetation to end December 2006. Mapped as buffered points (known collections) in remnant vegetation. Clearing prohibited in these areas. A permit must be obtained to clear remnant vegetation (under 2ha).	Negotiate conservation agreements to secure conservation of significant known populations of cycads on freehold and leasehold property. Search for the existence of further populations of all species. Detailed survey of populations currently considered threatened, and maps updated to reflect actual extent. Major landholders and custodians to be contacted and made aware of current regulations. Relevant legislation and permitting processes to be strengthened to prevent clearing of habitat.
3.2.2 Legal harvesting and commercial salvage	All populations	Permitted commercial harvesting of whole plants to cease December 2005 except under permitted salvage or bio-prospecting, where the reason for the salvage is not for commercial purposes. Harvesting of plant parts only under permit from the EPA.	Relevant legislation and permitting processes to be strengthened to prevent clearing of habitat. Harvesting of plant parts and seed to cease except for the purposes of this recovery plan.

3.2.3 Illegal destruction and harvesting	All populations	Information has been provided to the public and specifically to horticultural societies through, talks, displays and publications. These six 'Endangered' plant species may only be sold under permit from the EPA.	Major landholders and custodians to be contacted and made aware of regulations pertaining to the destruction and harvesting of plants and plant parts. Provide assistance with fencing of small isolated populations. Further education of general public, horticultural societies and nursery industry. Work with the industry to explore other means of addressing the horticulture and collector demand.
3.2.4 Loss of genetic variation and insect pollinators	All populations, especially small or fragmented populations < 500 individuals per area	Research on similar species overseas suggests low diversity within populations and high differentiation between populations. Some preliminary work on the identification of pollinators has been carried out for *M. lomandroides* and *M. platyrhachis.*	Undertake research to determine the genetic variation and robustness of population mosaics. Undertake research to determine pollinators and their life cycles particularly for *C. megacarpa, C. ophiolitica, M. cranei, and M. pauli-guilielmi.* Undertake research to determine dispersal mechanisms and vectors. Establish long-term monitoring plots including population statistics, pollinator populations and response to fire. Translocation of individual plants under immediate threat to suitable nearby habitat. Artificial augmentation for critical populations.
3.2.5 Land management practices • fire • timber harvesting	All populations	Observations on cone, seed and seedling loss due to fire have been made for some species. Some research and monitoring of *C. megacarpa* has been carried out. Timber harvesting guidelines have been written for *C. megacarpa* and are applicable to the other species.	Provision of interim management guidelines to be provided to landholders and custodians. Undertake research to determine optimum fire regimes. Establish long-term monitoring plots including population statistics, pollinator populations and response to fire. Long-term monitoring of populations affected by timber harvesting.

4. Recovery actions, objectives and performance criteria

Overall objectives

- To prevent further loss of individuals, populations, pollinator species and habitat critical for the species survival.
- To recover existing populations to normal reproductive capacity to ensure viability in the long-term, prevent extinction, maintain genetic viability, and improve conservation status.

4.1 Protect existing populations

Performance criteria: *All significant populations are known, surveyed, and protected in reserves, under provisions of the VMA, and/or are under specific conservation agreements between private landholders and EPA/QPWS.*

4.1.1 Negotiate conservation agreements to secure significant known populations of cycads on freehold and leasehold property

It is desirable that the populations of cycads are secured with perpetual arrangements that ensure continued appropriate management in the long-term. For cycads, a Conservation Agreement between the landholders and the EPA/QPWS is an appropriate model for significant populations not currently existing in national park, state forest or conservation reserves. These voluntary agreements are negotiated with landholders to create a nature refuge over part or all of a property and are attached to the land title. They allow for production and land management activities compatible with conservation of the values of the land such as sustainable grazing but generally prohibit further destruction or removal of individuals. QPWS Extension Officers undertake property assessments, negotiate the conservation agreement and provide follow-up advice and assistance with management of the nature refuge.

Nature refuge landholders with may be eligible for Queensland Government incentives. In addition, lessees of State land may be entitled to benefits under proposed changes under the *Land Act (1994)* and may be advantaged in seeking grants for conservation works such as fencing through Natural Resource Management funding bodies. A Conservation Agreement will provide access to volunteer groups to assist with conservation work, for example fencing on grazing properties where cycads are a threat to stock.

Where significant populations occur on private land, some controlled harvesting of cycad seeds and foliage for commercial sale by the landowner may provide a significant incentive for entering into a conservation agreement and providing on-ground management of populations.

Cycas megacarpa: The large population (or parts thereof) at Mt Morgan (Population 3) is currently the most significant population on freehold land, but Populations 5 and 14 are also significant populations occurring on freehold land in the Dee Range and Callide Range areas respectively.

Cycas ophiolitica: The large population at Glen Geddes (Population 7) would be most suitable for a Conservation Agreement, and would also contribute to conservation of endangered serpentinite landscapes. Populations 9 and 13 (Mt Arden Hills and Mt Sleipner) are also significant populations occurring on freehold land.

Macrozamia cranei: The negotiation of a Conservation Agreement with private landholders is a critical step in the recovery of this endangered species. This species is currently located only on freehold land. Populations 3 and 4 (near Texas) and Populations 5 and 6 adjacent to Gunyan SF 176 are the most critical for conservation.

4.1.2 Search for the existence of further populations of all species

Populations for which the survey and mapping information is minimal or non-existent may not be protected under the existing planning and permitting processes. Therefore, survey for further populations of all species is recommended. In particular:

Cycas megacarpa: Survey for additional populations in the Bouldercombe-Mt Morgan and Dee Range areas.

Cycas ophiolitica: Survey for additional populations, particularly in the area north-west of Yeppoon and west of Marlborough.

Macrozamia cranei: Further survey of populations in the area is recommended.

Macrozamia platyrhachis: Survey for additional populations of *M. platyrhachis,* particularly in more eastern parts of the Dawson Range and on Ceres Holding and Planet Downs Station.

4.1.3 Detailed survey of populations currently considered to be threatened, and maps updated to reflect actual extent

a. Detailed survey and mapping of populations so that accurately mapped remnant polygons of existing and potential habitat (including buffer areas) are available using the process outlined in the *Biodiversity Assessment and Mapping Methodology 2002*. Priority populations for survey are those occurring in or near areas likely to be cleared in the near future and, in particular, those occurring on land zoned urban and future urban. Populations of *C. ophiolitica* and *C. lomandroides* are affected (see 3.3 Areas under Threat and 3.4 Populations under threat).

b. Encourage councils to zone as “open space” or “conservation” in planning schemes and/or make provision for covenants to be agreed over these areas.

c. This recovery plan and related spatial information on extent of existing populations and potential habitat to be made available to local and State Government planning and permitting authorities so that appropriate planning and conservation provisions and codes can be developed and implemented, including for those populations occurring in non-remnant areas.

4.1.4 Major landholders and custodians to be contacted and made aware of current legislative regulations

Major landholders and custodians to be contacted and made aware of significance of populations and current protections and legislative regulations pertaining to clearing in areas where populations exist.

4.1.5 Relevant legislation and permitting processes to be strengthened

a. Relevant legislation to be strengthened to prevent clearing and consequent destruction of individual plants or populations in areas considered important habitat for ‘Endangered’ cycads.

b. Inter-government permitting process to be improved so that permits for clearing cannot be issued in areas considered important habitat for ‘Endangered’ cycads.

Potential contributors

Local government planning departments, EPA/QPWS, Queensland Department of Natural Resources, Mines and Water, NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee, Queensland Department of Main Roads, landholders, leaseholders, and private mining and development companies.

4.2 Prevent loss of individuals and populations from legal harvesting and salvage

Performance criteria: *Legal permits for commercial harvesting of plants or plant parts or seed ceased within five years, except for the purposes of this plan* (see 4.1.1, 4.3.4 and 4.6.2).

