Southern Macadamia Species Recovery Plan

Macadamia integrifolia

Macadamia tetraphylla

Macadamia ternifolia

Macadamia jansenii

Title:
Southern Macadamia Species Recovery Plan

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Executive Summary

Species Description and Taxonomy
Of the nine macadamia species, seven are found in Australia in two distinct clades (Johnson and Briggs 1975). The southern clade consists of four subtropical rainforest and wet sclerophyll mid stratum trees, all of which have simple leaves arranged in whorls of three or four or opposite, axillary flowers in brush-like hanging racemes, and rounded fruits with a hard brown inner shell protecting the edible nut.

Current Species Status
With the exception of *Macadamia jansenii,* which is listed as 'Endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Queensland *Nature Conservation Act 1992* (NC Act), all three other species are listed as 'Vulnerable', including *Macadamia tetraphylla* in New South Wales where it is listed under the *Threatened Species Conservation Act 1995* (TSC Act). In addition, all four species are listed on the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List for Threatened Plants (IUCN 1997).

Habitat and Distribution Summary
All four species are endemic to rainforest and wet sclerophyll forest communities found within the northeast New South Wales-southeast Queensland coastal region. They are genetically closely related, and except for *M. jansenii* which is known from a single location 150km north of the closest macadamia population, have overlapping ranges.

Threats Summary
Clearing for human population growth and development, fragmentation, altered fire regimes, small population size and weed species are the major processes affecting southern macadamia species. Climate change in the form of variable rainfall and higher temperatures, the potential for genetic pollution from commercial plantations, and a lack of public awareness of wild macadamias are also considered significant threats.

Recovery Objective
The overall objective of this plan is to protect wild populations of the four nominated species from decline, ensure their long-term viability, and raise awareness of flora conservation issues within the community.

Summary of Actions
Key actions required for the recovery of southern macadamias include surveying known macadamia populations, negotiating appropriate agreements with landholders to establish greater long-term security for priority areas on private property, providing land managers with the resources to develop and implement management plans for macadamia conservation, establishing an *ex-situ* conservation program for *Macadamia jansenii,* identifying gaps in the current understanding of southern macadamia species ecology and commensurate research priorities for conservation, and liaising with State Agencies, Local Authorities and Regional Bodies in order to incorporate macadamia conservation into their biodiversity conservation and natural resource management strategies. The total estimated cost of implementing recovery actions is $1,091,500.

1. General Information

Conservation Status

Macadamia belong to the Proteaceae, an ancient angiosperm family whose initial differentiation from ancestral forms occurred in the southeast of Australia 90-100 million years ago. Proteaceae appear to have been a major component of the early angiosperm dominated rainforests that once covered most of Australia. This Plan focuses on the four southern species of macadamia, all of which are subtropical rainforest mid stratum trees endemic to the northeast NSW-southeast Queensland coastal region. All are genetically closely related and, with the exception of *M. jansenii*, have overlapping ranges.

Table 1. Plant species included in the Southern Macadamia Species Recovery Plan.

Scientific Name	Conservation Status		
	NCA 1992	TSC Act 1995	EPBC Act 1999
Macadamia integrifolia Maiden & Betche	V	N/A	V
Macadamia jansenii C.L.Gross & P.H.Weston	E	N/A	E
Macadamia ternifolia F.Muell.	V	N/A	V
Macadamia tetraphylla L.A.S.Johnson	V	V	V

International Obligations

Macadamia species are currently not listed on any international agreements. This recovery plan is consistent with Australia's international obligations.

Affected Interests

This recovery plan has been initiated by and written for Horticulture Australia Limited (HAL) in conjunction with the Macadamia Conservation Committee (MCC). The MCC and other select individuals collectively constitute the Recovery Team for this plan (see Appendix 1), and is chaired by Ian McConachie.

Other affected interests may include:

- Australian Department of the Environment, Water, Heritage and the Arts (DEWHA)
- Australian Macadamia Society
- Brisbane Rainforest Action and Information Network
- Burnett-Mary Regional Group for Natural Resource Management
- CSIRO
- Fitzroy Basin Association
- Landholders
- Land for Wildlife participants
- Local Authorities
- Local indigenous groups
- Macadamia Conservation Research Network
- New South Wales Department of Environment and Climate Change (NSW DECC)
- Northern Rivers Catchment Management Authority
- Queensland Department of Environment and Resource Management (including the Queensland Herbarium) (QDERM)
- Queensland Fire and Rescue Service

- SEQ Catchments
- Southeast Queensland Fire and Biodiversity Consortium
- University of the Sunshine Coast

Consultation with Indigenous People
During the development of the plan, several Indigenous groups with connection to country providing macadamia habitat were contacted. These included the Kabi Kabi and Yuggera groups (SE Queensland), and the Southeast Queensland Traditional Owner Land and Sea Management Alliance (SEQTOLSMA). Macadamia nuts have been recorded as a valuable food, trading and cultural resource to Aboriginal people (SEQTOLSMA members pers. comm.). All these groups reiterated the importance of conserving threatened macadamia species. Indigenous people will be encouraged to be involved in the recovery process through the implementation of recovery actions.

Benefits to other Species or Communities
Specific localities for some macadamia populations recorded in this Plan provide valuable habitat for other State and Commonwealth listed threatened species and ecological communities. The protection of these sites will provide benefits to non-target taxa, and assist in the prioritisation of management actions. Some populations are also found in 'Endangered' and 'Of concern' regional ecosystems (see Tables 2-5). The protection of these vegetation communities provides an additional layer of protection to these populations.

Social and Economic Impacts
Populations of threatened species found on private lands are generally located in areas where in situ protection – for example, through fencing off and weed control – will have little or no negative economic impact on the viability of farm enterprises on these lands. Lack of protection of wild macadamia populations may have significant economic impacts on the macadamia industry.

2. Biological Information

Introduction

Macadamia belong to the Proteaceae, an ancient angiosperm family whose initial differentiation from ancestral forms occurred in the south-east of Australia 90-100 million years ago. The family is well known for other genera such as *Banksia, Grevillea,* and *Hakea*. Proteaceae appear to have been a major component of the early angiosperm dominated rainforests which once covered most of Australia. Macadamia were probably widely distributed within these early forests as evidenced by macadamia type fossil pollen recorded in sediments in south-east Australia, central coastal Queensland and New Zealand.

The commencement of significant and permanent change in climate beginning about 40 million years ago resulted in the contraction of rainforest towards coastal areas, a process which accelerated through the Quaternary period. This process contributed to adaptation to drier fire prone habitats by much of the Proteaceae family, with a relict rainforest component including macadamia*,* becoming progressively more restricted and disjunct in distribution over time and space.

There are nine species of macadamia, seven of which are found in Australia in two distinct clades (Johnson and Briggs 1975). The southern clade (the subject of this plan) consists of four subtropical rainforest and wet sclerophyll mid stratum trees endemic to the northeast NSW southeast Queensland coastal region. They are genetically closely related, and except for *M. jansenii* which is known from a single location 150 km north of the closest macadamia population, have overlapping ranges (see Figure 1). In fact, the wild distributions of *M. integrifolia*, *M. ternifolia* and *M. tetraphylla* are predominantly restricted to a narrow east-west zone broadly defined as the first line of significant hills west of the Pacific Ocean. Trees that display morphological characteristics of both *M. integrifolia* and *M. tetraphylla* are found in a hybrid zone up to 20 km wide (Peace 2005). While similar observations have not been reported for *M. integrifolia* and *M. ternifolia*, DNA marker studies have confirmed hybrid genotypes (Peace 2005). Hybridisation may be an important survival mechanism, providing a means of adaptation to changed environmental conditions, and evidence of the evolutionary retention of genes better adapted to the same. Hybrid populations offer important foci for ecological research, potentially improving long-term species viability where overlap occurs, and therefore may be important conservation priorities.

Macadamias have had a long association with humans – nut shells have been found in aboriginal middens near Brisbane and the first specimens were collected by the explorer Leichardt in 1843 about 60 km north of Brisbane. From 1860, settlers discovered the fine eating qualities of both *M. integrifolia* and *M. tetraphylla*, which were widely planted in farm yards and backyards as single trees grown from seeds of local wild stock.

The macadamia nut industry was founded around 1880 at Rous Hill near Lismore using seed from local wild stock, with similar plantings recorded near Maleny southeast Queensland in the early 20th century. Importantly, the long history of planting and transport of nuts by early settlers makes it difficult to distinguish planted trees from wild stock, especially in areas where agricultural activities have been abandoned and regrowth has occurred. This situation can confound identification of macadamia distribution and natural habitat, and has implications for distribution of genetic resources.

Important Populations

Given the fragmented and small nature of all populations of each species, all populations are considered important for the survival of each species.

