# Environment Protection and Biodiversity Conservation (National Recovery Plan for Macadamia Species) Instrument 2023

We jointly make this recovery plan under subsection 269A(3) of the *Environment Protection and Biodiversity Conservation Act 1999*.

Dated 4 October 2023

Tanya Plibersek

Minister for the Environment and Water (Commonwealth)

Dated 7 March 2023

Meaghan Scanlon

Minister for the Environment and the Great Barrier Reef (Queensland)

Minister for Science and Youth Affairs

## 2.1A Name

This instrument is the *Environment Protection and Biodiversity Conservation (National Recovery Plan for Macadamia Species) Instrument 2023*.

## 2.1B Commencement

This instrument commences the day after it is registered.

## 2.1C Authority

This instrument is made under subsection 269A(3) of the *Environment Protection and Biodiversity Conservation Act 1999*.

Australian Government

Department of Climate Change, Energy, the Environment and Water

Queensland Government

# National Recovery Plan for Macadamia Species

*Macadamia integrifolia*

*Macadamia tetraphylla*

*Macadamia ternifolia*

*Macadamia jansenii*



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This plan was prepared for the Commonwealth of Australia by Powell, M., Gould, L., Costello, G., Gregory, M. & Donatiu P with support from the Australian Macadamia Society.

Original Southern Macadamia Species Recovery Plan prepared by Glenn Costello, Michael Gregory and Paul Donatiu for Horticulture Australia Limited and the Australian Macadamia Society.

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Department of Climate Change, Energy, the Environment and Water
GPO Box 3090 Canberra ACT 2601
Telephone 1800 900 090
Web dcceew.gov.au



**Acknowledgement of Country**

Department of Climate Change, Energy, the Environment and Water recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge First Nations Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past and present.

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# Contents

# Tables



# Figures

# Executive summary

This Recovery Plan replaces the former Southern Macadamia Species Recovery Plan. It contains considerable new information gathered during the implementation of the former plan and utilises this to determine new actions and priorities for Macadamia conservation.

The review of the former Recovery Plan was an initiative of the Macadamia Conservation Committee (MCC) and was undertaken by members of that committee, with funding support from the Australian Macadamia Society and Horticulture Australia Ltd.

## Species description and taxonomy

Recent taxonomic reclassification of the *Macadamia* genus (Mast et al., 2008) has resulted in the five species of the former northern clade being placed in a newly created genus: *Lasjia* and the four remaining Macadamia species comprising the former southern clade being retained in the genus *Macadamia*. The four species of Macadamia are genetically similar, and all are mid stratum or sub canopy trees with simple leaves arranged either in whorls of three or four, axillary flowers in brush-like hanging racemes and bear rounded fruits with a hard brown inner shell protecting the nut.

## Current species status

The four species of Macadamia are currently listed as either endangered or vulnerable under relevant Commonwealth and State legislation across their respective ranges. In addition, all four species are listed in the Red List for Threatened Plants (IUCN 1997).

## Habitat and distribution summary

All four species are endemic to subtropical rainforest or to a lesser extent, wet sclerophyll communities containing a rainforest understory found within the north east New South Wales (NSW) and south east Queensland coastal regions. Except for *M. jansenii* (which is recorded from a single location approximately 150 km north of its closest congener population), they have overlapping ranges.

## Threats summary

Clearing to accommodate human population growth and development, habitat fragmentation, small population size, presence of weed species and altered fire regimes are the major threatening processes affecting 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 the conservation status of wild Macadamias are also considered significant potential threats.

## Recovery objective

The overall objective of this plan is to ensure the long-term viability of all four Macadamia species through maintaining existing populations and implementing measures to promote recovery.

# Summary of actions

Key actions required for the recovery of Macadamia species include:

- liaising with state agencies, local authorities and regional NRM organisations in order to incorporate Macadamia conservation into their biodiversity conservation and natural resource management strategies.
- 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.
- completing an ex-situ conservation program for *M. jansenii*.
- identifying gaps in the current understanding of Macadamia species ecology and commensurate research priorities for conservation.

Additional actions include assessment of the distribution of genetic diversity among Macadamia populations, conducting further research into the extent of pollen flow between Macadamia cultivars and wild populations, setting up long term monitoring of strategic populations to assess impacts of climate change and resurveying selected populations that have long term population data to assess the impacts of fragmentation on population structure. The recovery team commenced actions under this plan in 2014.

# 1 General information

The *Macadamia* genus is endemic to Australia and is the predominant Australian native commercial food crop. Two of the four Macadamia species produce a highly desired, edible nut and are extensively cultivated within and outside their natural distribution in Australia and internationally. Despite this, all four species are threatened in the wild.

Wild populations of Macadamia are genetic reservoirs for the Macadamia industry, which was founded from only a very small number of trees exported to Hawai'i in the late 1800s. Wild trees contain a genetic diversity that does not exist within cultivated trees and are a resource vital to building industry resilience to changes in weather patterns, emerging pests and possible diseases.

Preceding contemporary utilisation, Macadamias were harvested and eaten by First Nations communities along the east coast, as well as traded with other communities and, following colonisation, with settlers.

Macadamia nuts are also sought after by cockatoos and native as well as introduced rat species, though few other animals can crack the hard shell found on the edible species.

## Conservation status

This Plan encompasses the four Macadamia species, all of which are listed as threatened under relevant State threatened species legislation where they occur and under Commonwealth legislation (Table 1).

**Table 1. Legislative status of Australian Macadamia species**

| **Scientific Name** | **Macadamia species** | **–** | **–** |
|---|---|---|---|
| **–** | **Queensland[1]** | **NSW[2]** | **Australia[3]** |
| *Macadamia integrifolia* Maiden & Betche | Vulnerable | N/A | Vulnerable |
| *Macadamia jansenii* C.L. Gross & P.H. Weston | Endangered | N/A | Endangered |
| *Macadamia ternifolia* F. Muell | Vulnerable | N/A | Vulnerable |
| *Macadamia tetraphylla* L.A.S. Johnson | Vulnerable | Vulnerable | Vulnerable |

1 *Nature Conservation Act 1992* (Qld); 2 *Biodiversity Conservation Act 2016* (NSW); 3 *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

## International obligations

All four Macadamia species are listed on the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List for Threatened Plants (IUCN 1997), with *M. jansenii* listed as endangered and the other three species as vulnerable.

Australia is a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO 2009), adopted by consensus and as a binding international agreement at the Thirty-first Session of the Conference of the Food and Agriculture Organization of the United

Nations on 3 November 2001. Under the terms of this agreement, Australia is required to conserve the genetic resources of Macadamia species for food and agricultural purposes.

*Macadamia integrifolia, M. integrifolia x tetraphylla* and *M. tetraphylla* are included on the List of Exempt Native Species (LENS) for oil, fruit, husks and shells. Native species export permits may be required if these species are to be exported in any form or from any other species than those included on LENS.

# Affected interests

Macadamias have a restricted distribution within appropriate habitats which occur on public and private land across a range of tenures.

Organisations and individuals that may be affected by the actions in this Recovery Plan include:

- Traditional Owners, Indigenous Land Councils and other Aboriginal or Torres Strait Islander groups
- Australian Government, including Department of Climate Change, Energy, the Environment and Water (DCCEEW)
- State Government agencies, including:
  - NSW Department of Family and Community Services and Justice (DFCSJ)
  - NSW Department of Planning, Industry and Environment (DPIE)
  - NSW Local Land Services (LLS) North Coast, Northern Tablelands and North West regions
  - Queensland Department Aboriginal and Torres Strait Islander Partnerships (DATSIP)
  - Queensland Department of Agriculture and Fisheries (DAF)
  - Queensland Department of Environment and Science (DES)
  - Queensland Department of Natural Resources, Mines and Energy (DNRME)
  - Queensland Department of Fire and Emergency Services (DFES)
- Local Governments
- Industry, including:
  - Australian Macadamia Society
  - Growcom
  - Horticulture Innovation Australia
  - HQPlantations
- Non-government conservation organisations, including:
  - Brisbane Rainforest Action and Information Network
  - Landcare groups, for example, Big Scrub Landcare, Gympie Landcare, Noosa and District Landcare, Tamborine Mountain Landcare
  - Catchment associations, for example, Mary River Catchment Coordinating Committee, Gold Coast Catchment Association, Pine Rivers Catchment Association, Brisbane Catchments Network
  - Field naturalists' groups

  - Australian Native Plants Society (Australia) (ANPSA) and affiliated regional societies including Native Plants Queensland and Australian Plants Society NSW
  - Greening Australia
  - Environment groups, for example, Sunshine Coast Environment Council, GECKO, Queensland Conservation Council
- Regional Natural Resource Management (NRM) organisations, including:
  - Burnett-Mary Regional Group
  - Healthy Land and Water (South East Queensland)
- Research institutions, including:
  - CSIRO
  - Griffith University
  - Queensland Alliance for Agriculture and Food Innovation (QAAFI)
  - University of the Sunshine Coast
  - University of Queensland
  - Southern Cross University
- Land managers, public and private
- Northern Rivers Fire and Biodiversity Consortium, South East Queensland Fire and Biodiversity Consortium

## Consultation with First Nations people

During the development of the initial Plan, several Aboriginal groups with connection to Country providing Macadamia habitat were contacted. These included the Gubbi Gubbi and Yuggera groups, and the South East 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. Aboriginal people have been and will continue to be encouraged to be involved in the recovery process through the implementation of recovery actions. For example, in the Bundaberg region, the Recovery Team is actively working with the Gurang and Gooreng Gooreng peoples through the Gidarjil Corporation to establish and maintain four ex-situ populations of the endangered *M. jansenii*.