4.2.1 Relevant legislation and permitting processes to be strengthened

a. Relevant legislation and permitting processes to be strengthened to prevent clearing in areas where commercial salvage of individuals, plant parts or seeds is likely to result.

b. Prohibit salvage of individuals except for the purpose of translocation of individual plants under immediate threat as recommended in this plan (see also related action 4.1.5 above and note on permitted translocation).

4.2.2 Harvesting of plant parts and seed to be tied to the purposes of this plan

Harvesting of plant parts and seed to cease except for the purposes of this, or other official recovery plan of endangered species (see 4.1.1, 4.3.4 and 4.6.2).

Potential contributors

Queensland Department of Natural Resources, Mines and Water, EPA/QPWS, Queensland Department of Primary Industries and Fisheries, and NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee), landholders and leaseholders.

4.3. Prevent loss of individuals, plant parts and seeds to illegal harvesting and destruction

Performance criteria*: Illegal collecting or destructive activities are significantly reduced, incidents reduced by at least 50 percent in five years as estimated by phone poll of QPWS officers, custodians, and landholders.*

4.3.1. Major landholders and custodians to be made aware of current regulations

Major landholders and custodians to be contacted and made aware of significance of populations and current legislative regulations pertaining to the destruction and/or harvesting of plants, plant parts and seed (see also related action 4.1.4 above).

4.3.2 Provide assistance with fencing of small isolated populations

Assistance with fencing on grazing properties where cycads and macrozamias are a threat to stock is recommended. Landholders may be entitled to benefits under proposed changes for leaseholders under the *Land Act 1994* and may be advantaged in seeking grants for conservation works such as fencing through Natural Resource Management funding bodies, or access to volunteer groups if the area is declared a Nature Refuge (see related action 4.1.1 above).

4.3.3 Further education of general public, horticultural societies and nursery industry

a. Provide information and educational material to cycad and macrozamia enthusiasts and cycad-oriented societies and assist with development of policies to discourage collection of the species from the wild except in the instance of carrying out the recommendations of this plan.

b. Displays, talks and printed material to be provided to the general public and nursery industry. Note that this action has already been partially completed by the consultation process with cycad-oriented societies and the publishing of an article in the Palms and Cycads Magazine (Forster 2004).

The potential threat of introducing destructive boring weevils from wild harvested material into valuable private cycad gardens could be more widely advertised.

4.3.4 Develop and implement a plan to address the horticulture and collector demand.
a. Investigate the viability of commercial production, in horticulture, as an alternative legal source of material for collectors (see also related action 4.6.2 below).

b. Develop and implement a plan for the horticulture and collector market. The plan may include limited harvesting of seed and plant parts, and the use of new production technologies. The plan must be both ecologically and economically sustainable.

Of particular interest is the desirable "bluish" northern form of *Cycas ophiolitica*.

Potential contributors

Queensland and Australian cycad societies, commercial nursery industries specialising in cycads, Queensland Department of Primary Industry, landholders and leaseholders, local government, Queensland Department of Natural Resources, Mines and Water, NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee), EPA/QPWS.

4.4 Determine habitat, ecological and reproductive needs

Performance criteria: *Knowledge of population genetics, fire and pollinator ecology improved and applied to managing species and populations. Long-term monitoring plots established for a minimum of 20 years.*

4.4.1 Undertake research to determine the genetic variation and robustness

Genetic studies are needed for all species to determine the degree of genetic continuity and variation both within and between populations and mosaics of populations, and with closely related species. This information is necessary to determine whether or not a population is genetically robust and linked to other populations and closely related species in the area, thus informing the specific actions needed to augment and recover the species.

4.4.2 Undertake research to determine pollinators and their life cycles

Determination of the pollinators, their life cycles and dynamics of mutualisms between the cycad and pollinators is critical for the success of this plan. This information will inform specific management and recovery actions to be undertaken for the successful reproduction and therefore long-term survival of the species. This study should be carried out in conjunction with the long-term monitoring action in 4.4.5 once pollinators are identified.

Little is known about the pollinators, particularly for *C. megacarpa, C. ophiolitica, M. cranei, and M. pauli-guilielmi.*

4.4.3 Undertake research to determine seed dispersal mechanisms and vectors

Undertake dispersal studies to determine whether any is occurring, the vectors involved and the efficiency rates. This information is needed to determine if a population will naturally spread into nearby habitat or will need to be artificially augmented.

4.4.4 Undertake research to determine the optimum fire regimes for long-term survival

Understanding the effects of fire frequency, intensity and time of year on the reproductive ecology and survival of populations is critical for the successful management of populations for long-term survival. This study should be carried out in conjunction with the long-term monitoring action in 4.4.5.

4.4.5 Establish long-term monitoring plots

Establishment of long-term monitoring plots is the only means of determining the effects of management practices on population statistics over time. This information will inform future management guidelines and performance criteria for the species. It is recommended that monitoring be carried out in all significant populations or in at least one significant population per area for at least 20 years.

Monitoring should include population statistics relating numbers, age classes (size), fruiting events, seedling recruitment and attrition, response to fire, pollinator activity and other insect predation. These statistics need to be analysed against a background of environmental information such as the times and severity of fires, rainfall and drought events. It is recommended that expert ecological advice be sought before setting up the plots. For detailed actions see Forster (2005).

Setting up the plots and undertaking the monitoring will require considerable time and effort, and should be carried out under the auspices of a government department such as QPWS which can provide the capacity to accumulate and process data over a long period of time.

Potential contributors

Cycad-oriented societies, regional bodies and landholders, EPA/QPWS, NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee), local governments, landholders and leaseholders and relevant university experts and others.

4.5 Populations managed according to the best available knowledge.

Performance criteria*:* *Interim management guidelines available to landholders and custodians and updated every five years from research results.*

Action 4.5.1 Interim management guidelines available to landholders and custodians

Interim management guidelines to be developed and provided to landholders and custodians, these will include the exclusion of fire during critical reproduction events normally occurring between October and March. These are to be updated in accordance with research results after five years.

Action 4.5.2 Monitoring of populations affected by timber harvesting (pine plantations)

Long-term monitoring plots to be placed in areas where repeat harvests are planned (pine plantations) and harvesting guidelines updated as necessary.

Potential contributors

Local government planning departments, EPA/QPWS, Queensland Department of Natural Resources, Mines and Water, Queensland Department of Primary Industries and Fisheries, NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee and landholders.

4.6. Recovery of populations

4.6.1 Translocate individual plants under immediate threat to suitable habitat in the vicinity of nearby larger populations

Permitted translocation of currently threatened individuals into suitable nearby habitat or into nearby significant and preserved populations is a viable alternative. Note that a small population of *C. megacarpa* inundated by Burnett River Dam was translocated in May 2004. For information on translocation of cycads refer to technical report by Forster (2005).

4.6.2 Increase population numbers in critical populations

Critical populations likely to benefit from artificial augmentation include populations of *M. cranei*, as the most restricted and least-conserved species; northern populations of *C. ophiolitica* depending on the outcome of further survey work; populations of *M. pauli-guilielmi* which are all small, the result of habitat fragmentation, depending on the outcome of survey for age classes and seedling recruitment.

Populations with significant seedling numbers and active pollination will most likely increase naturally over time if management practices are right.

In the case of *M. cranei*, it is recommended to augment populations using nursery raised seedlings and introduce them into identified suitable nearby habitat. Information on propagation, transplantation and translocation is available in the technical report (Forster 2005) and from cycad oriented societies.

Cycad nurseries and landholders may be willing to undertake the labour of germination and raising seedlings in return for the right to sell a portion of the resultant seedlings (see also related action 4.3.4 above).

4.6.3 Review of recovery plan.

All species to be re-assessed at the end of five years using the additional survey and monitoring data, in order to establish and prioritise further threats and actions for the future.