On the basis of currently available information, it is not possible to prioritise *individual macadamia populations*. The Plan includes prioritised (high or medium) *population clusters* for each species on the basis of:

1. Extent of geographical range (particularly whether a cluster is found at the northern or southern limit of a species range).
2. High density areas (multiple populations of multiple individuals).
3. Areas of hybridisation (critical for the future evolution of macadamia species, particularly in light of climate change impacts).
4. Degree of genetic isolation and genetic differentiation.
5. Extent and pattern of available remnant habitat.

The site identifier (MGA northing), location, tenure, regional ecosystem (remnant; bold indicates that the biodiversity status of the RE is endangered, italics of concern, clear indicates no surrounding native vegetation), population size, and the priority (high, medium or low) of known population clusters for each species throughout its distribution are summarised in Tables 2-5.

Habitat Critical to Survival

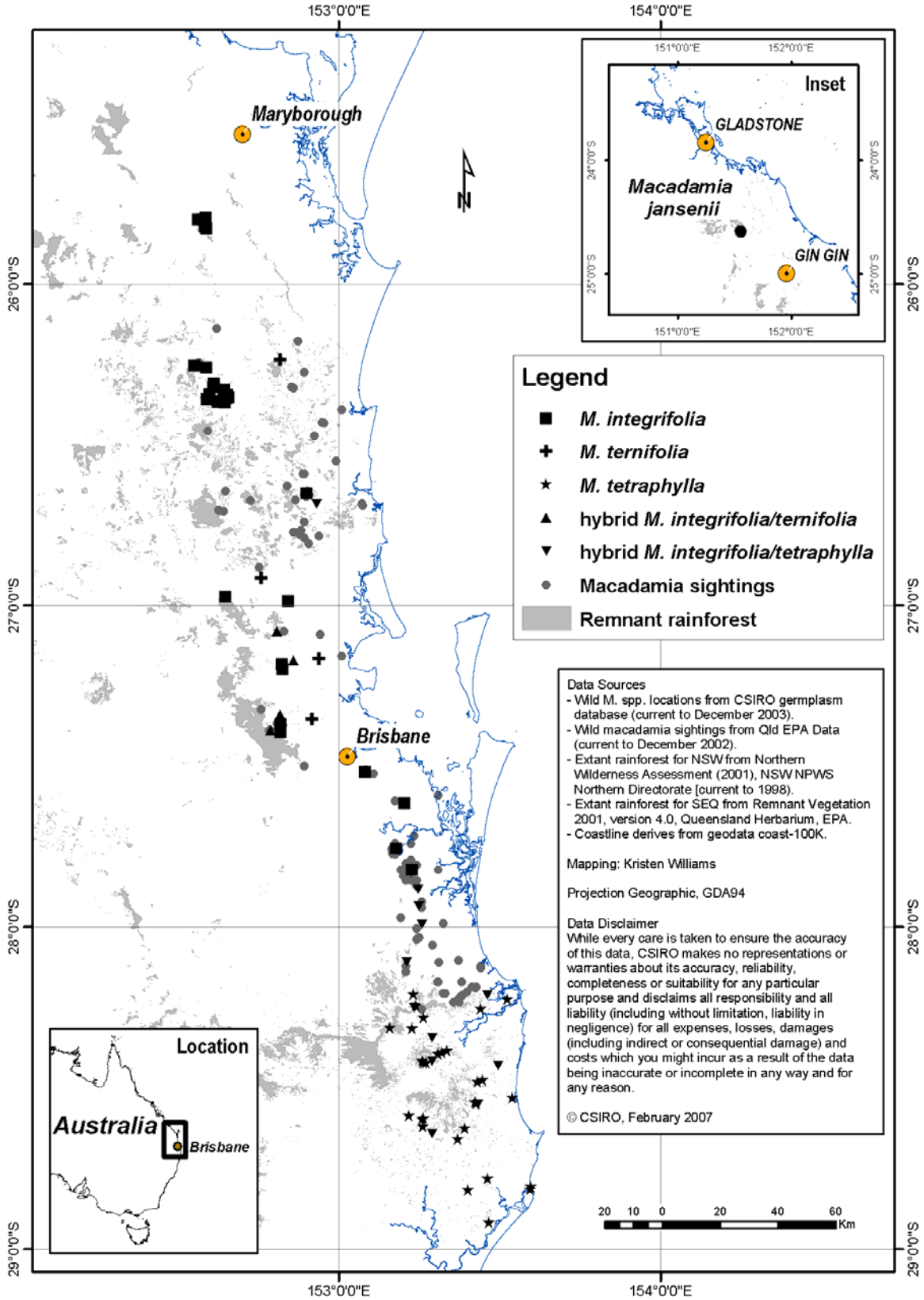
Detailed habitat information, in terms of soil, topographic position, climate, and regional ecosystems, is provided for each species.

Habitat critical to the survival of southern macadamia species includes:

- All areas currently occupied by each species.
- All areas currently occupied by *M. integrifolia/ternifolia* and *M. integrifolia/tetraphylla* hybrids.
- Areas of native vegetation which provide linkages between southern macadamia species' populations.

Areas of occupancy for all populations and the location of vegetation providing linkages between populations will be determined during the implementation of recovery actions.

Figure 1. Indicative distribution[1] of the four southern species of macadamia in Australia (Hardner *et al.* 2008; note that Macadamia sightings are unspecified).



[1] This map provides an overview of known southern macadamia species locations, and does not represent every known site.

Macadamia integrifolia (Queensland nut tree)

Description

Macadamia integrifolia (Queensland nut or Macadamia nut) is a long-lived perennial mid-storey evergreen subtropical rainforest tree to 20m tall, with greyish branchlets dotted with raised lenticels (Hauser and Blok 1992). Individuals are often multi stemmed with small crowns. The simple obovate to narrowly oblong leaves are arranged in whorls of three or opposite, and 5.5cm to 14cm long by 2.5cm to 6cm wide (Stanley and Ross 2002). Blade tips are rounded and finish in a short sharp point; the base tapers to petioles 5 to 10mm long. Axillary creamy-white flowers are arranged in brush-like hanging racemes 10 to 30cm long. Rounded fruits are green, 2.5 to 3.5cm wide with a hard brown inner shell protecting the edible nut. Flowering period is August to October with kernel maturation from December to March, with mature nuts falling to the ground thereafter.

Life history and ecology

Both introduced European honey (*Apis mellifera*) and native bees *Trigona* spp. appear to be the main pollinators, with native bees being superior pollinators. Seed dispersal is by small rodents and gravity fall, probably with some assistance from local stream flooding, although viable nuts tend not to float. There is evidence that the species prefers rainforest eco-tones where light levels are higher, however these areas are also relatively more fire prone. Hybridization has been documented between *M. integrifolia* and *M. ternifolia,* and between *M. integrifolia* and *M. tetraphylla* in areas where their range overlap. Natural inter-specific hybridization has been observed to occur in areas of range overlap between *M. integrifolia* and *M. tetraphylla,* and between *M. integrifolia* and *M. ternifolia* particularly where both species co-occur within a rainforest patch.

Genetic studies have been carried out on wild *M. integrifolia* DNA using RAFs (Radioactive Amplified DNA Fingerprinting) microsatellites and isozymes techniques (Neal 2007, Peace 2005). Both molecular marker evidence and evidence from variation for horticultural traits indicates there is moderate to high genetic diversity within the species and within populations (Neal 2007, Hardner *et al.* 2008). Results indicate some differentiation between populations in northern and southern regions however overall genetic differentiation between populations is moderate to low and increase with increasing distance between populations (> 50 km) indicating considerable past gene flow between populations. Evidence from paternity studies indicates considerable current gene flow by pollen occurs between populations even in a highly fragmented landscape (Neal 2007). These data indicate that the species may survive small population size if there is a network of small populations within a region (meta-population) that enable the maintenance of genetic diversity. *M. integrifolia* can hybridize with *M. tetraphylla* and *M. ternifolia*. Dispersal of pollen by flying insects and perhaps other flying organisms has ensured potential for gene flow even in modified landscapes (Neal 2007). However, little is known of fruit dispersal, except rodents that have been observed to move seeds from orchards into surrounding native bush habitat.

While small populations may be able to maintain themselves in a fragmented landscape where distances between patches are small, larger distances are not conducive to gene flow by pollen sufficient to maintain the genetic integrity of populations. The contrasting habitat matrix between populations may prevent dispersal of seed between these populations, except down creek lines. Therefore, if chance events lead to local population extinction, populations are not likely to be able to be replenished from neighbouring populations.

Distribution

Macadamia integrifolia is distributed along the foothills and coastal ranges of southeast Queensland from the NSW border to Mt Bauple near Maryborough, a distance of approximately 300 km. It is a scattered rare to occasional tree that is more common in the northern half of its range.