## Benefits to other species or communities

Specific localities for some Macadamia populations provide valuable habitat for a diverse range of other flora and fauna, including other State or Commonwealth listed threatened species and ecological communities. A significant proportion of Macadamia populations occur in the critically endangered Lowland Rainforest of Subtropical Australia ecological community (EPBC, 1999), others in regional ecosystems considered 'Endangered' or 'Of concern' under the *Vegetation Management Act 1999* (Qld) (VMA 1999) and others in endangered ecological communities listed in the *Biodiversity Conservation Act 2016* (NSW) (BCA 2016). The successful protection of Macadamia populations and implementation of recovery actions at these sites will provide benefits to non-target taxa and threatened communities.

# Recovery Plans relevant to the National Recovery Plan for Macadamia Species

The following approved Recovery Plans are relevant to this Plan:

- Border Ranges Rainforest Biodiversity Management Plan NSW & Queensland, 2010.
- Northern Rivers Regional Biodiversity Management Plan, 2010.

# Social and economic impacts

Populations of Macadamias found on private lands are generally located in areas where in-situ protection – for example, protective fencing and weed control – will have little or no negative economic impact on the viability of farm enterprises. In contrast, lack of protection of wild Macadamia populations may have significant economic impacts on the long-term viability of the Macadamia nut industry globally through a reduction in genetic diversity available for long term cultivar development including traits of resistance to disease and pathogens.

Horticulture Innovation Australia has recently produced a Strategic Investment Plan 2017–2021 (HIA 2017) for the Australian Macadamia industry. This plan identifies that wild Macadamia germplasm is a source of gene stock for commercial varieties and refers to providing allowance within the breeding program for conservation of wild Macadamia and supporting the work of the Macadamia Conservation Trust.

# 2 Biological information

## Introduction

*Macadamia* belongs 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 a long-term trend of contraction of rainforest towards coastal areas, 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.

Macadamia are endemic to the north east NSW and south east Queensland coastal regions. They are mid stratum or sub canopy trees whose prime habitat is subtropical rainforests, although they are also found in sclerophyll forests where rainforest is subdominant (often its presence is fire mediated).

Macadamia flowers are racemes of cream or pink flowers, which are followed by hard, woody fruits that enclose a hard-shelled nut containing a cream kernel. In two of the four Macadamia species, this kernel is edible, and cultivars of these species are the grown extensively within Australia and overseas. Macadamia flowering appears to be light-limited; trees growing within rainforest environments produce far less flowers than backyard or orchard trees, though, trees on rainforest edges or in forest gaps may produce abundant flowers.

The four species of Macadamias are all genetically closely related and three – *M. integrifolia*, *M. ternifolia* and *M. tetraphylla* – have overlapping ranges (refer Figure 1); *M. jansenii* is the exception and is known only from a single location 150 km north of the closest Macadamia population. The natural distribution of *M. integrifolia*, *M. ternifolia* and *M. tetraphylla* are predominantly restricted to a narrow east-west zone encompassing the coastal ranges and foothills west of the Pacific Ocean. Table 2 summarises the characteristic features that help to distinguish Macadamia species from each other.

**Table 2. Distinguishing features of Macadamia species**

| **Species** | **Feature** | **–** | **–** |
|---|---|---|---|
| **–** | **Leaves** | **Flower colour** | **Nuts** |
| *Macadamia integrifolia* | 3 leaves per node; smooth edges to older leaves; green new flush | Cream | Thick, hard, smooth shell; edible kernel |
| *Macadamia jansenii* | 3 leaves per node; smooth edges to leaves; green or pink new flush | Cream | Small with thin, smooth shell; bitter kernel |

| | | | |
|---|---|---|---|
| *Macadamia ternifolia* | 3 leaves per node; spiny leaves; pink new flush | Pink | Small with thin, smooth shell; bitter kernel |
| *Macadamia tetraphylla* | 4 leaves per node; spiny leaves, pink new flush | Pink | Thick, hard, rough shell; edible kernel |

Most knowledge of Macadamia has been gained through research to support the commercial industry, which has focused on *M. integrifolia*, and *M. tetraphylla*; further research is required to determine whether this knowledge can validly be applied to the other two species. In recent times, the industry has expanded its research to investigate the potential value of wild trees of these species and to explore characteristics of *M. ternifolia* and *M. jansenii* that may be of value to the industry.

*Macadamia integrifolia* is highly susceptible to fire damage (O'Hare et al. 2004). A known response by orchard trees in response to fires hot enough to destroy the cambium layer, is to shoot from roots below or near the ground (Rosedale 1969); this results in multi-stemmed trees. Multi-stemmed plants are common in wild populations of all four species, so it is assumed that all species are similarly susceptible to fire.

Pollen flow between Macadamia trees growing in highly fragmented landscapes has been reported at distances of up to 3 km (Neal 2007); it is likely that in more intact forest habitats, pollen exchange occurs across much shorter distances. Flower production is also reduced in shaded environments, such as under the rainforest canopy. Whilst self-pollination can occur in Macadamia, cross-pollination results in greater nut production.

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 improve long-term species viability where overlap occurs, and may be important conservation priorities.

Seed dispersal is by small rodents, cockatoos and gravity fall, probably with some assistance from local stream flooding. The role of seed predators such as cockatoos and rodents in effecting seed dispersal is likely to be limited. Studies of the caches of the introduced black rat (*Rattus rattus*) – a common predator of trees in orchards, backyards and wild populations close to urban areas – found they did not contain any undamaged nuts; thus, germination of the dispersed seed is unlikely (Elmouttie and Wilson 2005).

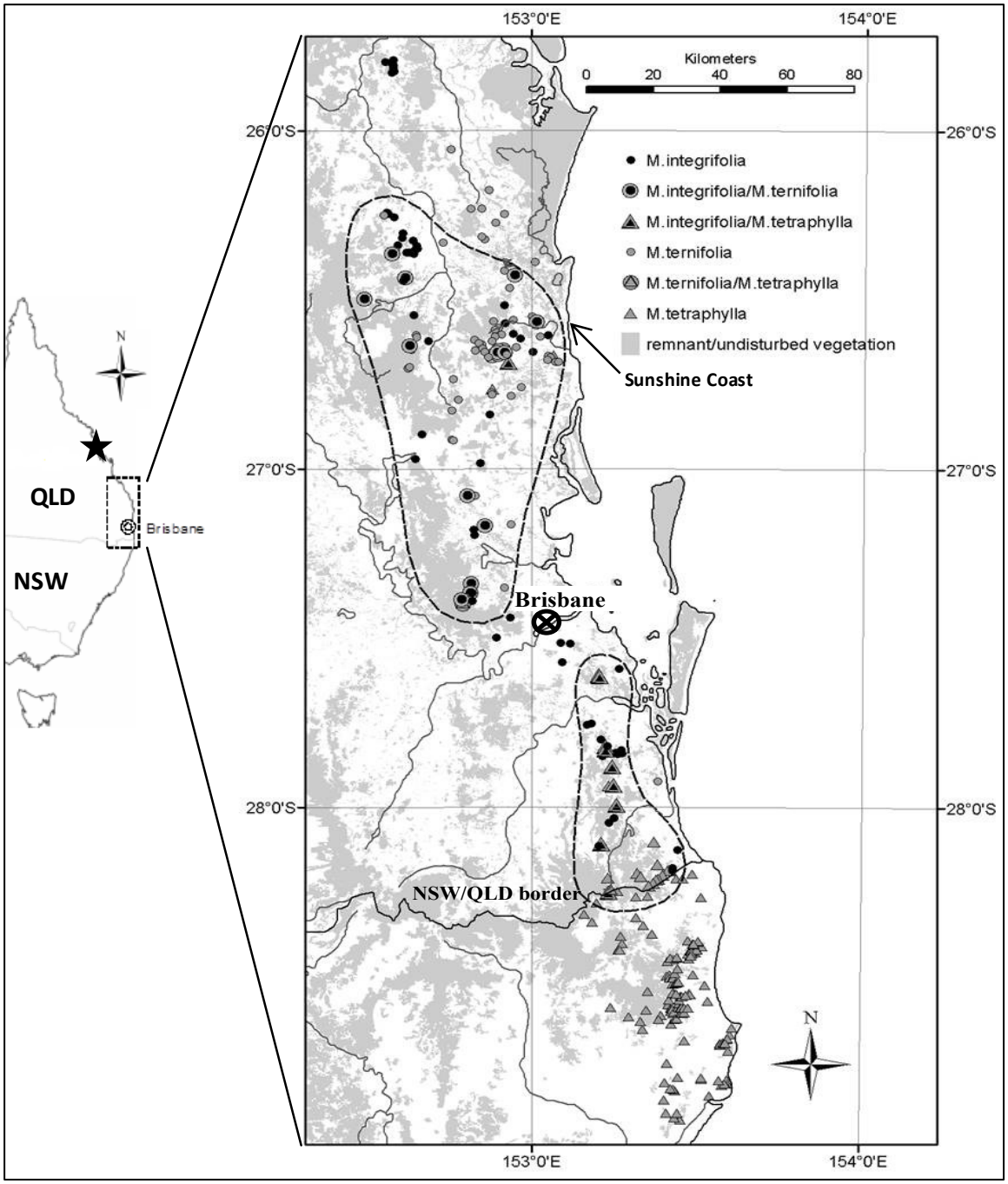
Macadamias have had a long association with humans; nut shells have been found in Aboriginal Middens near Brisbane and they are thought to have been a valuable trade item between Aboriginal communities along the east coast of Australia and subsequently with early settlers. Macadamia trees growing on the edges of the rainforest, thus receiving more light and producing more nuts, are likely to have been regularly cropped. It was mainly the women who searched for, collected and prepared the nuts. They cracked the nuts between rocks and either ate them immediately or roasted the nut in the ash of their fires and carried them as a non-perishable food source (McConachie 2012).