Potential contributors

The EPA/QPWS, Department of Natural Resources, Mines and Water, local government, NRM regional bodies (including Fitzroy Basin Association, Burnett Mary Regional Group and Queensland Murray Darling Committee), Queensland Department of Main Roads, community groups and landholders and custodians.

5. Management practices

Management practices on the ground directly affect the long-term survival of cycad species. The following management practices are prescriptive for the continued survival of the species.

- Halt clearing of habitat in the vicinity of significant populations.
- Prevent illegal destruction or removal of individuals.
- Fence populations where grazing animals are likely to be affected.
- Translocate immediately threatened individual plants under authorised permit and the provisions of this plan.
- Manage road verge and land maintenance activities such as mowing or grading so that individuals and especially seedlings are not damaged.
- Manage timber harvesting in the vicinity of significant populations to minimise damage (under the guidelines provided).
- Manage fire frequency, timing and intensity so that coning events and seedling survival are not affected.

6. Cost of recovery

Summary of Costs. Overall estimate of costs for the major actions.

	Descriptions	Estimated Cost $
4.1 Protect existing populations	Cost of survey work is estimated for 15 days per species, at $1000 per day. Other costs are unknown.	90,000
4.2 Prevent loss of individuals and populations from legal harvesting and salvage	Minimal costs	5,000
4.3. Prevent loss of individuals, plant parts and seeds to illegal harvesting and destruction	Costs associated with providing educational material are estimated at $5000. Costs of assistance with fencing are unknown and may be able to be sourced elsewhere. Costs of developing and implementing a plan to produce legal commercial stock will depend on partners and action 4.6 below, estimated at $10,000.	10,000
4.4. Determine habitat, ecological and reproductive needs	Costs associated with the various research actions will depend on student and University involvement but are estimated to be $100,000. Costs of establishing monitoring plots if done at the same time as survey (action 4.1) and research actions above should be minimal, add on six days to field work ($6000) per year.	130,000

4.5 Populations are managed according to best available knowledge	Developing interim guidelines and review is estimated at $5000. Monitoring populations associated with timber harvesting if done under the same monitoring plots in action 4.4 should be minimal, two more field days per year ($2000).	13,000
4.6. Recovery of populations	Cost of translocation of individuals is unknown. Costs of collecting seeds, growing seedlings, planting and care are estimated at $20,000 per species for the three species, but ongoing care may be needed by local volunteers.	60,000
Total $		**308,000**

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Glossary of terms

cone: reproductive structure of gymnosperms; organised collection of sporophylls on a central axis.

cycad: member of one of several families of Gymnosperms that have palm-like leaves and cone-like reproductive structures, commonly thought to be of ancient lineage and often associated with dinosaurs.

dispersal: the act of dispersing or scattering seed.

disjunct: geographically discrete.

endemic: restricted in occurrence to a particular area.

flagship species: a species that is interesting, attractive, has monetary value, and biological significant.

genetic: pertaining to the study of genes, hereditary and variation, flow and distribution of genetic material in a population over time.

germinate: sprout or begin to grow.

leaflet: primary division of a compound leaf.

masting event: the synchronous production of seeds within a population, followed by several years of minimal seed production.

megasporophyll: sporophyll bearing one or more ovules or later seeds, or potentially so (cf. microsporophyll).

metapopulation: a system of local populations connected by dispersing individuals or with significant genetic flow.

microsporophyll: sporophyll bearing microsporangia that contain pollen grains (cf. megasporophyll).

MVP (minimum viable population): the smallest isolated population that has a specified statistical chance of remaining extant for a specified period of time in the face of foreseeable demographic, genetic, and environmental factors and natural disasters.

mutual relationship (pollination): a biological interaction where both partners are dependent upon the other to complete their life cycle.

population: group of individuals of a species occupying a particular area.

recruitment: increase in a population due to migration, vegetative proliferation or reproduction from seed.

seed: fully mature ovule after fertilisation, with an embryo, storage tissue and all integuments.

species (sp.) (plural spp.): basic taxonomic rank; taxonomic rank below genus, but above subspecies or variety. A working definition for cycads is ‘one or more populations where individuals are morphologically similar, interfertile, but sometimes geographically and hence reproductively isolated from other such populations’.

species lineage: group of species (both extant and extinct) derived from a single ancestor.

subspecies (subsp.): taxonomic rank immediately below species; group of individuals which differ morphologically from another group but insufficiently so as to justify separate specific status. Subspecies are reproductively compatible but are reproductively isolated from each other.

systematic: pertaining to the study of plant taxa and their classification and evolutionary relationships, often referred to as taxonomy.

translocation: The movement of an individual from one location to another, transplanting.

trunk: in cycads, pertaining to an arborescent or decumbent, above-ground stem.

Appendix 1. Population statistics

Abbreviations: n/a = survey information not available; FHT = Freehold Title; GHPL = Grazing Homestead Perpetual Lease; ML = Military Land; NP = national park; RR = Road Reserve; SF = state forest reserve; VCL = vacant crown land; N = Not of concern; O = Of concern; E = Endangered; dom = dominant; subdom = sub-dominant. Populations are arranged north to south. Populations currently considered to be viable in the long term are highlighted.

*actual number

Table A. ***Cycas megacarpa***

Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	percentage	Vegetation management status	Polygon descriptor	Projected occupancy of population (ha)	Projected No. plants in population	No. plants per ha	No. plants in 50 x 50 m	Seedlings present In 50 x 50m plot
1	550772	GHPL	11.3.25/11.3.4/11.3.1	75/20/5	N/O/E	E-subdom	n/a	scattered	10	n/a	n/a
2	418803	n/a	11.12.1/11.3.4	80/20	N/O	O-subdom	c. 100	thousands	n/a	n/a	n/a
3	440251	FHT	11.11.3/11.11.15	90/10	N/N	N	>850	159800	188	47	+
4	551377	GHPL	11.11.3/11.11.15	90/10	N/N	N	n/a	hundreds	n/a	n/a	n/a
5	557661	FHT, RR	11.11.3/11.11.15	90/10	N/N	N	c. 100	5600	56	14	+
6	577622	RR	non-remnant	100	-	n/a	20	28*	1.4	n/a	+
7	648015	SF	11.3.26/11.3.25/11.11.3	50/35/15	N/N/N	N	1	5*	5	5	-
8	647811	SF	11.12.1/11.12.6	90/10	N/N	N	800	115200	144	36	+
9	648016	GHPL	11.12.1/11.12.6	90/10	N/N	N	n/a	49*	196	49	+
10	651639	VCL	12.1.3	100	N	N	n/a	n/a	n/a	n/a	n/a
11	577663	FHT, RR	11.12.6/11.12.1	60/40	N/N	N	5	19*	3.8	19	-
12	664738	FHT, RR	11.12.6/11.12.1	60/40	N/N	N	5	4*	1.3	4	-
13	772387	FHT	12.12.12/12.12.28	95/5	O/O	O-dom	n/a	n/a	n/a	n/a	n/a
14	578569	FHT, RR	11.11.15/11.11.4	95/5	N/N	N	>200	14400	72	18	+
15	578560	FHT, RR	11.11.15/11.11.4	95/5	N/N	N	c. 50	35*	8	2	+
16	660978	NP	12.12.11/12.5.5	90/10	N/O	O-subdom	n/a	< 10	n/a	n/a	n/a
17	647797	FHT, RR	12.12.5/12.12.7/12.12.8	80/15/5	N/N/O	O-subdom	100	33*	3	n/a	+
18	647796	RR	non-remnant	100	-	n/a	0.1	1*	1	1	-
19	635158	SF	12.11.6/12.11.7/12.11.8	80/15/5	N/N/N	N	c. 250	76750	307	77	+
20	590137	FHT	12.11.6/12.12.5/12.3.3	45/45/10	N/N/E	E-subdom	3	119*	39.7	n/a	+
21	590158	SF	12.12.5/12.12.4/12.3.7	85/10/5	N/N/N	N	2	c. 30	15	n/a	+