Habitat

The Queensland nut is found within lowland warm complex notophyll vine forest and Araucarian notophyll vine forest, which occur on basic and intermediate volcanics and alluvia in higher rainfall areas of southeast Queensland. This species occupies all topographic positions including ridges, scree slopes, foot slopes, gullies, benches and riverine terraces. Soils are predominantly alluvial or volcanic, well drained, often with significant surface exposure of rock fragments. Slope and aspect vary. Elevation range is 5 to 600m. Within suitable habitat, it is typically scantily distributed within the vegetation matrix.

Macadamia integrifolia is found in several rainforest regional ecosystems including complex notophyll vine forest, simple notophyll vine forest and simple microphyll-notophyll vine forest with emergent *Araucaria* and *Argyrodendron*. *M. integrifolia* is identified in the Queensland Herbarium Regional Ecosystem Description Database (REDD; EPA 2005) as occurring in Regional Ecosystems 12.3.1, 12.8.3, 12.11.10, and 12.12.16 (see Table 2). Note that the remnant extent of RE 13.3.1 is <10,000ha and 10-30% of the pre-clearing area remains (endangered). This ecosystem remains an important component in both dispersal amongst, and linkages between, *M. integrifolia* populations.

Populations

Both area of occupied habitat and the estimated extent of occurrence is unknown. Total population size is estimated to be 1000 mature individuals with almost 50 key populations with around 10-25 mature specimens at each locality. The site identifier (MGA northing), location, tenure, regional ecosystem, population size, and the priority (high, medium or low) of known population clusters of *M. integrifolia* throughout its distribution is summarised in Table 2.

Table 2. Known populations of *Macadamia integrifolia* in Australia by geographical cluster.

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
Bauple Group					**Medium**
7147100	Mt Bauple	National Park	Clear	>20	
7146400	Mt Bauple	Private property	Clear	>20	
7145600	Mt Bauple	Private property	Clear	<10	
7144100	Mt Bauple	Private property	Clear	>20	
7143400	Mt Bauple	Private property	Clear	>20	
Amamoor/Imbil Group					**High**
7096200	Gympie	State Forest	**12.3.1**	>20	
7095500	Mary River	Private property	Clear	10	
7090100	Mooloo	Private property	Clear	>20	
7088900	Mooloo	Private property	Clear	10-20	
7087958	Amamoor	State Forest	12.11.10	>20	
7086458	Amamoor	State Forest	12.11.10	>20	
7086100	Amamoor	Private property	12.11.10	20	
7085313	Amamoor	Private property	12.11.10	Unknown	
7085040	Amamoor	Private property	12.11.10	>20	
7084701	Amamoor	State Forest	12.11.10	>100	
7084479	Amamoor	Private property	12.11.10	>20	
7084100	Amamoor	State Forest	12.11.10	>20	
7083800	Amamoor	State Forest	12.11.10	<20	

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
7083556	Amamoor	Private property	12.11.10	20	
7076845	Mt Cooroy	State Forest	Clear	Unknown	
7075985	Imbil	State Forest	Unknown	Unknown	
7075099	Imbil	State Forest	Unknown	>20	
Blackall Range Group					**Medium**
7066750	Yandina	Unknown	*12.3.2*	Unknown	
7052092	Nambour	Conservation Reserve	12.8.3	>20	
7052100	Dulong	Private property	**12.3.1**	<20	
7048100	Palmwoods	Private property	Clear	10-20	
Samford/Pine Rivers Group					**Medium**
7016500	Villeneuve	Private property	Clear	>20	
7015000	Upper Caboolture	Private property	**12.9/10.16**	>20	
7004500	Campbells Pocket	Public land	Clear	10	
6994500	Moorina	Public land	Clear	>20	
6993200	Dayboro	Private property	Clear	<10	
6991600	Dayboro	Private property	**12.3.1**	<10	
6975709	Samford	Private property	Clear	10-20	
6972627	Olsen's Scrub	Private property	**12.3.1**	>50	
6972500	Samford showground	Public land	Clear	<10	
6970400	Mt Nebo	Private property	Clear	<20	
6970008	Samford	Private property	Clear	>20	
Southern Group					**High**
6956200	Holland Park	Public land	**12.3.1**	<10	
6956172	Carindale	Public land	Clear	<10	
6945600	Tingalpa	Public land	**12.3.1**	<10	
6945100	Mt Cotton	Private property	Clear	>20	
6929800	Belivah	Private property	Clear	10-20	
6924746	Beenleigh	Private property	12.11.10	Unknown	
6922500	Ormeau	Private property	Unknown	<10	
6922100	Ormeau	Public land	Clear	10-20	
6921100	Ormeau	Public land	Clear	<10	
6920404	Willow Vale	Private property	Regrowth	>20	
6915300	Upper Coomera	Private property	Clear	10-20	

Macadamia jansenii (Bulburin nut tree)

Description

Macadamia jansenii is a small, single or multi-stemmed tree 6-9m tall, with generally smooth bark dotted with prominent lenticels (Halford 1997). The oblanceolate to oblong-elliptic leaves are generally arranged in whorls of three, are 10-18cm long with an acute apex, tapered base and wavy margins (Harden *et al.* 2006). Net venation on leaf blades is distinct on both surfaces, especially when held up to the light. Petioles are 2-14mm long. The cream-brown flowers have tepals that are 7-9mm long; flowers have been observed in July and September. The globose fruit are 20-25mm in diameter. The kernel is mildly cyanogenetic and not edible.

Life history and ecology

Very little is known about the life history and ecology of this species. It is thought that the Bulburin nut tree is pollinated by native bees and seed dispersed by vertebrates (Gross and Weston 1992). Many of the mature individuals are multi-stemmed, suggesting that the species may facultatively resprout in response to fire or the impact of localised flooding.

Distribution

Endemic to central Queensland, *Macadamia jansenii* is known only from a 6000m^2 area restricted to the upper catchment of Granite Creek in Bulburin National Park (Gross and Weston 1992).

Habitat

Macadamia jansenii is found on steep, rocky, hilly terrain at about 350m above sea level, where it occurs on well drained, red brown, sandy clay loams (Gross and Weston 1992). All known individuals are found within 20m of a tributary of Granite Creek. *M. jansenii* is identified in the Queensland Herbarium REDD (EPA 2005) as occurring in Regional Ecosystem 12.12.13 (see Table 3). This form of simple notophyll vine forest is characterised by *Araucaria cunninghamii* (hoop pine), *Alangium villosum* (canary muskheart), *Argyrodendron trifoliatum* (brown tulip oak), *Baloghia inophylla* (scrub bloodwood), *Brachychiton discolor* (scrub bottletree), *Dendrocnide photinophylla* (shiny-leaved stinging tree) and *Harpulia pendula* (tulipwood).

Populations

The occupied habitat is approximately 10 hectares and the estimated extent of occurrence is approximately <2 km^2. Total population size is estimated to be 21 mature individuals in one population.

The site identifier (MGA northing), location, tenure, regional ecosystem, population size, and the priority (high, medium or low) of the known population of *M. jansenii* is summarised in Table 3.

Table 3. Known populations of *Macadamia jansenii* in Australia.

Site Identifier	Location	Tenure	RE Rem	Pop Size	Priority
7208293	Bulburin National Park, southwest Miriam Vale	National Park	12.12.13	21[2]	**High**

[2] Gross and Weston (1992) indicate that up to 33 individuals may constitute the known population of *Macadamia jansenii*, however a recent field-based investigation (April 2007) led by the University of the Sunshine Coast yielded only 21 individuals.

Macadamia ternifolia (Gympie nut)

Description

Macadamia ternifolia (Gympie nut) is a perennial lower storey evergreen subtropical rainforest tree to 6m tall, with brown branchlets dotted with raised lenticels (Hauser and Blok 1992). The simple, narrow-oblong to narrow-elliptical leaves are arranged in whorls of three, and 10-12cm long; new growth is pinkish red. Blade tips are pointed and the base tapers to petioles 3 to 13mm long (Stanley and Ross 2002). Axillary pinkish flowers are arranged in brush-like hanging racemes 4-20cm long. Compressed rounded fruits are greyish, 1.5-2cm long with a hard inner shell protecting the edible nut. The seed kernel is cyanogenetic and not edible. Flowering period is August to September with fruiting occurring from March to April (Hauser and Blok 1992).

Life history and ecology

Very little is known about the life history and ecology of this species. Both introduced European honey and native bees appear to be the main pollinators, with native bees *Trigona* spp. being superior pollinators. Seed dispersal is by small rodents and gravity fall, probably with some assistance from local stream flooding.

Distribution

Macadamia ternifolia is endemic to southern coastal Queensland, with a known national distribution of scattered populations extending from Goomboorian south to the Pine River.

Habitat

Gympie nut is found within lowland warm complex notophyll vine forest and Araucarian notophyll vine forest on basic and intermediate volcanics and alluvia in higher rainfall areas of southeast Queensland. This species occupies a range of topographic positions, typically scree slopes, foot slopes, gullies, benches and riverine terraces. Soils are alluvial or volcanic derived basaltic krasnozems, well drained, with significant surface exposure of rock fragments. Topographical locations are generally south facing rainforest gullies and scree slopes. It is scantily distributed in small clusters within the vegetation matrix.