Non-indigenous knowledge of Macadamia initiated with collection of specimens of the inedible *M. ternifolia* by the explorer Ludwig Leichardt in 1843, from about 60 km north of Brisbane. It wasn't until around 1860 that settlers realised the fine eating qualities of both *M. integrifolia* and *M. tetraphylla*, subsequently planting them widely in farmyards and backyards as single trees, grown from seeds of local wild stock.

Early realisation of the commercial potential of Macadamia in Australia was inhibited by insect pests (which caused many flowers, nutlets and nuts to be lost), rats and other seed predators, and lack of horticultural knowledge (McConachie 2012). Despite this, the Macadamia nut industry was founded around 1880 at Rous Hill near Lismore using seed from local wild *M. tetraphylla*, with similar plantings recorded near Maleny in south east Queensland in the early 20th century. It was not until a small handful of Macadamia were sent to Hawai'i in the late 1870s that their full potential was able to be exploited and the industry significantly expanded. Australian Macadamias are the source genetic material for a growing global industry.

From a conservation perspective, the potential translocation of wild trees by First Nations peoples, combined with the transport and planting of nuts both within and outside of the natural distribution of Macadamias that has occurred in Australia since European arrival, can make it difficult to distinguish planted trees from in-situ wild stock. This is particularly the case in areas where native vegetation has been cleared for settlement or agriculture, and regrowth has occurred. This situation confounds identification of Macadamia distribution, natural habitat, and has implications for distribution of genetic resources.

**Figure 1. Natural distribution of Macadamia and natural hybrids**




**Note:** Areas of vegetation are those remnants in 2005 in NSW (NSW Department of Environment and Heritage) and 2006 in Queensland (Queensland Herbarium). Dotted lines show the extent of hybrid zones. Star represents the approximate location of *M. jansenii* (adapted from Hardner et al. 2009).

# *Macadamia integrifolia* (Queensland nut tree)

## Description

*Macadamia integrifolia* is a long-lived perennial mid-storey to sub canopy evergreen subtropical rainforest tree to 25 m 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 5.5–14 cm long by 2.5–6 cm wide (Stanley and Ross 2002). Blade tips are rounded and finish in a short sharp point; the base

tapers to petioles 5–10 mm long. Axillary creamy-white flowers are arranged in brush-like hanging racemes 10–30 cm long. Rounded fruits are green, 2.5–3.5 cm wide with a hard, smooth, 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

*Macadamia integrifolia* is a long-lived species which matures at around ten years and has a juvenile period of more than six years (Queensland CRA/RFA Steering Committee 1997, cited in DoE 2019a). Trees (propagated from wild seed) over 100 years old are known; for example, the Walter Hill Tree, planted in the Brisbane Botanic Gardens, is at least 160 years old, and the Jordan Tree on the Gold Coast is thought to be over 140 years old (National Trust, 2013).

Knowledge of *M. integrifolia* response to fire has been gained through research to benefit the Macadamia industry. This has found that the species is highly susceptible to fire damage (O'Hare et al. 2004). A hot fire will burn the trunk, destroy the conductive tissue and cause gumming on Macadamia trees but if the cambium layer between the bark and the wood is killed, the tree may send up shoots from below the ground level and become multi-stemmed (Rosedale 1969). Neal (2007) considered multi-stemming in wild trees a response to stress or damage.

Both introduced European honey (*Apis mellifera*) and native bees (*Tetragonula* spp.) appear to be the main pollinators, with native bees being superior pollinators. Trees in orchards are rarely observed to produce seed from self-pollination (Neal 2007).

Seed dispersal is by small rodents, cockatoos and gravity fall, probably with some assistance from local stream flooding. The role of seed predators such as cockatoos and rodents in effecting seed dispersal is likely to be limited. Studies of the caches of the introduced black rat – a common predator of trees in orchards, backyards and wild populations close to urban areas – found they did not contain any undamaged nuts; thus, germination of the dispersed seed is unlikely (Elmouttie and Wilson 2005).

Hybridisation has been documented between *M. integrifolia and M. ternifolia*, and between *M. integrifolia* and *M. tetraphylla* in areas of range overlap where both species co-occur within the same rainforest patch.

Genetic studies have been carried out on wild *M. integrifolia* DNA using RAFs (Radioactive Amplified DNA Fingerprinting) microsatellites and isozymes techniques. Both molecular marker evidence and evidence from variation for horticultural traits indicates there is moderate to high genetic diversity within the species and among populations (Neal 2007; Hardner et al. 2009).

The latest paper on the phylogenetic structure of *M. integrifolia* confirms a deep divergence between northern and southern clades of the species, suggesting a historical barrier to seed dispersal north of Brisbane, between the Brisbane and Mary catchments (Nock et al. 2019). This is consistent with two subtropical refugia as defined by Weber et al. (2014). Each of the northern and southern clades forms two distinct sub-clades – Mt Bauple and Gympie for the northern clade and for the southern clade, a division by the Brisbane River valley into sites to the north-west of Brisbane and sites south of Brisbane to the Gold Coast (Nock et al. 2019). A fifth sub-clade was identified by Nock et al. (2019) which was only represented by three old trees transplanted from the wild. It is hoped that further surveying and DNA testing will find other

trees from this sub-clade and reveal their geographic origin, but it may be that they are from a population that is now extinct in the wild (Nock et al. 2019).

Evidence from paternity studies indicates presence of current gene flow by pollen between populations up to approximately 3 km 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. Neal et al. (2010) investigated the impact of habitat fragmentation on reproduction and growth of new trees in wild *M. integrifolia* populations, finding that fragmentation is not necessarily detrimental to reproduction in the short term, possibly because of increased flowering when the canopy cover is not as thick. This capacity for persistence is countered by localised seed dispersal and high predation on seeds, which make the species susceptible to fragmentation and variable population growth rates.

## Distribution

*Macadamia integrifolia* is naturally distributed along the foothills and coastal ranges of south east Queensland from the NSW border to Mt Bauple near Maryborough, a distance of approximately 300 km, and is more widespread and frequent in the northern half of its range. The observed pattern of distribution of the species is one of clusters of populations, which are thought to be due to association with refugial habitats arising from long term climate cycles together with limited capacity for dispersal during periods of favourable climate (Powell et al. 2014). The largest number of recorded populations and individuals are located in an area centred on the Amamoor Valley southwest of Gympie; this area may contain up to 90% of the total extant number of this species, potentially more than 10,000 individuals (Neal et al. 2010) of which more than half are mature individuals. The balance of population clusters collectively contains in the order of 500–1,000 individuals. The species co-occurs with *M. ternifolia* on the Blackall Range and Samford Valley and with *M. tetraphylla* in the southern part of its range.

Over the extent of its natural distribution, *M. integrifolia* is generally found within lowland warm complex notophyll vine forest and Araucarian notophyll vine forest, which occur on metamorphosed sediments and interbedded volcanics or alluvia in higher rainfall areas. 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 5–600 m.

The currently recorded extent of occupied habitat is approximately 1,500 ha and the modelled extent of available habitat is approximately 30,000 ha within an area of 6,800 km$^2$. Total population size is estimated to be between 5,000–10,000 mature individuals within approximately 60 key populations with 10–300 mature specimens at each locality. Further surveys will improve knowledge of population size and distribution. Within the few relatively few areas of intact habitat, it is typically scantily distributed within the vegetation matrix. In disturbed riparian zones, it tends to occur in a clumped pattern of distribution in small remnant patches of habitat that are prone to weed invasion.

## Habitat critical to the survival of the species

*Macadamia integrifolia* is found in a range of vegetation communities comprising complex and simple notophyll vine forests, simple microphyll-notophyll vine forest with emergent *Araucaria*

and *Argyrodendron*, and sclerophyll forests where rainforest is subdominant, and its presence is mediated by fire (Powell et al. 2010).

The Queensland Herbarium Regional Ecosystem Description Database (REDD) identifies four Regional Ecosystems (REs) 12.3.1, 12.8.3, 12.11.10 and 12.12.16 as habitat for *M. integrifolia* (see Table 3). Up to 66% of recorded populations of *M. integrifolia* occurring in remnant vegetation are located in these four RE types (Powell et al. 2010; Powell unpublished data). The majority of the other populations in remnant vegetation are found in riparian RE types or areas mapped as sclerophyll communities where rainforest is subdominant, and its presence is frequently fire mediated (Powell et al. 2014).