22	620757	SF	12.11.6/12.12.5/12.11.8	60/35/5	N/N/N	N	1.1	90*	81.8	n/a	-
23	579813	FHT	non-remnant	100	-	n/a	4	65*	16.25	n/a	+ (1)
24	579812	FHT	12.12.5/12.12.7	90/10	N/N	N	4	12*	3	n/a	-
25	590160	FR	12.12.5/12.12.4/12.3.7	85/10/5	N/N/N	N	2	54*	27	n/a	-
26	626413	SF	non-remnant	100	-	n/a	n/a	n/a	n/a	n/a	n/a
27	776049	FHT	12.11.6/12.11.8	65/35	N/N	N	c. 150	c. 300	2	n/a	n/a
28	661063	SF	12.11.6/12.11.17/12.3.3	50/40/10	N/N/E	E-subdom	n/a	n/a	n/a	n/a	n/a
29	620088	SF	12.11.6/12.11.5/12.11.9	60/20/20	N/N/O	O-subdom	n/a	< 50	n/a	n/a	n/a
30	555163	SF	12.12.16	100	N	N	c. 20	“thousands”	n/a	n/a	n/a
31	554865	FHT, RR	12.12.3/12.3.15/12.3.7	45/45/10	O/O/N	O-dom	1	7*	7	7	-
32	578570	FHT	non-remnant	100	-	n/a	0.25	1*	1	1	-
33	441743	FHT	12.11.6/12.11.5/12.12.5/12.12.3	40/35/15/10	N/N/N/O	O-subdom	n/a	n/a	n/a	n/a	n/a
34	398919	FHT	12.12.5/12.12.4/12.12.13	45/40/15	N/N/N	NotOfC	1	c. 20	n/a	n/a	n/a
35	576945	VCL	12.12.5	100	N	N	0.25	3*	1	3	-
36	517088	NP	12.11.6/12.11.7/12.11.12	35/35/30	N/N/N	N	1	14	14	14	-
37	577586	NP	12.11.7	100	N	N	1	c. 150*	150	25	+
38	598795	RR	non-remnant	100	-	n/a	0.1	3	3	3	-
39	316154	SF	12.12.4	100	N	N	n/a	n/a	n/a	n/a	n/a
40	396676	FHT	non-remnant	100	-	n/a	0.1	1♂	1	1	-
41	765779	SF	12.9-10.2/12.3.11	90/10	N/O	O-subdom	0.0001	1	1	1	-
42	662838	SF	12.12.5/12.12.7/12.12.12	55/30/15	N/N/O	O-subdom	1	<10	10	<10	-
43	474359	NP	12.12.9/12.12.10/12.12.11/12.12.5	35/25/20/20	O/O/N/N	O-dom	1	<20	20	<20	+
44	675776	FHT	12.11.6/12.11.14/12.3.11	70/20/10	N/O/O	O-subdom	1	<20	20	<20	n/a
45	565321	FHT	12.12.23/12.12.5/12.12.11/12.12.8	40/30/15/15	N/N/N/O	O-subdom	1	<20	20	<20	n/a
46	565319	SF	non-remnant	100	-	n/a	1	<40	40	<40	n/a

Table B. ***Cycas ophiolitica***

Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	Percentage	Vegetation management status	Polygon descriptor	Projected occupancy of pop. (ha)	Projected No. plants	Projected No. plants p er ha	No. plants in 50 x 50 m	Seedlings present (+/-)
1	667756	ML	11.11.15/11.11.4	80/20	N/N	N	n/a	n/a	n/a	n/a	n/a
2	577654	RR	non-remnant	100	-	n/a	0.25	5*	5	5	+ (2)
3	667755	ML	11.11.4/11.11.15	65/35	N/N	N	n/a	n/a	n/a	n/a	n/a
4	550962	FHT	11.11.7	100	N	N	n/a	n/a	n/a	n/a	n/a
5	574941	RR	11.11.7/11.3.25	95/5	N/N	N	c. 5	280	56	14	+
6	732823	SF	11.3.9/11.3.4	50/50	N/O	O-subdom	c. 5	c. 1000	n/a	n/a	+
7	564996	FHT	11.11.15	100	N	N	c. 60	c. 10080	168	42	+ (11)
8	491041	FHT, RR	non-remnant	100	-	n/a	n/a	common	n/a	n/a	n/a
9	653179	FHT, RR	non-remnant	100	-	n/a	>200	>28000	140	35	+
10	590148	NP	11.12.4	100	N	N	>400	>65600	164	41	+
11	590153	FHT, RR	11.12.6/11.12.4/11.12.3	55/25/20	N/N/N	N	n/a	common, hundreds	n/a	n/a	+
12	780435	NP	non-remnant	100	-	n/a	>1000	>180000	180	45	n/a
13	440253	FHT, RR	non-remnant	100	-	n/a	>400	>80000	200	50	n/a
14	652520	FHT	11.11.4	100	N	N	n/a	locally common	n/a	n/a	n/a
15	576943	FHT	11.12.3/11.3.4	70/30	N/O	O-subdom	0.25	7*	7	7	-
16	576944	FHT	11.1.4	100	N	N	0.25	16*	16	16	+

Table C. *Macrozamia cranei*

Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	Percentage	Vegetation management status	Polygon descriptor	Estimated no. of adults in 2003	Area of occupancy	Seeds present in 2003	No. seedlings present in 2003	Evidence of coning in 2003
1	608109	FHT	13.11.4/13.11.8	95/5	N/O	O-subdom	38	250sq.m	-	11	in 2002
2	626850	FHT	13.12.5	100	N	N	c. 12	c. 1 ha	-	3	-
3	603965	FHT	13.11.3/13.11.5	85/15	O/O	O-dom	>1000 in 1997	c. 5 ha	n/a	n/a	n/a
4	594332	FHT	13.11.3	100	O	O-dom	<1000 in 1997	c. 5 ha	n/a	n/a	n/a
5	625073	FHT	13.11.4/13.11.8	95/5	N/O	O-subdom	60	230sq.m	-	4	in 2002
6	593228	FHT	non-remnant	100	-	n/a	29	400sq.m	+	10	in 2002

Table D: *Macrozamia lomandroides* (data for sites 1-15 from Halford 1998).

Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	Percentage	Vegetation management status	Polygon descriptor	Estimated number of plants	Density (plants/ha)	Area of occupancy (ha)
1	590165	VCL7	12.3.11	100	O	O-dom	200-300	n/a	0.28
2	489808	SF5	12.5.8/12.5.4/12.3.12/12.5.11	60/30/5/5	O/N/O/E	E-subdom	54	1400	0.04
3	675789	SF	12.5.4/12.5.8	50/50	N/O	O-subdom	690	4600	0.15
4	675784	SF	12.5.8/12.5.4/12.3.12/12.5.11	60/30/5/5	O/N/O/E	E-subdom	409	900	0.44
5	675781	SF	12.5.8/12.5.4/12.3.12/12.5.11	60/30/5/5	O/N/O/E	E-subdom	6804	4900	1.4
6	675790	SF	12.5.8/12.5.4/12.3.12/12.5.11	60/30/5/5	O/N/O/E	E-subdom	220	300	0.074
7	675786	SF	12.5.4/12.5.10/12.5.8	80/10/10	N/N/O	E-subdom	6640	330	2.0
8	675788	SF	non-remnant	100	-	n/a	605	240	0.25
9	675787	SF	12.5.4/12.5.8	50/50	N/O	O-subdom	8775	390	2.25
10	675791	SF	12.5.4/12.5.10/12.5.8	80/10/10	N/N/O	O-subdom	7808	690	1.125
11	675793	SF	Pine plantation	100	-	n/a	18	18	0.001
12	675773	SF	Pine plantation	100	-	n/a	962	260	0.37
13	670247	NP	12.3.11	100	O	O-dom	50	60	0.08
14	670248	NP	12.1.3/12.1.2	85/15	N/N	N	13	10	0.1
15	670251	NP	12.5.8/12.3.5	70/30	O/O	O-dom	24	20	0.1
16	577590	RR	12.5.8/12.5.4/12.3.12/12.5.11	60/30/5/5	O/N/O/E	E-subdom	50	50	0.04
17	670249	NP	12.5.8/12.3.5	70/30	O/O	O-dom	common	n/a	n/a
18	670246	NP	12.5.8/12.3.5	70/30	O/O	O-dom	locally frequent	n/a	n/a
19	670250	NP	12.3.13	100	O	O-dom	n/a	n/a	n/a
20	670252	NP	12.5.8/12.5.10	95/5	O/N	O-dom	frequent	n/a	n/a
21	670253	NP	12.3.5/12.5.9	50/50	O/O	O-dom	common	n/a	n/a
22	675792	SF	12.5.4/12.3.11	70/30	N/O	O-subdom	locally occasional	n/a	n/a