Macadamia ternifolia is found in several rainforest regional ecosystems including complex notophyll vine forest, simple notophyll vine forest and simple microphyll-notophyll vine forest with emergent *Araucaria* and *Argyrodendron*. *M.ternifolia* is identified in the Queensland Herbarium REDD (EPA 2005) as occurring in a range of Regional Ecosystems including 12.3.1 (endangered), 12.8.3, 12.11.10, 12.12.1 and 12.9 – 10.16 (see Table 4). RE's 12.12.1 and 12.9-10.16 are classed as of concern with less than 30% pre-clearing remaining within a restricted remnant extent.

Populations

The occupied habitat is approximately 500 hectares and the estimated extent of occurrence is approximately 8000 km^2. Total population size is estimated to be between 1000 – 2000 mature individuals with approximately 20 key populations with around 5-20 mature specimens at each locality. Significant clusters occur in the Blackall Range Group with similarly important cluster populations in the Gympie/Kin Kin Group and Nambour/Buderim Group (densest cluster population). The area incorporating the Gympie/Kin Kin group including Mothar Mountain, Woodum Range and Mt Pinbarren is considered significant due to the genetic isolation of these populations from other species of Macadamia. The site identifier (MGA northing), location, tenure, regional ecosystem, population size, and the priority (high, medium or low) of known population clusters of *M.ternifolia* throughout its distribution is summarised in Table 4.

Table 4. Known populations of *Macadamia ternifolia* in Australia by geographical cluster.

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
Northern Group					**High**
7104580	Mt Wolvi	Unknown	*12.8.13*	Unknown	
7098300	Beenham Range	Private property	Unknown	<10	
7093846	Kin Kin	Private property	12.11.10	Unknown	
7089227	Mt Pinbarren near Pomona	National Park	12.11.10	<20	
7080930	Mt Tinbeerwah, Tewantin	Forest Reserve	12.8.3	Unknown	
7078158	Maroochy River, Eumundi	Unknown	12.11.10	Unknown	
7076652	Mt Cooroy	National Park	*12.8.13*	<20	
7075799	Mitchell Creek Road	Unknown	**12.3.1**	Unknown	
7062994	Mt Ninderry	Unknown	12.12.14	Unknown	
Central Group					**Medium**
7058744	Kureelpa Falls	Council Reserve	12.8.14	Unknown	
7056887	Little Yabba Forest	State Forest	12.11.3	Unknown	
7052115	Booloumba Creek	National Park	12.11.10	Unknown	
7051393	Triunia NP	National Park	12.12.15	10-20	
7050715	McIntyre property, Woombye	Private property	**12.3.1**	<20	
7050464	Kondalilla Falls	National Park	*12.12.1*	Unknown	
7049520	Walli State Forest	State Forest	12.11.3	<10	
7047702	Cunnington property Buderim	Private property	12.9/10.7	Unknown	
7047699	Montville, Blackall Range	Unknown	12.8.8	Unknown	
7042161	Obi Obi Gorge	Unknown	12.8.3	Unknown	
7039208	Hightor Reserve	Con. Reserve	12.8.3	Unknown	
7037546	Mary Cairncross Park	Nature Reserve	12. 12.8.3.	<20	
7037213	Mooloolah River headwaters	Forest Reserve	12.9-10.17	Unknown	
7035378	Policeman Spur	Con. Reserve	12.12.16	<20	
7034656	London Creek NW Beerwah	Unknown	**12.9-10.16**	Unknown	
7022800	Woodford	Private property	Unknown	<10	
7004500	Campbells Pocket	Public land	Clear	>20	
7004474	Hughes property, Wamuran	Private property	12.11.10	Unknown	
Southern Group					**High**
6996017	Burpengary Creek	Council Reserve	**12.3.6**	<20	
6994500	Moorina	Public land	Clear	10-20	
6985838	Lacey's Creek, Dayboro	Unknown	12.11.3	Unknown	
6978426	Love Creek Falls, Mt Glorious	National Park	*12.12.1*	Unknown	
6974300	Draper's Crossing	Public land	Riparian	<10	
6972627	Olsen's Scrub	Private property	**12.3.1**	>20	
6970649	Goat Track at Manorina	National Park	12.12.16	Unknown	
6970400	Mt Nebo	Private property	Clear	<20	
6970338	Mt Glorious	State Forest	12.12.16	Unknown	
6910892	Pine Ridge Road	Unknown	12.3.5	Unknown	

Macadamia tetraphylla

Description

Macadamia tetraphylla (Queensland nut or Rough-shelled bush nut) is a perennial mid-storey evergreen subtropical rainforest tree to 18m tall, with greyish-brown branchlets dotted with pale elongated lenticels (Hauser and Blok 1992). The simple oblong lanceolate leaves are arranged in whorls of three to four, 6-20cm long and 2-4cm wide. Blade tips are pointed, margins sharply serrated and petioles are 2-8mm long (Stanley and Ross 2002). New leaves of *M. tetraphylla* are bright red in colour, whereas those of *M. integrifolia* are light green. Axillary pinkish purple flowers are arranged in brush-like hanging racemes 15-45cm long. Compressed rounded fruits are greyish-green, 2-3.5cm wide with a hard inner shell protecting the nut. The seed kernel is edible and not cyanogenetic. Flowering period is August to September with fruit maturing and falling from March (Hauser and Blok 1992).

Life history and ecology

Very little is known about the life history and ecology of this species. Pollination is similar to other Macadamia species. Seed dispersal is by small rodents and gravity fall, probably with some assistance from local stream flooding. *M. tetraphylla* has moderate to high genetic diversity recorded within the species and its populations, however very low genetic differentiation between populations has been recorded at a regional scale (Peace 2005).

Distribution

Macadamia tetraphylla is endemic to eastern Australia, with a known national distribution of scattered populations extending from the Coomera River south of Brisbane to the Richmond River in northern New South Wales, and an altitudinal range of 100-800m. *M. tetraphylla* is found within the Big Scrub, which has been extensively cleared, substantially altering the original distribution.

Habitat

Macadamia tetraphylla is found in several regional ecosystems from complex notophyll vine forest to littoral rainforest to wet sclerophyll communities. *M. tetraphylla* is identified in the Queensland Herbarium REDD (EPA 2005) as occurring in several rainforest ecosystems including 12.2.1, 12.3.2, 12.8.8, 12.9/10.16 and 12.11.15 which are considered of concern or endangered (see Table 5). In NSW, *M. tetraphylla* occurs in several Endangered Ecological Communities, including lowland rainforest in the NSW North Coast and Sydney Basin Bioregions, littoral rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions, and lowland rainforest on floodplain in the NSW North Coast Bioregion.

Populations

Both the area of occupied habitat and the estimated extent of occurrence is unknown. Total population size is estimated to be between 1000 – 2000 mature individuals with approximately 75 key populations with around 5-20 mature specimens at each locality.

The site identifier (MGA northing), location, tenure, regional ecosystem, population size, and the priority (high, medium or low) of known population clusters of *M. tetraphylla* throughout its distribution is summarised in Table 5. As per the discussion on page 10, there are large areas of range overlap between *M.tetraphylla* and *M.integrifolia*, with a significant number of sites occupied by both species in areas of respective range overlap, with hybridisation occurring between pairs of co-occurring species (Peace 2005).

Table 5. Known populations of *Macadamia tetraphylla* in Australia.