A substantial number of populations occur in areas not mapped as remnant vegetation; areas where stands of *M. integrifolia* have been preserved, but other native vegetation has been cleared.

**Table 3. Habitat critical to survival of *Macadamia integrifolia***

| Regional Ecosystem | Short Description | VMA Status[1] |
|---|---|---|
| 12.3.1 | Gallery rainforest (notophyll vine forest) on alluvial plains | E |
| 12.8.3 | Complex notophyll vine forest on Cainozoic igneous rocks. Altitude <600 m | LC |
| 12.11.10 | Notophyll vine forest +/- Araucaria cunninghamii on metamorphics +/- interbedded volcanics | LC |
| 12.12.16 | Notophyll vine forest on Mesozoic to Proterozoic igneous rocks | LC |

1 VMA Status: status under the *Vegetation Management Act 1999* (Qld); E = Endangered, OC = Of Concern; LC = Least Concern

## Priority populations

Populations of *M. integrifolia* have been prioritised using criteria including population size, proximity to other populations (based on pollen transfer distance) and occurrence within remnant vegetation. To account for mapping error, any population mapped as being within 50 m of remnant vegetation is assumed to be located within remnant vegetation.

**Table 4. Priority populations of *Macadamia integrifolia***

| Priority | Criteria |
|---|---|
| VERY HIGH | Populations with at least two neighbouring populations within 3 km AND within 50 m of remnant vegetation AND Population Class 26–49 or greater<br>OR<br>Populations where two Macadamia species are recorded as present |

| Priority | Criteria |
|---|---|
| HIGH | Populations with at least two neighbours within 3 km AND within 50 m of remnant vegetation AND Population Class 11–26 or greater<br>OR<br>Populations with at least two neighbours within 3 km AND Population Class 26–49 or greater<br>OR<br>Populations within 50 m of remnant vegetation AND Population Class 26–49 or greater |
| MEDIUM | All other populations |

The known population clusters of *M. integrifolia* throughout its distribution are summarised in Table 5. Information is provided on the site identifier (Site Id: MGA northing), location, tenure, habitat (cleared, RE number or unknown), population size (Pop Size), and conservation priority (Priority: very high, high or medium).

**Table 5. Known populations of *Macadamia integrifolia* in Australia by geographical cluster**

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| Bauple Group | – | – | – | – | – |
| 7147288 | Bauple | National Park | Non remnant | 11–25 | High |
| 7146903 | Bauple | Private property | 12.12.16 | 11–25 | Very high |
| 7145788 | Bauple | Private property | Non remnant | 6–10 | High |
| 7145377 | Bauple | Private property | Non remnant | Unknown | High |
| 7145274 | Bauple | Private property | Non remnant | 6–10 | High |
| 7144924 | Bauple | Private property | 12.12.16 | 11–25 | Very high |
| 7144417 | Bauple | Private property | 12.12.16 | 6–10 | High |
| 7143588 | Bauple | Private property | Non remnant | 6–10 | High |
| 7143092 | Bauple | Private property | 12.12.16 | 1–5 | High |
| Amamoor/Imbil Group | – | – | – | – | – |
| 7096732 | Mary Ck | Private property | 12.3.7 | 1–5 | High |
| 7096334 | Mary Ck | Forest lease area | 12.11.10 | 51–100 | Very high |
| 7095930 | Mary Ck | Forest lease area | 12.11.10 | 11–25 | High |
| 7091012 | Amamoor | Private property | Non remnant | 6–10 | Medium |
| 7090288 | Amamoor | Private property | Non remnant | 11–25 | High |
| 7089787 | Eel LA | Forest lease area | 12.11.10 | 26–50 | High |
| 7089088 | Amamoor | Private property | Non remnant | 11–25 | High |
| 7088354 | Eel LA | Forest lease area | 12.11.10 | 51–100 | High |
| 7088145 | Amamoor | Forest lease area | 12.11.10 | 51–100 | Very high |
| 7088056 | Amamoor | Forest lease area | 12.11.10 | 1–5 | High |
| 7087676 | Eel LA | Forest lease area | 12.11.10 | 6–10 | High |
| 7087572 | Amamoor | Forest lease area | 12.11.10 | 101–200 | Very high |
| 7087413 | Amamoor | Forest lease area | 12.11.10 | 11–25 | Very high |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7086980 | Amamoor | Forest lease area | 12.11.10 | 6–10 | High |
| 7086840 | Amamoor | Forest lease area | 12.11.10 | 1–5 | High |
| 7086651 | Amamoor | Forest lease area | 12.11.3 | 101–200 | Very high |
| 7086609 | Amamoor | Road reserve | Hoop | 11–25 | Very high |
| 7086533 | Amamoor | Road reserve | Non remnant | 6–10 | High |
| 7086162 | Amamoor | Forest lease area | 12.11.10 | 1–5 | High |
| 7086084 | Amamoor | Road reserve | 12.3.1 | 11–25 | Very high |
| 7085956 | Amamoor | Forest lease area | 12.11.10 | 51–100 | Very high |
| 7085906 | Amamoor | Private property | 12.3.7 | 26–50 | Very high |
| 7085752 | Amamoor | Forest lease area | 12.11.10 | 6–10 | High |
| 7085501 | Amamoor | Private property | Non remnant | 51–100 | High |
| 7085065 | Amamoor | Road reserve | Non remnant | 6–10 | High |
| 7084904 | Amamoor | Forest lease area | 12.11.10 | 101–200 | Very high |
| 7084899 | Amamoor | Road reserve | 12.3.1 | 6–10 | High |
| 7084832 | Amamoor | Road reserve | 12.3.1 | 26–50 | Very high |
| 7084510 | Amamoor | Road reserve | Non remnant | 11–25 | High |
| 7084352 | Amamoor | Road reserve | Hoop | 11–25 | High |
| 7084288 | Amamoor | Reserve | 12.11.3a | 51–100 | Very high |
| 7084194 | Amamoor | Forest lease area | Hoop | 51–100 | High |
| 7084155 | Amamoor | Reserve | Non remnant | 6–10 | High |
| 7083988 | Amamoor | Forest lease area | Plant | 11–25 | Very high |
| 7083698 | Amamoor | Private property | Non remnant | 51–100 | High |
| 7083379 | Amamoor | Forest lease area | 12.3.1 | 26–50 | Very high |
| 7083322 | Amamoor | Road reserve | 12.3.1 | 51–100 | Very high |
| 7083103 | Amamoor | Forest lease area | 12.11.10 | 11–25 | Very high |
| 7083102 | Amamoor | Private property | Non remnant | 101–200 | High |
| 7083016 | Amamoor | Private property | 12.11.10 | 1–5 | High |
| 7076037 | Mitchell Ck | Forest lease area | 12.3.1 | 11–25 | High |
| 7075098 | Mitchell Ck | Forest lease area | 12.3.1 | 11–25 | Very high |
| 7073740 | Mitchell Ck | National Park | 12.11.3 | 11–25 | Very high |
| 7073389 | Mitchell Ck | Forest lease area | 12.11.10 | 11–25 | Very high |
| Blackall Range/Dulong Group | – | – | – | – | – |
| 7061290 | Dulong | Private property | Non remnant | 51–100 | High |
| 7052081 | Dulong | National Park | 12.8.3 | 11–25 | Very high |
| 7051640 | Keils Mountain | Private property | Non remnant | Unknown | Medium |
| 7051381 | Dulong | Unknown | 12.12.2 | 6–10 | Medium |
| 7051208 | Dulong | Reserve | Non remnant | 11–25 | Very high |
| Samford/Pine Rivers Group | | | | | |
| 7016689 | Villeneuve | Private property | Non remnant | 11–25 | High |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7015188 | Upper Caboolture | Private property | 12.9–10.4 | 11–25 | High |
| 7004689 | Campbells Pocket | Public land | Non remnant | 6–10 | Very high |
| 6994689 | No details | Public land | Non remnant | 6–10 | Very high |
| 6993389 | No details | Private property | Non remnant | 1–5 | Medium |
| 6991789 | Terrors Ck | Private property | 12.3.1 | 1–5 | High |
| 6975713 | Samford | Private property | Non remnant | 11–25 | Medium |
| 6972817 | Olson's Scrub | Private property | 12.12.16 | 51–100 | Very high |
| 6972689 | Samford | Public land | Non remnant | 1–5 | Medium |
| 6970589 | Mt Nebo | Private property | Non remnant | 6–10 | Very high |
| 6970196 | Samford | Private property | Non remnant | 11–25 | High |
| Southern Group | | | | | |
| 6956478 | Carindale | Public land | Non remnant | 1–5 | High |
| 6947895 | Little Eprapah Ck | Unknown | Non remnant | 6–10 | High |
| 6945789 | No details | Public land | 12.3.1 | 6–10 | High |
| 6945289 | Mt Cotton | Private property | Non remnant | 11–25 | High |
| 6931076 | Logan | Private property | 12.11.10 | 11–25 | Very high |
| 6929989 | Belivah Scrub | Private property | Non remnant | 6–10 | High |
| 6929959 | Bahrs Scrub | Reserve | 12.11.10 | Unknown | High |
| 6929538 | Bahrs Scrub | Reserve | 12.11.10 | Unknown | High |
| 6924746 | Ormeau | Unknown | 12.11.10 | Unknown | High |
| 6922689 | Ormeau | Private property | 12.11.5a | 1–5 | High |
| 6922289 | Ormeau | Public land | Non remnant | 11–25 | High |
| 6921289 | Ormeau | Public land | Non remnant | 1–5 | High |
| 6921251 | Willow Vale | Private property | Non remnant | 1–5 | High |
| 6920568 | Willow Vale | Public land | Non remnant | 1–5 | High |
| 6920357 | Willow Vale | Private property | Non remnant | 51–100 | High |
| 6920033 | Willow Vale | Private property | Non remnant | 1–5 | High |
| 6919726 | Ormeau | Reserve | 12.11.3 | 11–25 | Very high |
| 6919556 | Ormeau | Reserve | 12.11.10 | 51–75 | Very high |
| 6915819 | Wongawallen | Private property | Non remnant | – | Very high |
| 6912305 | Tamborine | Reserve | 12.11.3 | 11–25 | Very high |
| 6909789 | Tamborine | Public land | Non remnant | 6–10 | Very high |
| 6909203 | Tamborine | Reserve | 12.3.1 | 1–5 | Very high |
| 6908649 | Tamborine | Reserve | 12.11.5a | 1–5 | High |
| 6901633 | Beechmont | Reserve | 12.11.3a | 51–75 | Very high |
| 6897613 | Beechmont | Unknown | 12.11.1 | Unknown | High |
| 6897436 | Beechmont | Unknown | Non remnant | 1–5 | High |
| 6896351 | Beechmont | Unknown | Non remnant | 51–100 | High |
| 6896020 | Beechmont | Unknown | Non remnant | 6–10 | High |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 6895809 | Beechmont | Unknown | Non remnant | 11–25 | High |
| 6890812 | No details | Private property | Non remnant | 11–25 | High |
| 6889817 | Beechmont | Reserve | Non remnant | 6–10 | High |
| 6886668 | Bonogin | Reserve | Non remnant | 26–50 | High |
| 6882602 | Nicholls Scrub | National Park | Non remnant | 6–10 | High |