Table E. *Macrozamia pauli-guilielmi*

Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	Percentage	Vegetation management status	Polygon descriptor	Area of occupancy (ha)	Number of adult plants*	Number of adult plants in 50 x 8 m	Coning evidence	Seedlings present (+/-)
1	577588	VCL	12.5.4/12.5.8	75/25	N/O	O-subdom	1	c. 150*	38	+	31
2	675794	FHT, VCL	12.5.4/12.5.8	75/25	N/O	O-subdom	0.1	105	n/a	+	n/a
3	663691	NP	12.5.12/12.5.4/12.3.4	40/40/20	O/N/N	O-dom	0.25	3	n/a	n/a	n/a
4	675772	SF	12.3.11	100	O	O-dom	0.0075	15	n/a	+	n/a
5	627615	SF	non-remnant	100	-	n/a	c. 0.5	<100	n/a	n/a	+
6	770254	SF	non-remnant	100	-	n/a	n/a	occasional	n/a	-	n/a
7	620756	FHT	12.2.9/12.2.11/12.2.7	65/30/5	N/N/O	O-subdom	0.25	1	1	-	-
8	675771	SF	Pine plantation	100	-	n/a	2.4	1224*	n/a	+	n/a
9	670255	SF	non-remnant	100	-	n/a	0.075	42	n/a	-	n/a
10	636273	FHT	12.5.10/12.5.4/12.5.8/12.5.9	35/35/15/15	N/N/O/O	O-subdom	n/a	n/a	n/a	n/a	n/a
11	670321	FHT SF RR	12.9-10.19	100	N	N	2	126	n/a	-	n/a
12	670320	SF	12.11.6/12.11.14	60/40	N/O	O-subdom	1.5	20	n/a	+	
13	670262	SF	12.3.13/12.3.12/12.3.14	40/30/30	O/O/O	O-dom	1	10	n/a	-	n/a
14	670263	SF	12.5.12	100	O	O-dom	5	3600*	n/a	-	n/a
15	670256	SF	Pine plantation	100	-	n/a	c. 5	<100	n/a	-	n/a
16	675770	SF	12.5.12/12.5.9	85/15	O/O	O-dom	0.25	214	n/a	-	n/a
17	670323	SF	12.5.12	100	O	O-dom	1.5	1950*	n/a	+	n/a
18	670261	SF	12.5.12/12.5.9	85/15	O/O	O-dom	2.5	158	n/a	+	n/a
19	670257	SF	12.5.12/12.5.10	90/10	O/N	O-dom	8	5120*	n/a	n/a	n/a
20	640103	SF	non-remnant	100	-	n/a	n/a	occasional	n/a	n/a	n/a
21	640118	SF	Pine plantation	100	-	n/a	n/a	occasional	n/a	n/a	n/a
22	640012	SF	12.9-10.3/12.9-10.19/12.9-10.2/12.3.11	40/30/25/5	O/N/N/O	O-dom	n/a	uncommon	n/a	n/a	n/a
23	670317	SF	12.11.5/12.9-10.2/12.3.11	60/30/10	N/N/O	O-subdom	3	105	n/a	+	n/a
24	670318	SF	12.11.5/12.9-10.2/12.3.11	60/30/10	N/N/O	O-subdom	0.03	3	n/a	+	n/a
25	55062	SF	12.9-10.4	100	N	N	n/a	occasional	n/a	+	n/a
26	670745	NP	12.2.7	100	O	O-dom	0.03	23	n/a	n/a	18
27	670746	NP	12.9-10.17/12.9-10.1	50/50	N/O	O-subdom	0.5	62	n/a	-	n/a