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
Northern Group					**High**
6924919	Pimpama River, Ormeau	Council Reserve Private property	12.8.4	>20	

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
6915699	Curry Road, Wongawallan	Private property	12.12.16	>20	
6915300	Upper Coomera	Private property	Clear	10-20	
6914527	Oxenford Road, Upper Coomera	Unknown	*12.11.15*	Unknown	
6913025	Wallaby Lookout	Unknown	**12.9/10.16**	Unknown	
6911790	Otmoor Road, Coomera River	Unknown	12.3.7	Unknown	
6911502	Mt Tamborine NP	National Park	12.8.3	Unknown	
6909600	Guanaba River Park, Beenleigh	Public Land	12.8.3	10-20	
6904608	Clagiraba Creek north Clagiraba Rd	Private property	Unknown	<10	
6894000	Waters Road, Bonogin	Unknown	12.11.2	Unknown	
6890697	Mudgeeraba SF	State Forest	12.11.5	Unknown	
6890400	Beechmont	Private property	Unknown	<10	
6889628	Rosins Lookout	Unknown	12.8.3	Unknown	
6888523	Numinbah SF	State Forest	12.11.5	Unknown	
6887500	Smith Street, Bonogin	Roadside	12.11.2	Unknown	
6882441	Paradise Valley, Austinville	Unknown	12.11.2	Unknown	
6882413	Nicholls Scrub NP	National Park	12.8.3	Unknown	
6881963	Clagiraba FR	Forest Reserve	12.11.3	Unknown	
6881627	Tallebudgera Valley	Council Land	*12.3.2*	10-20	
6880602	Kuralboo Creek	Unknown		Unknown	
6879300	Cave Creek crossing	Public Land	*12.8.8*	>20	
6878209	Currumbin Valley	Private property and roadside	12.11.2	<10	
Mt Warning Caldera					**Medium**
6877685	Palm Springs, Numinbah	Unknown	*12.8.8*	Unknown	
6877532	Cave Creek Road, Numinbah	Roadside	*12.8.8*	<10	
6876951	Ewerts Road, Natural Bridge	Private property	*12.8.8*	<10	
6876620	Natural Bridge	National Park	12.11.3	>20	
6876340	Tomewin CP	Conservation Park	12.11.2	Unknown	
6875612	Camp Eden	Private property	12.11.2	Unknown	
6875085	Lamington NP	National Park	12.8.4	Unknown	
6874500	Camp Bornhoffen, Numinbah Valley	Private property	*12.8.8*	>20	
6878800	Terranora Country Club, Bilimbil	Private property	Unknown	>20	
6877600	Banora Point	Public Land		<10	
6875051	Crystal Creek Retreat	Private property		<10	
6874200	Hogans Scrub	Public Land		<10	
6871200	Couchy Creek	Public Land		10-20	
6867700	Limpinwood NR	Nature Reserve		<10	

Site Id	Location	Tenure	RE Rem	Pop Size	Priority
6867500	Limpinwood Road	Public Land		>20	
6864200	Everests Road, Eungella	Private property		>20	
6860296	Wollumbin NP	National Park		>20	
6860289	Mt Warning NP	National Park		Unknown	
6860000	Mt Warning Road	Private property		>20	
6859300	Sia School	Private property		10-20	
6858900	Wollumbin Refuge	Private property		>20	
6856500	Uki	Private property		>20	
6856200	Palmers Road, Uki	Private property		>50	
6856514	Burringbar Creek	Unknown		Unknown	
6855800	Cedar Creek	Private property		<10 x 2	
6854500	Mooball-Pottsville Road	Private property		>20	
6849800	Inner Pocket NR	Nature Reserve		<10	
6849100	Blindmouth	Private property		>20	
6845178	Settlement Road, Main Arm	Council Land	Regrowth	<10	
6843700	Brunswick Heads NR	Nature Reserve		<10	
Big Scrub Group					**High**
6843659	Nightcap NP	National Park		Unknown	
6841300	Left Bank Rd Mullumbimby	Private property		>20 x 3	
6839951	Whian Whian SCA	State Conservation Area		Unknown	
6839946	Goonengerry	National Park		<10	
6837600	Nimbin (northern edge)	Public Land		<10	
6836724	Nimbin	Public Land		<10	
6836700	Tuntable Creek Road	Public Land		<10	
6836210	Lismore	Private property		10-20	
6833900	Tuntable Creek Road via Nimbin	Private property		>20	
6833200	Nightcap NP	National Park		10-20	
6831300	Towns Road, The Channon	Private property		>20	
6829400	Corndale Rd, Dorroughby	Private property		<10	
6826838	Dunoon	Unknown		Unknown	
6826221	Byron Creek, Bangalow	Unknown		Unknown	
6815900	Old Tintenbar Road	Private property		>20	
Southern Group					**High**
6813100	Amber Dr, Lennox Head	Public Land		>20	
6812548	Lennox Head	Council Reserve		<10	
6812100	Castle Dr, Lennox Head	Private property		>20	
6812000	Wollongbar	Public Land		<10	
6802575	Victoria Park NR	Nature Reserve		<10	
6800700	Coolgardie Road via Ballina	Private property		>20	
6736208	Clarence River	Unknown		Unknown	

3. Threats

Biology and Ecology relevant to Threats

Inappropriate Fire Regimes

Fire is a recognised disturbance phenomenon that alters the composition of a community by killing some plants, stimulating vegetative regrowth in others, and promoting widespread germination of seed when temperatures are sufficient to break seed dormancy (Whelan 1995). Different plant species vary in their fire regeneration strategies, but all are affected by spatial and temporal variation in the fire regime (fire frequency, intensity, and season). There is evidence that some rainforest species resprout strongly following fire (Williams 2000) and that rainforest elements found in wet sclerophyll forest can survive repeated low intensity fires (Donatiu 2007 unpublished data).

Land Clearing and Fragmentation

Remnant bushland throughout southeast Queensland and northeast New South Wales is threatened by clearing for horticulture, agriculture and grazing, and substantial urban and industrial development. The continued fragmentation and isolation of these vegetation communities makes it increasingly difficult to maintain ecological processes and diversity in the patches that remain. Isolated populations or individual trees may have lower reproductive potential, if effective pollinators and dispersers are more readily attracted to larger or more intact populations.

Habitat Modification by Weeds

Weeds displace native flora, compete for resources (such as pollinators, light, nutrients and water), create habitats that are conducive to other exotic species, and alter the composition of vegetation communities. For example, increases in the abundance of lantana (*Lantana camara*) and exotic grasses (such as green panic – *Panicum maximum*) at rainforest margins can substantially raise fuel loads and affect both fire intensity and frequency. Weeds can also cause changes in ecosystem function and the way species interact, influencing patterns of pollination, competition, and the dispersal of seeds. The interface between bushland and other land uses is particularly susceptible to the spread of exotic species that flourish in this altered environment and displace native species. Species that pose a direct threat to rainforest communities are lantana (a weed of national significance) and exotic vines such as cat's claw creeper (*Macfadyena unguis-cati*).

Small Population Size/ Reduced Gene Flow

Most macadamia species locations in this Plan contain small populations. When population size is reduced, genetic integrity and population viability may be compromised, sometimes resulting in inbreeding; there is also the potential loss of local genetic strains through hybridisation with commercial macadamia varieties (NSW NPWS 2002). Data indicate that macadamia populations in more fragmented small remnants have higher reproductive success and greater regeneration than populations in larger more intact fragments, thus fragmentation itself does not appear to negatively affect population demography and regeneration (Neal 2007). Macadamia species maintain themselves via suckering and are likely to be able to survive single rare fire events, possibly explaining how these species have retained high level of genetic diversity despite naturally small population sizes.

Macadamia populations will also potentially maintain genetic diversity within fragmented small populations via gene flow due to pollen, maintaining themselves via a meta-populations structure rather than acting as isolated independent populations. Fragmentation may increase pollinator movements between fragments as pollinators are forced to search for flowers in the landscape and this could increase levels of gene flow between populations within a local region. Pollinators are likely to be sensitive to changes in the intervening habitat matrix.

Whilst *in situ* macadamia populations are likely to be able to maintain themselves in a fragmented landscape better than some other species, there is less evidence that populations are able to be recolonised or rescued by neighbouring populations. Seed dispersal will be affected by land use changes, making populations susceptible to stochastic events, leading to local population extinction. Actions which enhance connectivity between populations may enable new populations to establish within suitable habitat currently, and provide opportunities for population expansion and recolonisation (Lindenmayer and Burgman 2005).

Climate Change

It is anticipated that global warming will significantly alter the distribution of rainforest ecosystems in Australia. The four species covered by this Plan inhabit forests at a range of altitudes, which may still be affected by increasing temperatures and variable rainfall patterns. In particular, macadamia populations at the extreme of an individual species' latitudinal range may be affected by climate-induced variation in temperature and rainfall. Climate change will also affect the timing of phenology, the initiation of flowering pollination vectors, and the maturation of fruit in macadamia and other species. Given these species are known to have range overlap, and are known to have considerable variation in timing of phenology, it is anticipated that climate change is likely to either lead to increased or decreased potential for hybridization between the species. Further since both onset of flowering and maturation of fruit are known to be determined by climatic parameters we can predict that elevated temperatures and decreased rainfall at specific times of the year will reduce the reproductive capacity of natural populations in those parts of the ranges affected, especially at the edges of the species distributions. Finally, climate change may exacerbate other existing threats such as fire and weeds. For example, climate change may alter the distribution and abundance of some weeds, particularly exotic vines at remnant edges, creating additional concerns for land managers seeking to conserve populations in small fragments.

Identification of Specific Threats

Macadamia integrifolia

The major threats facing *M. integrifolia* have arisen as a consequence of land clearing, and are shared by the rainforest community that co-occurs with the species. These include loss and fragmentation of habitat, with associated consequences such as change in community composition, habitat degradation due to edge effects, weed invasion, reduction in connectivity among populations, and potentially reduced gene flow through changes in pollination and dispersal vectors.