# *Macadamia jansenii* (Bulburin nut tree)

## Description

*Macadamia jansenii* is a small, single or multi-stemmed tree up to 12 m tall (Shapcott and Powell 2011), with generally smooth bark dotted with prominent lenticels (Halford 1997, cited in Costello et al. 2009). The oblanceolate to oblong-elliptic leaves are generally arranged in whorls of three, are 10–18 cm 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 2–14 mm long. The cream-brown flowers have tepals that are 7–9 mm long; flowers have been observed in July and September. The globose fruit are 20–25 mm in diameter. Nut shells are thin and smooth and contain a mildly cyanogenic, inedible kernel. Surveys coordinated by the University of the Sunshine Coast in 2019 found almost all plants larger than 1 m in height were multi-stemmed, with larger plants having up to 25 stems/trunks (G. Hayward, 2019, pers. comm. 13 Nov).

## Life history and ecology

Very little is known about the life history and ecology of this species. It is thought that *M. janensii* is pollinated by native bees and seed dispersed by vertebrates (Gross and Weston 1992). Most mature individuals are multi-stemmed (G. Hayward, 2019, pers. comm. 13 Nov), suggesting that the species may facultatively re-sprout in response to fire or localised flooding.

Whilst the susceptibility of *M. jansenii* to fire is not known, commercial Macadamias are sensitive to fire (O'Hare et al. 2004), causing concern for *M. jansenii* when wildfires came within 10 km of *M. jansenii* habitat in late 2018 (ABC 2018).

## Distribution

Endemic to the northern part of the SEQ bioregion, *M. jansenii* is known only from a 4000 $m^2$ area restricted to the upper catchment of Granite Creek in Bulburin National Park, within which the area of occupancy is 16 $km^2$ (G. Hayward, 2019, pers. comm. 13 Nov).

In 2018, surveys conducted by Keith Sarnadsky on behalf of the Macadamia Conservation Trust located an additional 37 mature trees and associated juveniles, expanding the known habitat along a narrow 6 km reach within the same catchment (MCT 2019).

Follow-up surveys in 2019 by Glenn Hayward and Alison Shapcott (University of the Sunshine Coast) and Liang Ansel Lee (University of Queensland), found 193 plants, 56 of which were less than 1 m in height (G. Hayward, 2019, pers. comm. 13 Nov).

### Habitat critical to the survival of the species

*Macadamia jansenii* is found on alluvial terraces of a second order watercourse and on adjacent steep, rocky slopes at about 150 m above sea level, where it occurs on well drained, red brown, sandy clay loams (Gross and Weston 1992; Shapcott and Powell 2011). All known individuals are found within 20 m of a tributary of Granite Creek, Bulburin National Park. *Macadamia jansenii* is identified as occurring in Regional Ecosystem 12.12.13 (see Table 6). This form of simple notophyll vine forest is characterised by *Araucaria cunninghamii* (Hoop pine), *Alangium villosum* (Canary muskheart), *Argyrodendron trifoliolatum* (Brown tulip oak), *Baloghia inophylla* (Scrub bloodwood), *Brachychiton discolor* (Scrub bottletree), *Dendrocnide photinophylla* (Shiny-leaved stinging tree) and *Harpullia pendula* (Tulipwood).

### Priority populations

The only known population of *M. jansenii* is summarised in Table 6. This is potentially comprised of up to four subpopulations; however, this cannot be confirmed until genetic analyses are completed (G. Hayward, 2019, pers. comm. 13 Nov). Information is provided on the site identifier (Site Id: MGA northing), location, tenure, habitat (cleared, RE number or unknown; population size (Pop Size), and conservation priority (very high, high or medium).

**Table 6. Known populations of *Macadamia jansenii* in Australia**

| Site Id | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7208293 | Bulburin NP, southwest Miriam Vale | National Park | 12.12.13 | 193 | Very high |

## *Macadamia ternifolia* (Gympie nut)

### Description

*Macadamia ternifolia* is a perennial lower to mid-storey evergreen subtropical rainforest tree to 18 m 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 10–12 cm long; new growth is pinkish red. Blade tips are pointed and the base tapers to petioles 3–13 mm long (Stanley and Ross 2002). Axillary pinkish or cream flowers are arranged in brush-like hanging racemes 4–20 cm long. Compressed rounded fruits are greyish, 1.5–2 cm long with a thin, hard inner shell protecting the nut. The seed kernel is cyanogenic and not edible. Flowering period is June to August with fruiting occurring from March to April.

### Life history and ecology

Total population size is estimated to be between 1,500–2,500 mature individuals. 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 being superior pollinators. Seed dispersal is by small rodents and streams (Barry and Thomas 1994, cited in DoE 2019b) and trees can live for over 100 years, with a juvenile period of six years (Queensland CRA/RFA Steering Committee 1997, cited in DoE 2019b).

No information is available on the species' susceptibility to fire, however, the known sensitivity of commercial Macadamias (O'Hare et al. 2004), suggests application of the precautionary principle.

## Distribution

*Macadamia ternifolia* is endemic to southern coastal Queensland, with a known national distribution of scattered populations extending from Goomboorian (north of Gympie), south to Mt Nebo northwest of Brisbane. *Macadamia ternifolia* is found within lowland warm complex notophyll vine forest and Araucarian notophyll vine forest predominantly on basic and intermediate volcanics and alluvia 15–700 m above sea level (ASL) in higher rainfall areas. This species occupies a range of topographic positions, including 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. In the remnant landscape, *M. ternifolia* is frequently found in riparian RE types (Powell et al. 2014). The majority of extant *M. ternifolia* populations are located on the scarps of the Maleny Plateau extending along the Blackall Range predominantly in riparian habitats draining into coastal lowlands to the east and south or the Mary Valley to the west. A cluster of populations is located on the Conondale Ranges west of the Mary River at approximately 600 m ASL (Powell unpublished data). A finger of populations extends northward along coastal foothills to Goomboorian, a distance of approximately 50 km. *Macadamia ternifolia* is also found in the Sunshine Coast suburb of Buderim and the Brisbane suburbs of Samford Valley and Mt Nebo. Typically, populations are small and tend to occur in clusters within the forest matrix or along riparian zones.

The occupied habitat is approximately 1,350 ha and the modelled extent of available habitat is approximately 22,000 ha within an area of 3,100 km$^2$. The total population is found within approximately 60 key locations with 5–25 mature specimens at each. Significant population clusters occur in the north from Goomboorian to Cooroy; the centre of the species range in the Blackall Range, Maleny and Buderim; in the Conondale Ranges and west of Kenilworth; and Samford Valley/ Mt Nebo in the south. Further surveys will improve knowledge of population size and distribution.

## Habitat critical to the survival of the species

*Macadamia ternifolia* is found in several rainforest regional ecosystems including complex and simple notophyll vine forest and simple microphyll-notophyll vine forest with emergent *Araucaria* and *Argyrodendron*. *Macadamia ternifolia* is identified in the Queensland Herbarium REDD as occurring in endangered RE 12.3.1 (see Table 7), though it is also frequently found in RE 12.8.3, 12.11.10, 12.12.1 and 12.12.16 (Powell unpublished data).