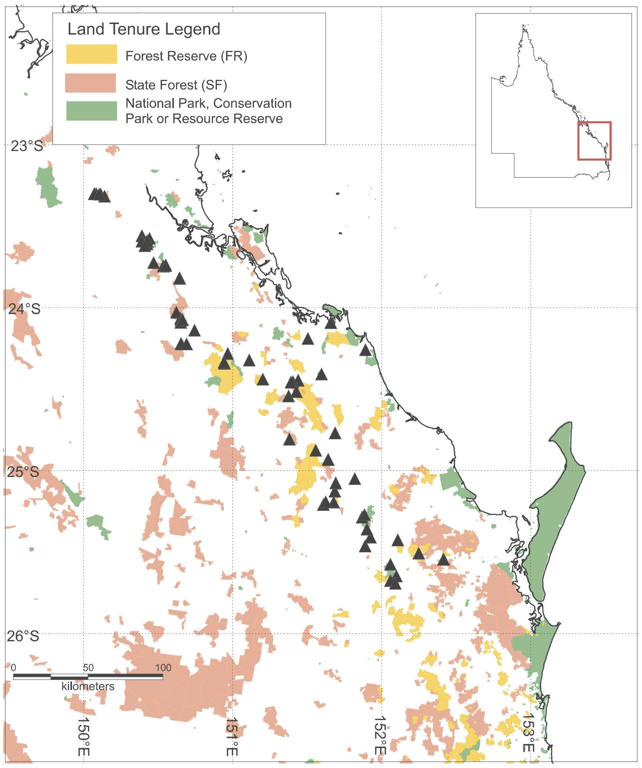
Table F: *Macrozamia platyrhachis*

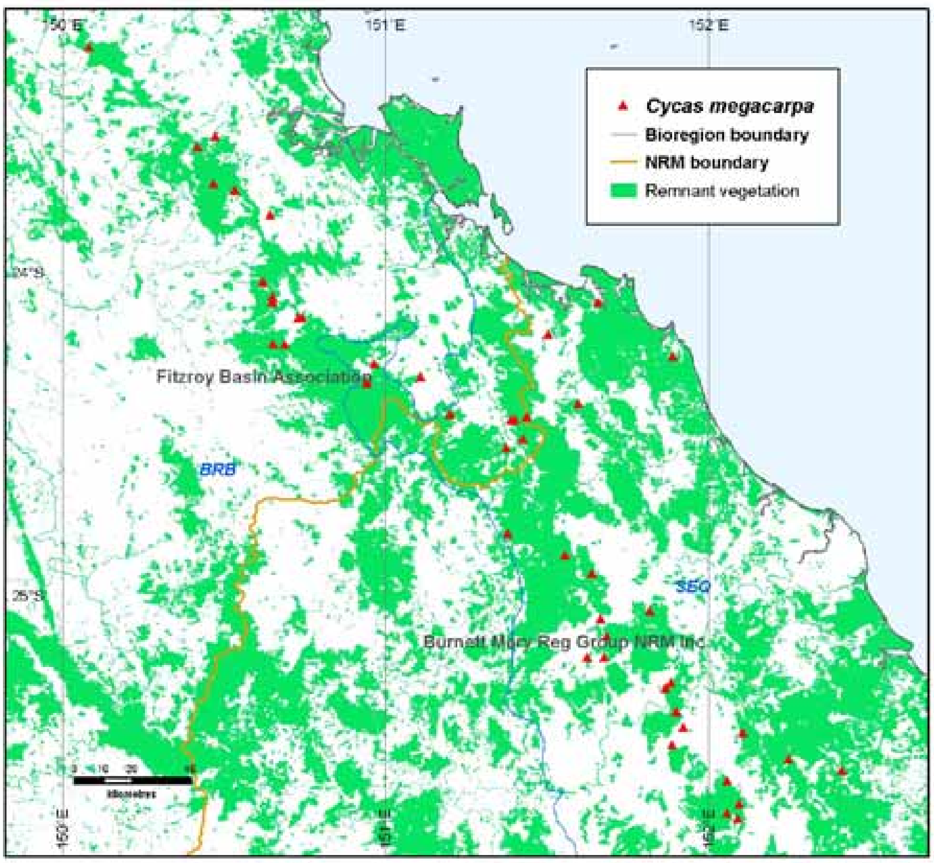
Number (north to south)	AQ number (specimen voucher)	Tenure	Regional ecosystem	Percentage	Vegetation management status	Polygon descriptor	Projected occupancy of population (ha)	Projected No. plants in population	Number of plants per ha	No. plants in 50 x 8 m	Seedlings present	Evidence of coning	Evidence of pollinators
1	576535	GHPL	11.10.13	100	N	N	25	42500	1700	68	-	2003	+
2	732665	GHPL	11.5.2/11.5.7	95/5	N/N	N	36	47700	1325	53	-	?2001	-
3	732395	GHPL	11.5.7/11.5.2	80/20	N/N	N	144	198000	1375	55	-	none	-
4	732666	GHPL	11.5.7/11.5.2	80/20	N/N	N	9	34650	3850	154	-	?2001	-
5	608110	NP	11.10.5	100	N	N	9	41175	4575	183	4/0.4 ha	2003	+
6	764928	NP	11.10.5	100	N	N	16	32800	2050	82	-	2003	+
7	576536	NP	11.10.13	100	N	N	9	24790	2750	80	-	2003	+
8	576417	NP	11.7.2	100	N	N	49	122500	2500	110	-	2003	+
9	763561	NP	11.10.13	100	N	N	16	22400	1400	56	-	2003	+
10	756519	NP	11.10.13	100	N	N	36	25200	700	28	-	2003	+
11	756520	SF	11.10.13	100	N	N	16	19600	1225	49	-	2003	+
12	664319	GHPL	11.10.13	100	N	N	n/a	thousands	n/a	n/a	n/a	n/a	n/a

Appendix 2 Distribution maps

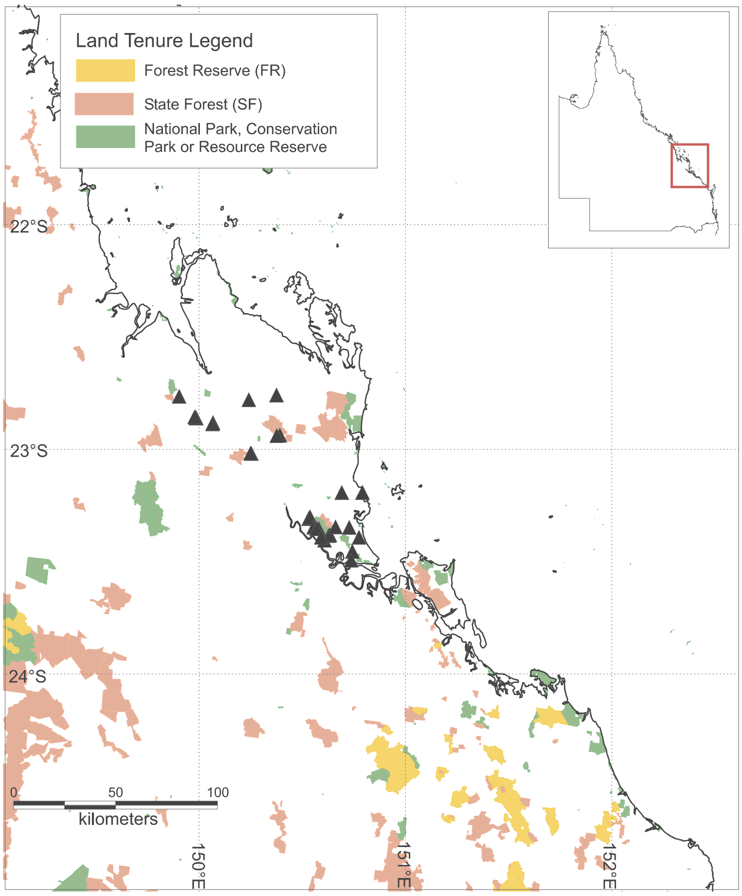
Maps based on Herbarium specimen records HERBRECS 2005 data