Adjacent land uses such as grazing, urban development, or cropping (with their associated impacts of herbicide usage, nutrient runoff from fertilizers, and changed hydrology) can adversely affect remnant patches of rainforest vegetation. Many recorded *M. integrifolia* sites are located in small patches of remnant vegetation that are too small in area and/or too degraded to be mapped as remnant vegetation. At several sites the population comprises a number of single trees retained for their edible nuts when the original vegetation was cleared.

Only a minority of recorded *M. integrifolia* sites are located within protected areas, and these are often threatened by weeds and fire. Macadamia trees can be killed by intense or too frequent fires.

Threats to the genetic resources of *M. integrifolia* include loss of individuals and populations through ongoing habitat degradation, inbreeding depression in small and/or isolated populations and inappropriate selection of genetic material (i.e. a small number of genetically diverse individuals) for reintroduced populations sourced from *ex-situ* gene banks.

Loss of populations through ongoing land clearing for urban development or agriculture is a significant ongoing threat to *M. integrifolia*. Many sites are located in areas that are threatened by urban development arising from population pressures facing the region. Remnant populations on private property have limited protection or security of tenure.

On the basis of the currently available information the fundamental actions that will provide a significant reduction in threat level at the majority of *M. integrifolia* sites are protection from clearing for development, weed management, managed grazing, modification or elimination of inappropriate fire regimes, natural regeneration, and restoration of those sites where individual trees are located in open ground.

Macadamia jansenii

The major threat affecting the Bulburin Nut is that the known distribution is restricted to one population in an area that occupies less than a hectare. This makes the species highly susceptible to a single disturbance event (such as fire) or disease. Notwithstanding the effort to date, it also reinforces the need to search for additional populations and establish either a second population or an *ex situ* gene bank for the species.

Threats to genetic resources are increased due to the single population, the movement of self-pollen and resultant reproductive outputs (or lack of) depending on the mating system of the species (i.e. inbreeding depression of the species is self-compatible). Wildfire and inappropriate fire regimes are significant threats to *M. jansenii*. Extended drought conditions exacerbated by rising temperatures may provide the conditions for fire to erode the rainforest mantle that protects the existing population. Lantana is also found in canopy breaks downstream of the source population, but is not currently threatening individual trees.

Macadamia ternifolia

Macadamia ternifolia faces a similar suite of threats to *M. integrifolia* – habitat modification by weeds, altered fire regimes, loss of connectivity between populations, and reduced gene flow where pollinators or dispersers have been affected. It is unclear whether biological threats,

such as insects and fungus, are exacerbated by these threatening processes. Riparian and riverine corridors, once critical habitat linkages, have been extensively cleared for agriculture and subsequent urban development, especially in the Sunshine Coast lowlands. Remnant notophyll vine forests are prone to invasion by weed trees such as camphor laurel (*Cinnanmomum camphora*) and weed vines such as cat's claw creeper (*Macfadyena ungis-cati*) on disturbed margins and edges. Many remnants are often too narrow to be mapped at 1:10 000 scale which places constraints on identification of habitat sites. Enhancing habitat linkages and providing appropriate management and protection of small linkage populations is considered important for maintenance of meta-population structure.

Habitat in western areas of the species distribution has also been extensively cleared for pasture, cropping and forestry. These remnants can be degraded by weed infestation in conjunction with wildfire damage on margins.

Macadamia tetraphylla

Macadamia tetraphylla faces a similar suite of threats to *M. integrifolia* and *M. ternifolia* – habitat modification by weeds, altered fire regimes, loss of connectivity between populations, reduced gene flow where pollinators or dispersers have been affected, and illegal collection of viable plant material (fruits, cuttings and seedlings). The high urban growth zone from Beenleigh to the Gold Coast represents a major threat to local remnant wild *M. tetraphylla* and *M. integrifolia* populations which are subject to intense pressure from urban expansion and subdivision. Some roadside populations are subject to road widening and ongoing maintenance (slashing, spraying).

Furthermore, the diversity of *M. tetraphylla* habitats presents complex challenges to effectively manage threatening processes. Those coastal populations found in littoral rainforest are highly susceptible to fragmentation and edge effects resulting from clearing for urban development and other land uses. These areas are also vulnerable to invasion by aggressive weeds, such as lantana and asparagus fern, which can modify remnant structure and composition. In NSW, *M. tetraphylla* has been identified as a species at risk from bitou bush *(Chrysanthemoides monilifera)* (DECC 2006).

Populations that occur in wet sclerophyll forest (WSF) face contentious views over how fire should be managed in this vegetation type. Recently, the southeast Queensland Fire and Biodiversity Consortium published fire management guidelines for WSF based on a fire frequency of 20-100 years (Watson 2001). Similar work has recently been completed by the NSW Hotspots Fire Project for Northern Rivers' vegetation communities (Watson 2006). The proliferation of woody weeds at remnant edges can provide sufficient fuel to increase both fire frequency and intensity in these remnants. Groups such as the Brisbane Rainforest Action and Information Network have experimented with replacing degraded remnant edges with layered native edge plantings designed to provide sufficient lateral branching and leaf massing to 'seal' remnant edges (Donatiu pers. comm. 2008), but such closure has yet to be attempted in WSF remnants.

Threats Summary

Species	Threats	Current Actions	Future Actions
All Species	❖ Land clearing, fragmentation, loss of connectivity	❖ Resources to restore rainforest habitat provided to private landholders under SEQ Rainforest Recovery Project	❖ Liaison with SEQ Rainforest Recovery Project and other programs to access resources for landholders who wish to protect macadamia habitat on their property ❖ Provision of additional resources to land managers to rehabilitate macadamia habitat
	❖ Inappropriate fire regimes	❖ Designation of ecologically appropriate fire regimes for WSF and rainforest communities (SEQFBC/NSW Hotspots Fire Project)	❖ Provision of fire and biodiversity workshops to land managers responsible for managing macadamia habitat
	❖ Habitat modification by weeds	❖ Some management of weed incursions at selective sites that provide habitat for populations of southern macadamia species ❖ Preparation of Qld and NSW lantana TAP ❖ Preparation of a NSW TAP for bitou bush and boneseed (DEC 2006)	❖ Provision of resources to land managers to reduce the impact of specific weed species in areas of known essential habitat
	❖ Lack of managed grazing	❖ Rebates for fencing under Australian Government funding programs	❖ Provision of resources to land managers to reduce the impact of grazing in areas of known essential habitat
	❖ Reduced gene flow	❖ Studies of genetic characterisation of macadamia species and impact of habitat fragmentation on the population viability (CSIRO and USC) ❖ Development of *ex-situ* gene banks	❖ Targeted research on population genetics
	❖ Climate change	❖ Identification of climate change corridors for rainforests in northeast NSW and SEQ in Border Ranges Rainforest Biodiversity Management Plan (DECC in prep.)	❖ Modelling of the projected impact of climate change on the ecology, distribution, and habitat of southern macadamia species
Macadamia jansenii	❖ Lack of *ex-situ* gene bank	❖ Nil	❖ Establishment of an *ex-situ* gene bank for *Macadamia jansenii* at all three trial sites

4. Recovery Objectives, Performance Criteria and Actions

Overall Objective

The overall objective of the Southern Macadamia Species Recovery Plan is:

To protect known wild populations of the four nominated species from decline, ensure their long-term viability, and raise awareness of flora conservation issues within the community

Performance Criteria

1. New populations of southern macadamia species are identified and recorded on State databases.

2a. Sustainable land management strategies are developed and implemented to reduce the impact of threatening processes in habitats critical to the survival of southern macadamia species.

2b. Increase in landholder capacity to manage and conserve threatened southern macadamia species populations.

2c. Increase in the number of on-ground works undertaken by land managers to manage priority macadamia habitat.

3a. Priority research needs identified by the Macadamia Conservation Research Network in conjunction with local land managers, developed into research briefs and implemented by researchers.

3b. New ecological information is incorporated into land and species management manuals and made available to land managers in biennial workshops.

4a. Increase in public awareness of the environmental, cultural and economic significance of threatened southern macadamia species.

4b. Increase in land managers capacity to manage and conserve threatened southern macadamia species populations.

5. Progress made on the completion of recovery plan actions is reviewed annually.

Objectives and Actions

1. Identify and evaluate the extent and quality of southern macadamia species populations and their habitat

1.1 Determine whether additional populations of macadamia species occur within southern Queensland and northern NSW

Searches will target areas likely to provide habitat for macadamia species, especially nominated regional ecosystems. All new information will be incorporated into state databases such as Queensland DERM Wildnet and New South Wales Atlas of NSW Wildlife and PlantNET, and provided to DEWHA.

1.2 Survey known macadamia populations for data deficiencies (including size, distance to nearest population, and reproductive viability) and prioritise macadamia populations for conservation, management and research purposes

Many records of macadamia populations are data deficient, prohibiting their prioritization for management. Others are dated, and the populations may have been lost to clearing, or are not true wild populations. Habitat which is important for survival, including the area occupied by populations, and habitat linking populations, will be identified. Once this information has been collected, southern macadamia species populations can be prioritised for conservation, management and research.