## Priority populations

Prioritisation of populations has been assessed using the same criteria as those used for *M. integrifolia*. The site identifier (Site Id: MGA northing), location, tenure, habitat, population size (Pop Size), and the priority (very high, high or medium) of known population clusters of *M. ternifolia* throughout its distribution is summarised in Table 7.

**Table 7. Known populations of *Macadamia ternifolia* in Australia by geographical cluster**

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| Northern Group | – | – | – | – | – |
| 7117921 | Goomboorian | Private property | Regrowth | 11–25 | Medium |
| 7107639 | Wolvi | Private property | 12.11.16 | 26–50 | High |
| 7098488 | Beenham Range | Private property | Regrowth | 6–10 | Medium |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7097408 | Gympie | Private property | Regrowth | 11–25 | High |
| 7089202 | Mt Pinbarren | National Park | 12.8.13 | 1–5 | Medium |
| 7081477 | Skyring Ck | Private property | 12.3.2 | 1–5 | Medium |
| 7076845 | Mt Cooroy | Reserve | 12.8.13 | 1–5 | Medium |
| 7076193 | Cooroy | Reserve | 12.8.13 | 11–25 | High |
| 7073901 | Eerwah Vale | Private property | 12.11.10/12.11.2 | 11–25 | Medium |
| Blackall Range/Maleny/Buderim Group | – | – | – | – | – |
| 7063183 | Maroochy River | Unknown | 12.12.14 | Unknown | Medium |
| 7063181 | Maroochy River | Unknown | 12.12.14 | Unknown | Medium |
| 7062218 | Yandina | Unknown | Regrowth | 1–5 | Medium |
| 7061731 | Kureelpa | Unknown | Regrowth | 1–5 | Medium |
| 7058977 | Maroochy River | Unknown | 12.3.1 | 6–10 | Medium |
| 7057490 | Kureelpa | Unknown | 12.8.3 | 1–5 | Medium |
| 7056837 | Maroochy River | Unknown | 12.3.1 | Unknown | Medium |
| 7056817 | Maroochy River | Unknown | Regrowth | Unknown | Medium |
| 7056691 | Maroochy River | Unknown | 12.9–10.17d | 1–5 | Medium |
| 7055983 | Mapleton | Private property | 12.12.16/12.12.1 | 11–25 | High |
| 7055705 | Mapleton | Unknown | 12.12.2 | 1–5 | Medium |
| 7055102 | Kureelpa | Unknown | Non remnant | 6–10 | Medium |
| 7054520 | Mapleton | Unknown | 12.8.8 | 1–5 | Medium |
| 7053231 | Huntingdale | Unknown | 12.3.2 | 6–10 | Medium |
| 7052999 | Flaxton | Private property | 12.8.3 | 11–25 | High |
| 7052853 | Mary River | Unknown | 12.12.1 | Unknown | Medium |
| 7052238 | Kenilworth | National Park | 12.11.10/12.11.1 | 6–10 | Medium |
| 7052156 | Kenilworth | National Park | 12.11.10 | 1–5 | Medium |
| 7052104 | Woombye | National Park | 12.8.3 | 11–25 | Very high |
| 7052050 | Woombye | Unknown | 12.12.1 | Unknown | Very high |
| 7052006 | Woombye | Unknown | 12.12.1 | 11–25 | Very high |
| 7051870 | Kenilworth | National Park | 12.11.10/12.11.1 | 11–25 | High |
| 7051767 | Mapleton | Unknown | 12.12.2 | 1–5 | Medium |
| 7051581 | Woombye | Unknown | 12.12.15 | Unknown | Very high |
| 7051471 | Woombye | Reserve | 12.12.1/12.12.16 | 11–25 | Very high |
| 7051381 | Woombye | Unknown | 12.12.2 | 1–5 | Medium |
| 7051204 | Woombye | Unknown | 12.9–10.14 | 6–10 | Medium |
| 7050788 | Woombye | Unknown | Non remnant | 6–10 | Medium |
| 7050722 | Woombye | Unknown | 12.3.2 | 6–10 | Medium |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7050267 | Mary River | Unknown | Non remnant | Unknown | Medium |
| 7050023 | Woombye | Unknown | 12.8.3 | 1–5 | Medium |
| 7049928 | Woombye | Unknown | 12.11.2 | Unknown | Medium |
| 7049867 | Woombye | Unknown | 12.5.2 | 1–5 | Medium |
| 7049153 | Woombye | Unknown | 12.8.3 | 1–5 | Medium |
| 7048444 | Maroochydore | Private property | 12.8.3 | 1–5 | Medium |
| 7048413 | Buderim | Unknown | Non remnant | 1–5 | Medium |
| 7048407 | Buderim | Unknown | 12.8.3 | 6–10 | Medium |
| 7047287 | Maleny | Unknown | Non remnant | Unknown | Medium |
| 7042645 | Maleny | Unknown | 12.12.15a | 1–5 | Medium |
| 7042237 | Maleny | Unknown | 12.8.3 | Unknown | Medium |
| 7041720 | Mooloolabah | Private property | 12.3.2 | 51–100 | Very high |
| 7041637 | Maleny | Unknown | 12.8.3 | Unknown | Medium |
| 7040178 | Maleny | Unknown | 12.9–10.17d | 1–5 | Medium |
| 7039400 | Mooloolah River | Unknown | 12.8.3 | 6–10 | Medium |
| 7037856 | Maleny | Reserve | 12.8.3 | 26–50 | High |
| 7037562 | Maleny | Unknown | 12.8.3 | Unknown | Medium |
| 7037434 | Maleny | National Park | 12.3.1 | 26–50 | High |
| 7037277 | Maleny | National Park | 12.8.3 | 1–5 | Medium |
| 7037115 | Maleny | Unknown | 12.8.3 | Unknown | Medium |
| 7037099 | Maleny | National Park | 12.9–10.16 | 26–50 | High |
| 7035508 | Maleny | Reserve | 12.12.16/12.12.1 | 26–50 | Very high |
| 7035460 | Maleny | Unknown | 12.3.1 | 6–10 | Medium |
| 7034844 | Maleny | Unknown | 12.9–10.16 | 1–5 | Medium |
| 7033713 | Maleny | Private property | 12.12.16/12.12.1 | 11–25 | High |
| 7033541 | Stanley River | Unknown | 12.12.16/12.12.1 | Unknown | Medium |
| 7032502 | Maleny | Unknown | Non remnant | Unknown | Medium |
| Conondale/Kenilworth West Group | – | – | – | – | – |
| 7064410 | Kenilworth | Forest lease area | 12.11.10/12.11.3 | 1–5 | Medium |
| 7062348 | Kenilworth | Forest lease area | 12.3.1 | 6–10 | Medium |
| 7061868 | Kenilworth | Forest lease area | 12.11.1 | 1–5 | Medium |
| 7061458 | Kenilworth | National Park | 12.3.1 | 11–25 | High |
| 7059446 | Kenilworth | Forest lease area | 12.3.1 | 6–10 | Medium |
| 7059191 | Kenilworth | Forest lease area | 12.3.1 | 6–10 | Medium |
| 7057075 | Conondale | Unknown | 12.11.3 | Unknown | Medium |
| 7056538 | Conondale | Unknown | 12.11.10 | 1–5 | Medium |
| 7055837 | Kenilworth | Forest lease area | 12.11.3 | 11–25 | High |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 7053653 | Conondale | Unknown | 12.11.10/12.11.1 | 1–5 | Medium |
| 7052891 | Conondale | National Park | 12.11.3/12.11.2 | 26–50 | Very high |
| 7052303 | Conondale | Unknown | 12.11.10 | Unknown | Medium |
| 7049120 | Mary River | Unknown | 12.11.2 | Unknown | Medium |
| 7047002 | Conondale | National Park | 12.11.9/12.11.3 | 11–25 | Very high |
| 7046781 | Mary River | Unknown | 12.11.1 | Unknown | Medium |
| 7046568 | Conondale | National Park | 12.11.9/12.11.3 | 26–50 | Very high |
| 7046208 | Nambour | Unknown | 12.11.2/12.11.1 | Unknown | Medium |
| Southern Group | – | – | – | – | – |
| 7022865 | Woodford | Private property | Non remnant | 11–25 | Medium |
| 7022688 | Woodford | Unknown | Non remnant | 6–10 | Medium |
| 7004689 | Campbells Pocket | Reserve | Non remnant | 6–10 | Very high |
| 6995309 | Burpengary | Reserve | 12.3.1 | 11–25 | Medium |
| 6994689 | Moorina | Reserve | Non remnant | 11–25 | Very high |
| 6974489 | Draper | Private property | Non remnant | 1–5 | Medium |
| 6972817 | Mt Nebo | Private property | 12.12.16 | 51–100 | Very high |
| 6970589 | Mt Nebo | Private property | Non remnant | 11–25 | Very high |
| 6969825 | Mt Nebo | Private property | 12.12.15 | 26–50 | Very high |
| 6969080 | Mt Nebo | National Park | 12.11.10 | 11–25 | Very high |

# *Macadamia tetraphylla* (Rough-shelled bush nut)

## Description

*Macadamia tetraphylla* is a perennial mid-storey evergreen subtropical rainforest tree to 18 m tall, with greyish-brown branchlets dotted with pale elongated lenticels (Hauser and Blok 1992). The simple oblong lanceolate leaves are usually arranged in whorls of four, 6–20 cm long and 2–4 cm wide. Blade tips are pointed, margins sharply serrated and petioles are 2–8 mm 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 15–45 cm long. Compressed rounded fruits are greyish-green, 2–3.5 cm wide with a hard-inner rough surfaced shell protecting the edible kernel. Flowering period is August to September with fruit maturing and falling from March (Hauser and Blok 1992).