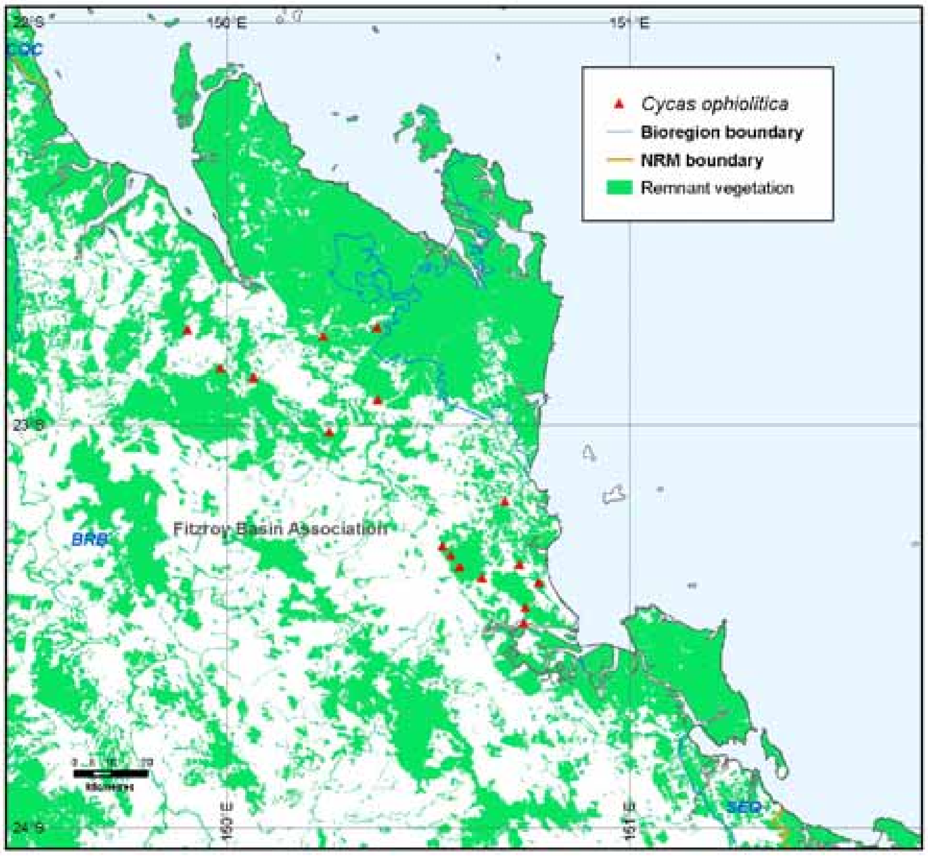
Cycas megacarpa



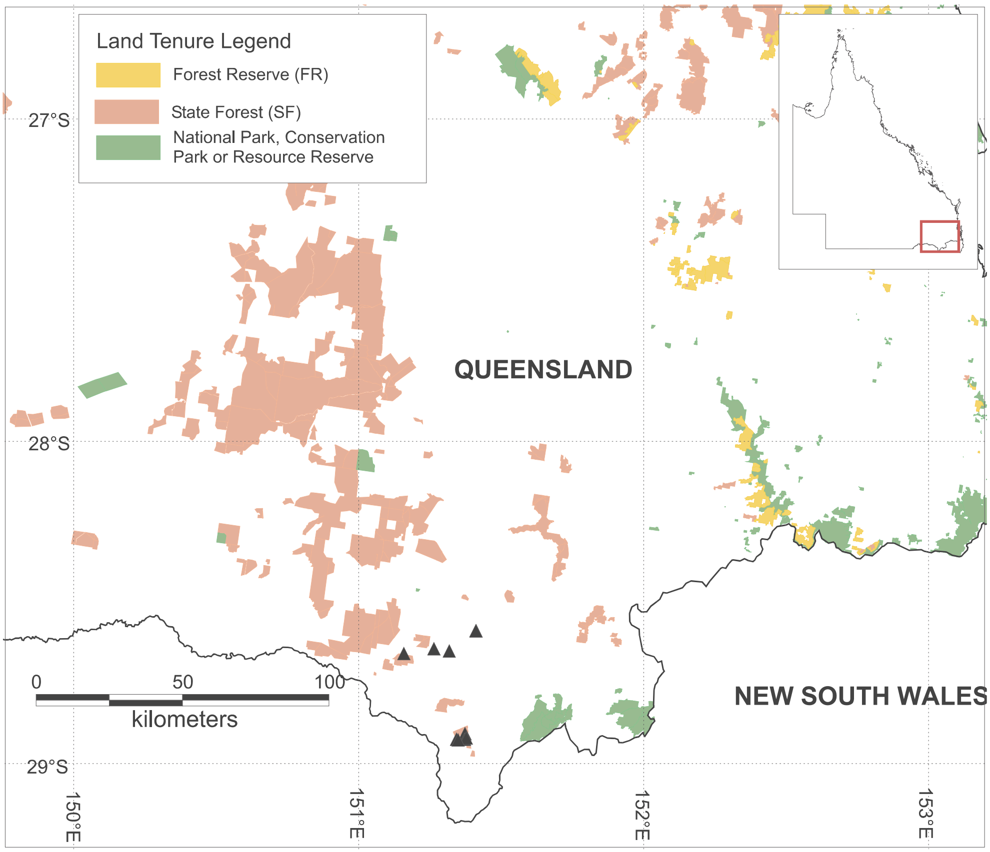


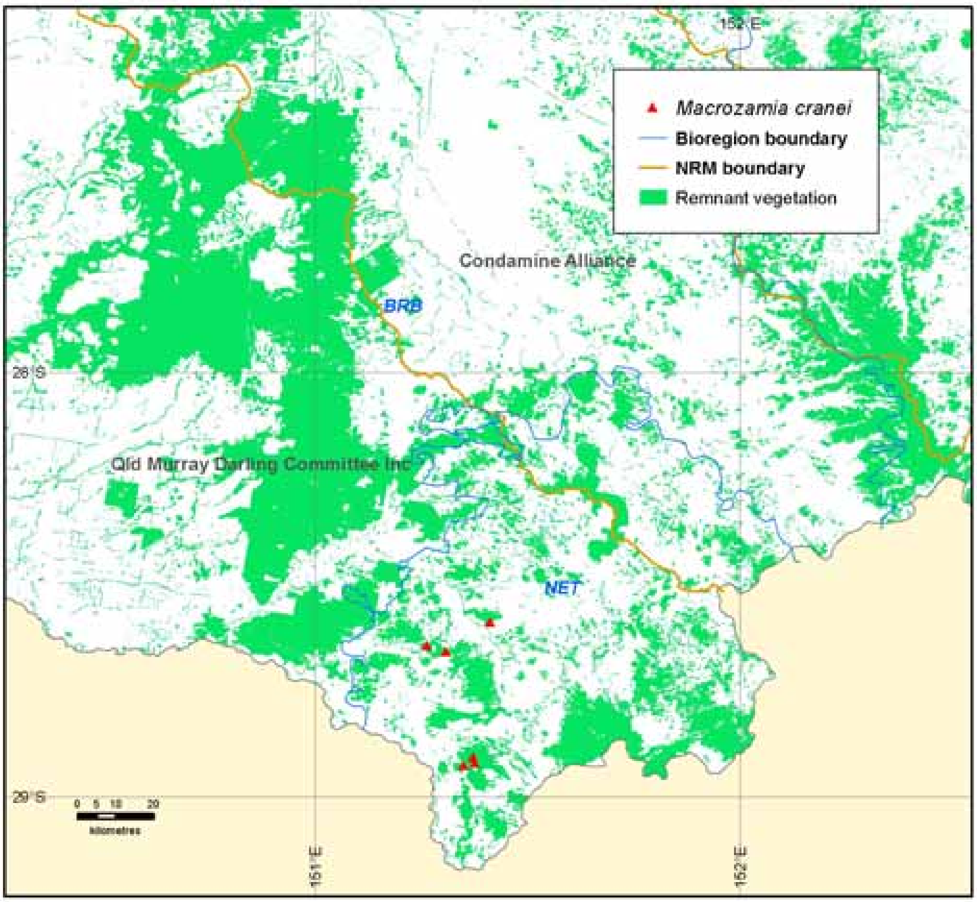
Cycas ophiolitica



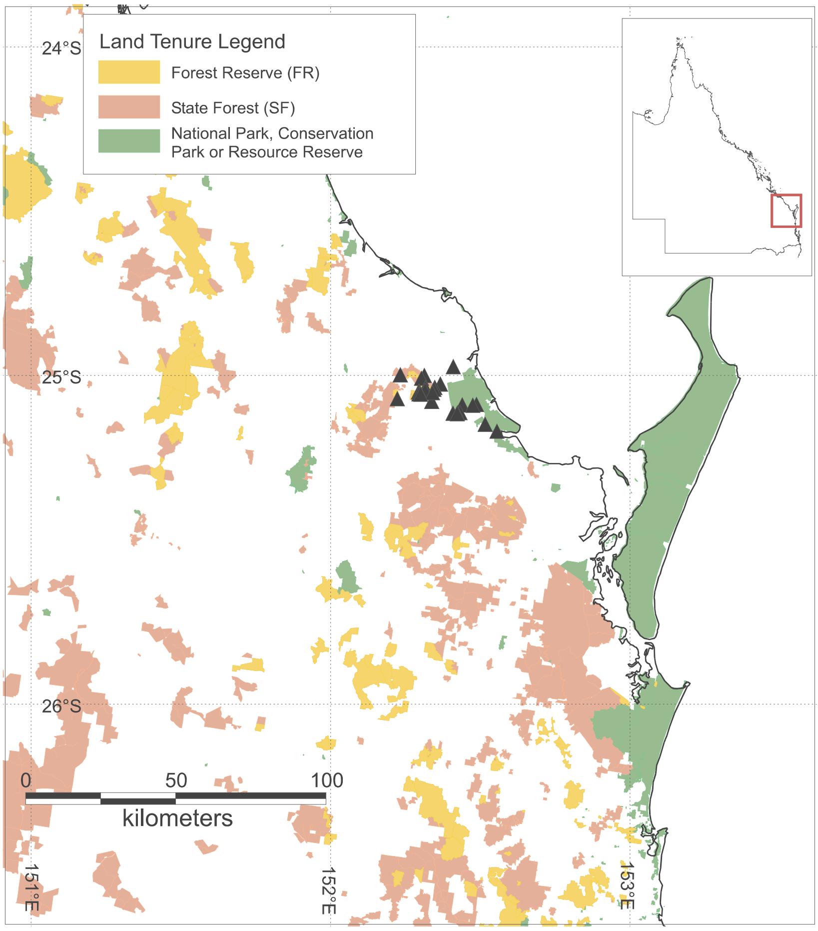