2. Reduce and manage the major threatening processes affecting southern macadamia species habitat

2.1 Negotiate appropriate agreements with landholders to establish greater long-term security for priority areas on private property

Where there is strong interest, landholders with significant populations of threatened macadamia species will be encouraged to enter into a management contract with local regional bodies, Voluntary Conservation Agreement (VCA), or a perpetual conservation agreement such as a Nature Refuge.

2.2 Provide information to land managers (landholders, macadamia growers, etc.) and decision-making authorities to ensure that known locations of macadamia species are considered for protection when making development decisions

Southern macadamia populations are found throughout the fastest growing region in Australia. Land managers and approval authorities require detailed information about the location and priority of remnant populations to improve decisions made in regard to developments that may impact on these populations or exacerbate the threatening processes that they face.

2.3 Encourage land managers to develop management plans using existing information and/or new information as it becomes available

Land managers that want to protect macadamia habitat on property that they manage will be strongly encouraged to develop management plans to:

- Achieve long-term protection of macadamia habitat appropriate to the tenure of the habitat.
- Reduce the impact of weed species.
- Manage grazing in priority population areas.
- Rehabilitate priority population areas.

2.4 Provide practical resources to land managers for the long-term protection of macadamia habitat appropriate to the tenure of the habitat

Practical resources are required to remove invasive weeds, erect fences, manage grazing, and provide labour and provenance protocols (to source seed and tube stock) to rehabilitate macadamia habitat and undertake restoration plantings.

2.5 Identify, map, control and monitor weed threats for priority populations

The impact of weeds on macadamia populations and habitat is variable. Weed incursions need to be identified, mapped and monitored as a means of prioritizing their control and management, particularly in areas where they contribute to the exacerbation of other threatening processes (such as fire intensity and frequency).

2.6 Conduct fire and biodiversity workshops with land managers responsible for managing macadamia habitat as a means of developing fire management plans

Recent efforts by QDERM to develop fire regimes for bioregional vegetation types will be incorporated into workshop proceedings. Annual workshops will include information on fire management planning, fire ecology, and provide practical operational tools for the effective management of threatened species populations.

2.7 Model the projected impact of climate change on the ecology, extent of habitat, and processes that threaten southern macadamia species

Climate change will affect the phenology, flowering, fruit maturation, hybridization between, and reproductive capacity of macadamia species. Modeling climate impacts may assist with the prioritization of management actions in later years of the Plan.

2.8 Establish an *ex-situ* conservation program for *Macadamia jansenii* at multiple sites

The known distribution of this species is restricted to one population. It is critical that *ex-situ* gene banks in the form of planted specimens be established for *Macadamia jansenii* at existing *ex-situ* sites at Tiaro and Burpengary.

2.9 Establish monitoring programs for priority threatened macadamia populations
Using an accepted pro-forma (that includes triggers for management responses), this action will provide land managers with a resource tool to monitor the health and condition of remnant threatened macadamia populations. Information will be held by local regional bodies and made available to the MCC.

2.10 Review and amend the macadamia industry Code of Sound Orchard Practice to reflect knowledge of threats to wild populations
Growers and planners require an industry code of practice, based on sound research, that provides' guidelines for the development of new commercial macadamia plantations. This is an area requiring significant research and investigation before conclusive recommendations about the placement of new commercial plantings can be made. On the basis of this research, recommendations on how to reduce the threat of genetic contamination to wild stock may need to be incorporated into this Code of Practice.

3. Increase knowledge of southern macadamia species and their ecology to effect their conservation and management

3.1 Develop research priorities for conservation
All macadamia species in this plan are affected by one or more threatening processes. The absence of information on mechanisms to address some of these threatening processes will direct the selection of research priorities (for example, determining the genetic diversity of distinct populations, identifying appropriate sites to enhance linkages between populations, examining the potential impact of climate change on pollinators, determining the impact, tolerance and requirements for disturbance, and identifying opportunities to reintroduce populations within clusters to maintain connectivity and enhance diversity).

3.2 Continue to liaise with research institutions to address prioritised research gaps
MCRN will continue to generate and resource research priorities.

3.3 Facilitate Aboriginal participation and the use of traditional knowledge in the recovery of southern macadamia species
Consultation with traditional owners with a relationship to country providing habitat for wild macadamia populations indicated that most of these sites had never been surveyed for indicators of their cultural importance.

4. Improve awareness and understanding of southern macadamia species, especially the management requirements of these species and their major threats

4.1 Develop community education tools that build understanding of the conservation management requirements of southern macadamia species
Land managers require additional information about the native flora found on their properties, particularly threatened species. The MCC will investigate opportunities to: distribute macadamia species profiles to local landholders, sign significant roadside remnants, profile species in local newspapers, and develop fact sheets on threatening processes.

4.2 Liaise with State Agencies, Local Authorities and Regional Bodies in order to incorporate macadamia conservation into their biodiversity conservation and natural resource management strategies

State Agencies, Local Authorities and Regional Bodies provide substantial resourcing for on-ground conservation. Strategies that direct these resources, or assist in managing threats, should include management actions consistent with the protection and conservation of macadamia populations.

5. Manage, monitor and evaluate the Southern Macadamia Species Recovery Plan

5.1 Maintain the role of the Macadamia Conservation Committee as the coordinating body for the recovery plan

The MCC currently includes representatives from DEWHA, SEQ Catchments, Sunshine Coast University, HAL and local macadamia growers. These organisations will maintain their role in the MCC, and formally review the plan before the end of the five-year period from adoption as a national recovery plan.

5.2 Monitor and evaluate the outcomes of the Recovery Plan using an adaptive management framework

MCC members will review and update the recovery plan as new information becomes available. All new records of threatened species populations should be provided to land management agencies and approval authorities to assist with decision making.

Table 6. Summary of relationship between specific objectives, performance criteria, actions and potential contributors.

Specific Objective	Performance Criteria	Action	Potential Contributors	Priority
1. Identify and evaluate the extent and quality of southern macadamia species populations and their habitat	1. New populations of southern macadamia species are identified and recorded on secure sections of State databases	1.1 Determine whether additional populations of southern macadamia species occur within southern Qld and northern NSW	MCC, QDERM, NSW DECC	Medium
		1.2 Survey known macadamia populations (including size, distance to nearest population, and reproductive viability) and prioritise macadamia populations for conservation, management and research purposes	SEQ Catchments, QDERM, NRCMA, BMRG, Local Authorities, NSW DECC	High
2. Reduce and manage the major threatening processes affecting southern macadamia species habitat	2a. Sustainable land management strategies are developed and implemented to reduce the impact of threatening processes in habitats critical to the survival of southern macadamia species 2b. Increase in landholder capacity to manage and conserve threatened southern macadamia species populations 2c. Increase in the number of on-ground works undertaken by land managers to manage priority macadamia habitat	2.1 Negotiate appropriate agreements with landholders to establish greater long-term security for priority areas on private property	QDERM, Regional Bodies, NSW DECC	High
		2.2 Provide information to land managers (landholders, macadamia growers, local authorities, etc.) to ensure that known locations of macadamia species are considered for protection when making development decisions	QDERM, Regional Bodies, NSW DECC, Local Authorities, DEWHA	Medium
		2.3 Encourage landowners to develop management plans using existing information and/or new information as it becomes available	SEQ Catchments, QDERM, NRCMA, BMRG, Local Authorities, NSW DECC	High
		2.4 Provide practical resources to land managers for the long-term protection of macadamia habitat appropriate to the tenure of the habitat	SEQ Catchments, NRCMA, BMRG, Local Authorities, Landholders	High

Specific Objective	Performance Criteria	Action	Potential Contributors	Priority
		2.5 Identify, map, control and monitor weed threats in order to reduce the impact of specific weed species for priority populations	SEQ Catchments, BMRG, NRCMA	Medium
		2.6 Conduct fire and biodiversity workshops with land managers responsible for managing macadamia habitat as a means of developing fire management plans	SEQFBC, SEQ Catchments, BMRG, NRCMA, Landholders	High
		2.7 Model the projected impact of climate change on the ecology, extent of habitat, and processes that threaten southern macadamia species	USC, CSIRO, NSW DECC	Low
		2.8 Establish an *ex-situ* conservation program for *Macadamia jansenii* at multiple sites	CSIRO, MCRN	High
		2.9 Establish monitoring programs for priority threatened macadamia populations	Regional Bodies, Local Authorities	Medium
		2.10 Review and amend the macadamia industry Code of Sound Orchard Practice to reflect knowledge of threats to wild populations	MCC,	Low
3. Increase knowledge of threatened southern macadamia species and their ecology to effect their conservation and management	3a. Priority research needs identified by the Macadamia Conservation Committee in conjunction with local land managers, developed into research briefs and implemented by researchers	3.1 Develop research priorities for conservation	MCC, CSIRO, USC	High
		3.2 Continue to liaise with research institutions to address prioritised research gaps	MCC	Low
	3b. New ecological information is incorporated into land and species management manuals and made available to land managers in biennial workshops	3.3 Facilitate Aboriginal participation and the use of traditional knowledge in the recovery of southern macadamia species	MCC, Indigenous Groups, SEQTOLSMA, Regional Bodies, NSW DECC	Medium