## Life history and ecology

Little is known about the life history and ecology of this species. Pollination is thought to be principally carried out by native and European bees with seed dispersal by small rodents and gravity fall, probably with some assistance from local stream flooding. Pollen and seed dispersal leading to hybridisation has been observed between wild *M. tetraphylla* and cultivated *M. integrifolia* (O'Connor et al. 2015).

A study into the breeding system and fecundity of *M. tetraphylla* (Pisanu et al. 2009) found that the species had a low fruit to flower ratio and that the species was weakly self-compatible but

incapable of self-pollination. Pisanu et al. (2009) identified a lack of light and competition with other more rapidly growing rainforest limits flower production, whilst insect pests and high seed predation, limits seed production and germination. An optimal outbreeding distance of 2 km was identified but the authors concluded that many wild populations do not have conspecifics at optimal distances owing to habitat fragmentation.

*Macadamia tetraphylla* has moderate to high genetic diversity recorded within the species and its populations, however, relatively low genetic differentiation between populations has been recorded at a regional scale (Peace 2005). Spain and Lowe (2011) investigated the genetics of six wild *M. tetraphylla* populations, finding a lack of genetic structure among adults. However, in the juvenile cohort, genetic differentiation and relatively high inbreeding scores were identified. The observed patterns were positively correlated with density of adult individuals consistent with the clumped distribution pattern of individuals commonly observed in small fragments (Pisanu 2001).

No information is available on the susceptibility of *M. tetraphylla* to fire, however, the known sensitivity of commercial Macadamias (O'Hare 2004), suggests application of the precautionary principle.

## Distribution

*Macadamia tetraphylla* is endemic to eastern Australia, with a known national distribution of scattered populations extending from Mt Cotton south of Brisbane to the Richmond River in northern NSW at an altitudinal range of 30–800 m ASL. Much of the habitat in which it naturally occurs has been almost entirely cleared, significantly altering the original pattern of distribution of the species.

In NSW, the extant distribution of *M. tetraphylla* is:

- in the Tweed Valley, on the slopes and along tributaries draining Wollumbin (Mount Warning) and in the Border Ranges from the coast to Numinbah
- within the area of the former Big Scrub, including the western and southern foot slopes of the Nightcap Ranges and Whian Whian State Forest, extending north along the east facing slopes and foothills and adjacent lowland areas of Mt Jerusalem National Park to Mooball
- a cluster of populations occurs on the southern scarp of the Alstonville Plateau near Dalwood.

In Queensland, the range of *M. tetraphylla* extends north from the border with NSW along the coastal ranges and valleys to Mt Cotton south east of Brisbane; a distance of approximately 40 km.

Across its range a relatively large number of *M. tetraphylla* individuals are located in or adjacent to road reserves in disturbed landscapes dominated by the weed tree species camphor laurel (*Cinnamomum camphora*); these individuals are potentially important in maintaining connectivity among populations. In addition, *M. tetraphylla* was frequently inter-planted with banana trees in early banana plantations and survive in the recovering landscape where agricultural activities have long been abandoned.

The occupied habitat is approximately 750 ha, and the modelled extent of available habitat is approximately 48,000 ha within an area of 2,400 km$^2$. Total population size is estimated to be

between 1,500–3,000 mature individuals within approximately 60 key populations with 10–100 mature specimens at each locality. Further surveys will improve knowledge of population size and distribution.

## Habitat critical to the survival of the species

*Macadamia tetraphylla* is found in several vegetation communities, including complex notophyll vine forest, littoral rainforest and wet sclerophyll forests. In Queensland, *M. tetraphylla* is identified in the Queensland Herbarium REDD as occurring in three Least Concern (VMA 1999) rainforest regional ecosystems (RE 12.8.3, 12.11.10 and 12.12.16). In NSW, *M. tetraphylla* is categorised as a site-managed species under the DPIE Saving our Species Program and occurs in the following seven vegetation classes and four Endangered Ecological Communities (BCA 2016):

- NSW Vegetation Class
  - Coastal Floodplain Wetlands
  - Coastal Swamp Forests
  - Dry Rainforests
  - Littoral Rainforests
  - North Coast Wet Sclerophyll Forests
  - Northern Escarpment Wet Sclerophyll Forests
  - Subtropical Rainforests
- NSW Endangered Ecological Community
  - Subtropical Coastal Floodplain Forest of the New South Wales North Coast Bioregion
  - Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions
  - Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions
  - Lowland Rainforest on Floodplain in the New South Wales North Coast Bioregion

## Priority populations

Prioritisation of populations was undertaken using the same criteria as that for *M. integrifolia*. A summary of known population clusters of *M. tetraphylla* throughout its distribution is summarised in Table 8; data includes the site identifier (Site Id: MGA northing), location, tenure, habitat, population size, and the priority (very high, high or medium). There are areas of range overlap between *M. tetraphylla* and *M. integrifolia*, with a significant number of sites occupied by both species and hybridisation occurring between species (Peace 2005). NSW DPIE Saving our Species Program has identified one site, Wollumbin National Park, as a key management site for *M. tetraphylla*.

**Table 8. Known populations of *Macadamia tetraphylla* in Australia by geographical cluster**

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| Northern Group (QLD) | – | – | – | – | – |
| 6915819 | Wongawallan | Private property | Non remnant | 26–50 | Very high |
| 6910421 | Eagle Heights | Reserve | 12.11.10 | 6–10 | Medium |
| 6909789 | Guanaba River Park | Reserve | Non remnant | 12–25 | Very high |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 6909566 | Beenleigh | Reserve | 12.3.7a | Unknown | Medium |
| 6909203 | Guanaba | Reserve | 12.3.1/12.3.2 | 1–5 | Medium |
| 6903289 | Clagiraba Creek | Private property | Non remnant | 1–5 | Medium |
| 6901633 | Clagiraba | Reserve | 12.11.3a | 51–75 | Very high |
| 6896799 | Beechmont | Public land | Non remnant | 11–25 | Medium |
| 6896061 | Beechmont | Public land | Non remnant | 11–25 | Medium |
| 6893046 | Beechmont | Public land | Non remnant | 11–25 | Medium |
| 6890589 | Beechmont | Private property | 12.8.3/12.8.4 | 1–5 | Very high |
| 6887900 | Bonogin | Public land | 12.11.3 | 6–10 | Medium |
| 6887520 | Beechmont | Unknown | Non remnant | 6–10 | Medium |
| 6886990 | Beechmont | Unknown | Non remnant | 1–5 | Medium |
| 6886668 | Bonogin | Reserve | – | 26–50 | Very high |
| 6885935 | Numinbah | Reserve | – | 26–50 | High |
| 6884259 | Austinville Rd | Public land | 12.11.1 | 6–10 | Medium |
| 6881627 | Tallebudgera_1 | Public land | 12.3.2/12.3.1 | 11–25 | High |
| 6881104 | Tallebudgera_3 | Public land | Dist | 1–5 | Medium |
| 6881045 | Austinville CA | Reserve | 12.8.3 | 6–10 | Medium |
| 6880866 | Murwillumbah | Unknown | 12.8.3 | Unknown | Medium |
| 6880024 | Currumbin Ck Rd | Public land | – | 11–25 | Very high |
| 6879986 | Tallebudgera _2 | Private property | Non remnant | 6–10 | Medium |
| 6879510 | Natural Bridge | Private property | Non remnant | 26–50 | High |
| 6879231 | Beechmont | Unknown | 12.8.8 | 26–50 | Very high |
| 6878209 | Currumbin | Private property | Non remnant | 1–5 | Medium |
| 6877577 | Currumbin | Public land | Non remnant | 6–10 | Medium |
| 6877226 | Natural Bridge | Reserve | 12.8.3 | 11–25 | High |
| 6876747 | Currumbin | Public land | Non remnant | 1–5 | Medium |
| 6876331 | Currumbin | Reserve | 12.11.1 | Unknown | Medium |
| 6875689 | Springbrook | Reserve | 12.8.3 | 12–25 | High |
| Wollumbin (Mount Warning) Group | – | – | – | – | – |
| 6882033 | Murwillumbah | Unknown | 12.11.1 | Unknown | Medium |
| 6881194 | Bilambil Heights | Private property | Non remnant | 11–25 | Medium |
| 6878989 | Terranora | Private property | Subtropical rainforest | 11–25 | High |
| 6877789 | Banora Pt | Public land | Not assessed | 6–10 | Medium |
| 6876942 | Duroby | Private property | Early regrowth RF | 11–25 | Medium |
| 6876798 | Bilambil | Private property | Subtropical rainforest | 1–5 | Medium |
| 6876711 | Bilambil | Private property | Brush Box open forest | 1–5 | Medium |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 6876161 | Bilambil | Private property | Non remnant | 11–25 | Medium |
| 6876088 | Duroby | Public land | Non remnant | 11–25 | Medium |
| 6875592 | Bilambil | Reserve | Subtropical rainforest | 61–75 | High |
| 6875576 | Bilambil | Private property | | 26–50 | High |
| 6875151 | Upper Duroby | Private property | Non remnant | 11–25 | Medium |
| 6874389 | Hogans Scrub | Public land | Moist forest/rainforest | 6–10 | Medium |
| 6872321 | Chillingham | Private property | Brush Box open forest | 26–50 | Very high |
| 6872310 | Couchy Ck | Public land | Non remnant | 11–25 | Medium |
| 6871389 | Couchy Ck | Public land | Non remnant | 11–25 | Medium |
| 6870474 | Limpinwood | Private property | Non remnant | 26–50 | Medium |
| 6868009 | Chillingham | Private property | Non remnant | 1–5 | Medium |
| 6867889 | Limpinwood NR | Reserve | Rainforest/riparian | 6–10 | Medium |
| 6867689 | Limpinwood Rd | Public land | Eucalypt open forest | 11–25 | Medium |
| 6867243 | Crystal Creek | Private property | Not assessed | 51–75 | High |
| 6866730 | Crystal Creek | Private property | Early regrowth RF | 101–200 | Very high |
| 6866426 | Tyalgum | Private property | Early regrowth RF | 101–200 | Very high |
| 6864389 | Eungella | Private property | Non remnant | 11–25 | Medium |
| 6860189 | Mt Warning Rd | Private property | Non remnant | 11–25 | Medium |
| 6859489 | Sia School | Private property | Eucalypt open forest | 11–25 | High |
| 6859089 | Wollumbin | Private property | Eucalypt open forest | 11–25 | High |
| 6856689 | Uki | Private property | Non remnant | 11–25 | Medium |
| 6856389 | Uki | Private property | Non remnant | 26–50 | High |
| 6855989 | Cedar Ck 1 | Private property | Rainforest/riparian | 6–10 | Medium |
| 6855889 | Cedar Ck 2 | Private property | Rainforest/riparian | 6–10 | Medium |
| Central Group | – | – | – | – | – |
| 6854689 | Mooball | Private property | Non remnant | 11–25 | Medium |
| 6849989 | Inner Pocket NR | Reserve | Moist eucalypt forest | 6–10 | Medium |
| 6849289 | Blindmouth | Private property | Moist eucalypt forest | 11–25 | Medium |
| 6849110 | Billynudgel | Private property | Moist eucalypt forest | 26–50 | High |
| 6845178 | Main Arm | Public land | Not assessed | 1–5 | Medium |
| 6843889 | Brunswick Heads | Reserve | Coastal complex | 6–10 | Medium |