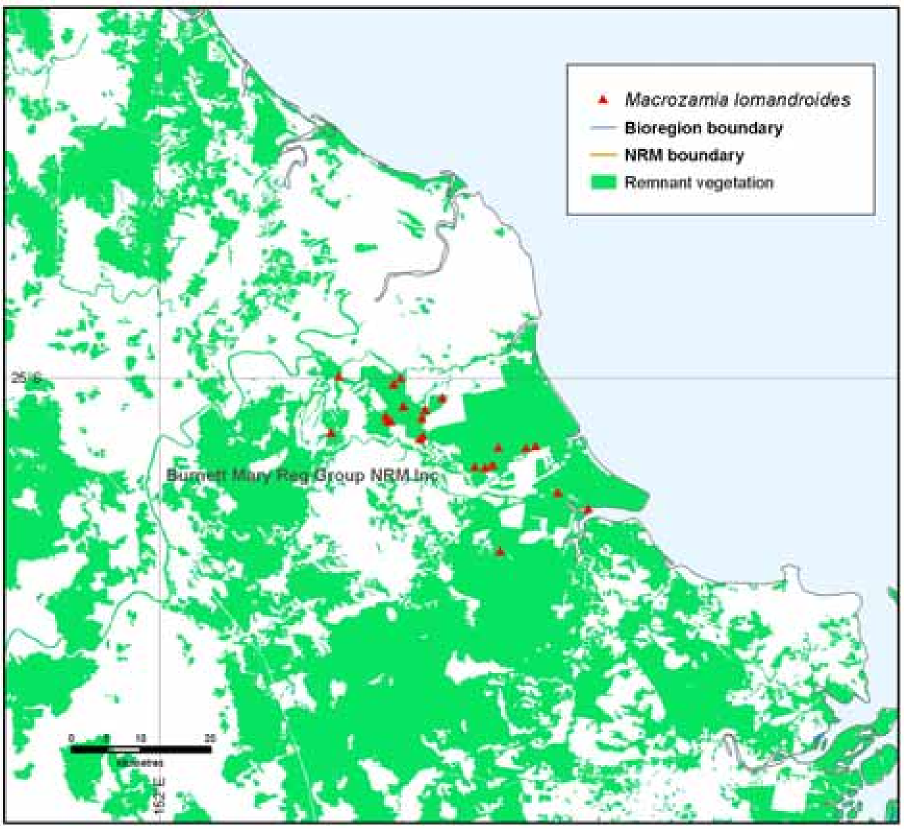
Macrozamia cranei



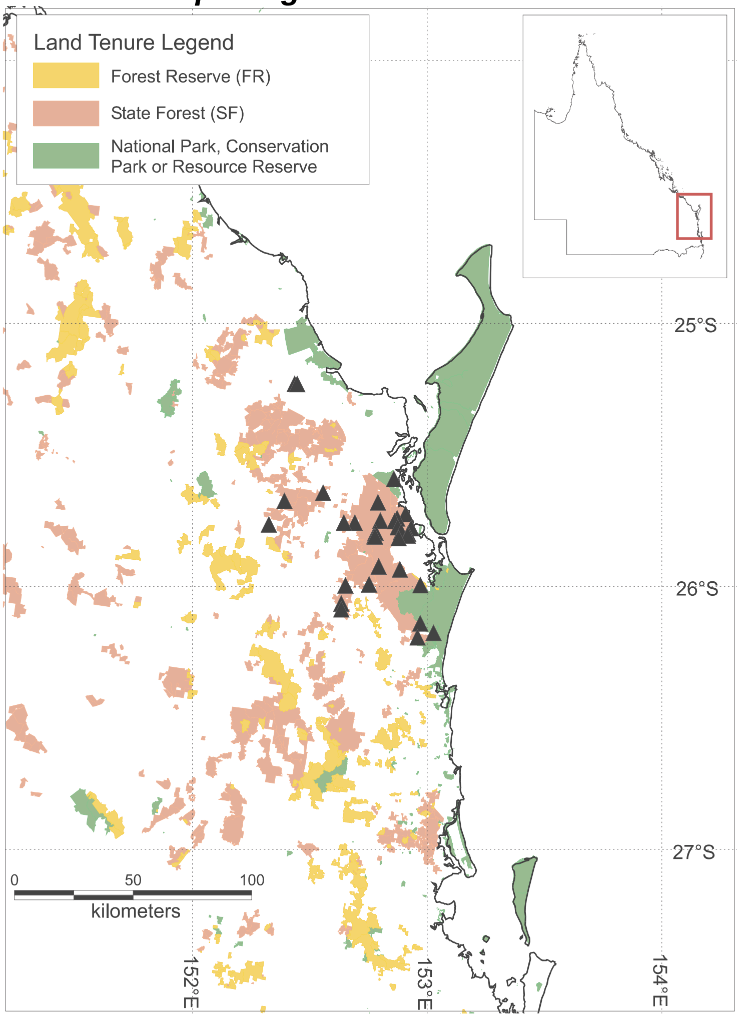


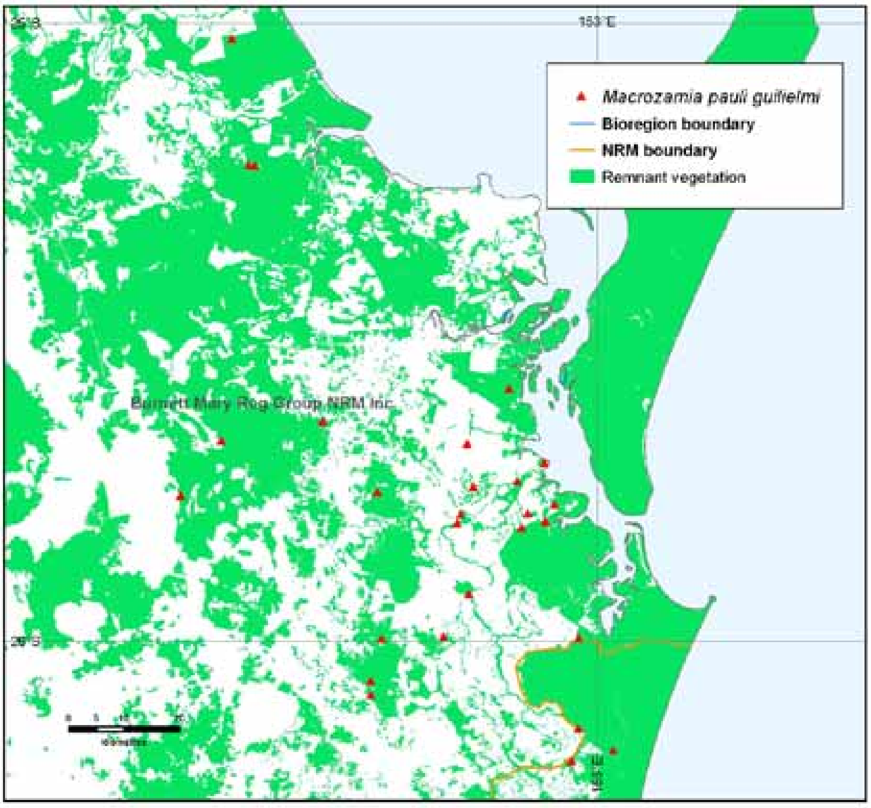
Macrozamia lomandroides





Macrozamia pauli-guilielmi





Macrozamia platyrhachis