Specific Objective	Performance Criteria	Action	Potential Contributors	Priority
4. Improve community awareness and understanding of threatened southern macadamia species, especially the management requirements of these species	4a. Increase in public awareness of the environmental, cultural and economic significance of threatened southern macadamia species 4b. Increase in land managers' capacity to manage and conserve threatened macadamia species	4.1 Develop community education tools that build understanding of the conservation management requirements of threatened southern macadamia species	MCC, BMRG, SEQ Catchments, NRCMA, NSW DECC	Medium
		4.2 Liaise with State Agencies, Local Authorities and Regional Bodies in order to incorporate macadamia conservation into their biodiversity conservation and natural resource management strategies	MCC, QDERM, NSW DECC	High
5. Manage, monitor and evaluate the Southern Macadamia Species Recovery Plan	5. Progress made on the completion of recovery plan actions is reviewed annually	5.1 Maintain the role of the Macadamia Conservation Committee as the coordinating body for the recovery plan	MCC	Low
		5.2 Monitor and evaluate the outcomes of the Recovery Plan using an adaptive management framework	MCC	Low

5. Costs of Recovery

The indicative costs of recovering species identified in this plan are detailed in Table 7.

Table 7. Costs associated with recovering flora species in the Southern Macadamia Species Recovery Plan.

Action	Lead	Year 1	Year 2	Year 3	Year 4	Year 5	Total
1.1 Determine whether additional populations of southern macadamia species occur within southern Qld and northern NSW	MCC	10,000	10,000	5,000			25,000
1.2 Survey known macadamia populations (including size, distance to nearest population, and reproductive viability) prioritise macadamia populations for conservation, management and research purposes	MCC	15,000	15,000				30,000
2.1 Negotiate appropriate agreements with landholders to establish greater long-term security for priority areas on private property	Regional Bodies	10,000	10,000				20,000
2.2 Provide information to land managers (landholders, macadamia growers, local authorities, etc.) to ensure that known locations of macadamia species are considered for protection when making development decisions	MCC	2,500	2,500	2,500	2,500		10,000
2.3 Encourage land managers to develop management plans for macadamia conservation	Regional Bodies	20,000	20,000	20,000	20,000	20,000	100,000
2.4 Provide practical resources to land managers for the long-term protection of macadamia habitat appropriate to the tenure of the habitat	Regional Bodies	100,000	100,000	100,000	100,000	100,000	500,000
2.5 Identify, map, control and monitor weed threats for priority populations	Regional Bodies	20,000	20,000	20,000	20,000	20,000	100,000
2.6 Conduct fire and biodiversity workshops with land managers responsible for managing macadamia habitat as a means of developing fire management plans	Regional Bodies	5,000		5,000		5,000	15,000
2.7 Model the projected impact of climate change on the ecology, extent of habitat, and processes that threaten southern macadamia species	USC	50,000	50,000	50,000			150,000
2.8 Establish an *ex-situ* conservation program for *Macadamia jansenii*	CSIRO	25,000					25,000

at multiple sites							
2.9 Establish monitoring programs for priority threatened macadamia populations	MCC	5,000	5,000	5,000	5,000	5,000	25,000
2.10 Review and amend the macadamia industry Code of Sound Orchard Practice to reflect knowledge of threats to wild populations	MCC/HAL	5,000					5,000
3.1 Develop research priorities for conservation	MCRN	2,500					2,500
3.2 Continue to liaise with research institutions to address prioritised research gaps	MCRN	20,000	20,000				40,000
3.3 Facilitate Aboriginal participation and the use of traditional knowledge in the recovery of southern macadamia species	MCC	7,000	7,000				14,000
4.1 Develop community education tools that build understanding of the conservation management requirements of southern macadamia species	MCC	10,000	5,000	5,000	5,000	5,000	30,000
4.2 Liaise with State Agencies, Local Authorities and Regional Bodies in order to incorporate macadamia conservation into their biodiversity conservation and natural resource management strategies	MCC	In-kind	In-kind	In-kind	In-kind	In-kind	
5.1 Maintain the role of the Macadamia Conservation Committee as the coordinating body for the recovery plan	MCC	In-kind	In-kind	In-kind	In-kind	In-kind	
5.2 Monitor and evaluate the outcomes of the Recovery Plan using an adaptive management framework	MCC	In-kind	In-kind	In-kind	In-kind	In-kind	
Year/Grand Totals		**307,000**	**264,500**	**212,500**	**152,500**	**155,000**	**1,091,500**

6. Management Practices

Management Practices necessary to avoid significant impacts on southern macadamia species include:

- Conservation-based management of all Conservation Parks, National Parks and reserves in which the species occur.
- Educational activities, including fact sheet distribution, by all relevant agencies.
- Continuation of voluntary private land conservation schemes.
- Maintenance of State and national species databases.
- Compliance by macadamia growers with the Code of Sound Orchard Practice.
- Continuation of roadside marker schemes.

Under the EPBC Act any action which could have a significant impact on a matter of National Environmental Significance, including the listed threatened macadamia species, must be referred to the Minister for the Environment, Heritage and the Arts, for a decision as to whether referral and assessment is required. This is separate from any other development approval process requirements.

Actions which could have a significant impact on the southern macadamia species, include those which could result in any of the following within habitat critical to survival of the species:

- Change of fire regimes.
- Removal of vegetation.
- Increased competition from weeds.
- Increased hybridisation with commercial macadamia strains.
- Removal or destruction of *Macadamia integrifolia, M. jansenii, M. ternifolia* or *M. tetraphylla* plants, or of viable plant material (fruits, seeds, cuttings, seedlings).
- Increased herbicide usage, nutrient runoff or changed hydrology.

7. Evaluation of Recovery Plan

The Macadamia Conservation Committee will monitor the progress and delivery of the Southern Macadamia Species Recovery Plan throughout the life of the plan. Interim reviews will be at the discretion of HAL and the MCC, but new information – whether from research generated as a result of the plan or derived from work undertaken within specific actions – will be incorporated into the plan on an annual basis.

The plan will be evaluated by members of the MCC before the end of the five-year period from adoption as a national recovery plan. Implementation of all management actions will be assessed against the designated performance criteria in Section 5.

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Acronyms

AMS	Australian Macadamia Society
BRAIN	Brisbane Rainforest Action and Information Network
BMRG	Burnett-Mary Regional Group for Natural Resource Management
DEWHA	Australian Department of the Environment, Water, Heritage and the Arts
E	Endangered (category under threatened species legislation)
EPBC Act	Commonwealth *Environment Protection & Biodiversity Conservation Act 1999*
FBA	Fitzroy Basin Association
HAL	Horticulture Australia Limited
MCC	Macadamia Conservation Committee
MCRN	Macadamia Conservation Research Network
MGA	Map Grid of Australia
NC Act	Queensland *Nature Conservation Act 1992*
NP	National park
NR	Nature refuge
NRCMA	Northern Rivers Catchment Management Authority
NSW DECC	NSW Department of Environment and Climate Change
QDERM	Queensland Department of Environment and Resource Management (including the Queensland Herbarium)
RAF	Radioactive Amplified DNA Fingerprinting
REDD	Regional Ecosystem Description Database (Queensland Herbarium)
SEQC	Southeast Queensland Catchments Ltd
SEQFBC	Southeast Queensland Fire and Biodiversity Consortium
SEQTOLSMA	Southeast Queensland Traditional Owner Land & Sea Management Alliance
SF	State forest
TAP	Threat Abatement Plan
TSC Act	NSW *Threatened Species Conservation Act 1995*
USC	University of the Sunshine Coast
V	Vulnerable (category under threatened species legislation)
VCA	Voluntary Conservation Agreement
WSF	Wet sclerophyll forest

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Appendix 1: Recovery Team Membership

Name	Position	Organisation
Ian McConanchie	Macadamia Grower	MCC
Annie Keys	Biodiversity Coordinator	Australian Government-DEWHA
Samantha Lloyd	Environmental Partnerships Manager	SEQ Catchments
Michael Powell	PhD Student	MCC
Alison Shapcott	Senior Lecturer	University of Sunshine Coast
Kim Jones	Research Coordinator	HAL
John Gillett	Chairman, Research and Development Committee	AMS
Glenn Costello	Consultant	PMG Eco-Professional
Mike Gregory	Consultant	PMG Eco-Professional
Paul Donatiu	Consultant	PMG Eco-Professional