| Site ID | Location | Tenure | Habitat | Pop Size | Priority |
|---|---|---|---|---|---|
| 6842289 | Mullumbimby Ck | Private property | Not assessed | 11–25 | Medium |
| 6841989 | Mullumbimby Ck | Private property | Not assessed | 11–25 | Medium |
| 6841489 | Mullumbimby Ck | Private property | Not assessed | 11–25 | Medium |
| 6837789 | Nimbin | Public land | – | 1–5 | Medium |
| 6837185 | Mullumbimby | Public land | – | 1–5 | Medium |
| 6836889 | Tuntable Ck Rd | Public land | – | 1–5 | Medium |
| 6836399 | Lismore | Private property | – | 11–25 | Medium |
| 6836270 | Upper Coopers Ck | Private property | Moist forest complex | 11–25 | Medium |
| 6836089 | Upper Coopers Ck | Private property | – | 1–5 | Medium |
| 6834280 | Goonengerry | Public land | – | 1–5 | Medium |
| 6834089 | Tuntable Ck Rd | Private property | – | 11–25 | Medium |
| 6833389 | Minyon Falls FR | Reserve | Moist forest complex | 11–25 | High |
| 6831489 | The Channon | Private property | – | 11–25 | Medium |
| 6829589 | Dorroughby | Private property | – | 1–5 | Medium |
| Southern Group | – | – | – | – | – |
| 6814998 | Tintenbar | Private property | – | 11–25 | Medium |
| 6814050 | Tintenbar | Private property | – | 61–75 | Medium |
| 6813577 | Lennox Head | Private property | – | 6–10 | Medium |
| 6813289 | Lennox Head | Public land | – | 11–25 | Medium |
| 6812289 | Lennox Head | Private property | – | 11–25 | Medium |
| 6812189 | Wollongbar | Public land | – | 6–10 | Medium |
| 6811285 | Alstonville | Private property | – | 6–10 | Medium |
| 6807575 | Alstonville | Private property | – | 11–25 | Medium |
| 6806785 | Alstonville | Reserve | Subtropical rainforest | 11–25 | Medium |
| 6803113 | Dalwood | Private property | Subtropical rainforest | 26–50 | High |
| 6802932 | Alstonville | Reserve | Subtropical rainforest | 12–25 | Medium |
| 6802759 | Dalwood | Private property | Subtropical rainforest | 26–50 | High |
| 6800889 | South Ballina | Private property | – | 11–25 | Medium |

# 3 Threats

## Biology and ecology relevant to threats

### Habitat loss and fragmentation

The long-term impacts of land clearing and habitat fragmentation are underlying factors contributing to the threatened status of Macadamia species. This is exacerbated by ongoing clearing of remnant bushland throughout south east Queensland and north east NSW for horticulture, agriculture, urban and industrial development and associated infrastructure.

The extent of land clearing in some areas of Macadamia habitat has dire consequences for long term persistence of Macadamia species in those areas. Approximately 80% of the Regional Ecosystem communities, most frequently occupied by *M. integrifolia* and *M. ternifolia* in Queensland within core areas of their respective ranges, have been cleared (Powell et al. 2014). Depending on the Macadamia species, between 30% and 50% of recorded populations in Queensland occur in areas that are either cleared or are patches of remnant vegetation too small in area to be included in 1:50,000 (SEQ) or 1:100,000 (non-SEQ) regional ecosystem mapping undertaken by the Queensland Herbarium. In NSW, almost the entire extent of the former Big Scrub, thought to comprise the core range for *M. tetraphylla*, was cleared in the 19th and early 20th centuries (Floyd 1990). Most extant populations of *M. tetraphylla* occur along the fringes of this area and the foot slopes of Wollumbin (Mount Warning) and its caldera.

Whilst a number of populations of Macadamia occur in protected tenures, such as National Parks and Conservation Reserves, many populations are located on private land. The loss of individual trees or small populations from private land particularly is difficult to detect, reducing the effectiveness of the legislative protection afforded to Macadamia species by State and Commonwealth governments. A relatively large number of Macadamias occur as a single or few individuals in paddocks (left for their edible nuts when the land was cleared), in roadside remnants, or in gullies and scarps too steep to be cleared. These scattered individuals and small populations may have an important role in maintaining connectivity among the population network for each species; ensuring the long-term persistence of these populations, however, is problematic.

Documented impacts of habitat fragmentation on Macadamia species include weed invasion, reduced frequency of optimal outbreeding distance among populations, genetic isolation of populations, and genetic population differentiation resulting in increased population divergence and likely eventual loss of genetic variation in future generations (Pisanu et al. 2009; Spain and Lowe 2011). Fragmented habitat areas are also likely to be more susceptible to fire. Populations in smaller fragments have been shown to have higher reproduction relative to those within intact habitats due to higher availability of resources, especially light (Neal et al. 2010), however, it is thought that these benefits are outweighed by more pervasive threats of isolation and weed invasion (Pisanu et al. 2009). Moreover, Spain and Lowe (2011) found that levels of inbreeding in juveniles in *M. tetraphylla* populations was related to adult trees density which are higher within small fragments relative to those within intact forests. They speculate that higher levels of seedling establishment and survival in disturbed habitats may lead to higher levels of inbreeding in those habitats.

Land clearance is a Listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

## Small population size

Genetic drift, loss of genetic diversity, inbreeding depression, factors affecting reproductive success, and ability to sustain critical population size all affect the viability of threatened species populations (Lindenmayer and Burgman 2005). When population size is reduced, genetic diversity can be reduced and population viability compromised, sometimes resulting in inbreeding as has been found in small, isolated populations of *M. tetraphylla* (Spain and Lowe 2011). Some species can tolerate high levels of inbreeding without loss of the ability to reproduce. Even so, small plant populations are still vulnerable to single disturbance events such as wildfire, drought, disease or heavy weed incursion.

The Macadamia species in this Plan occur primarily in small populations, however, considerable debate surrounds what constitutes a viable population in species with naturally small and spatially diffuse populations. In the case of Macadamias, habitat models predict that the species likely occupied contiguous areas of suitable habitat prior to arrival of Europeans and clearing. Limited dispersal ability and the patchy spatial pattern of rainforest communities in the landscape, however, especially in riparian systems, meant that populations were naturally small and patchily distributed in the landscape.

All Macadamia species can maintain themselves via coppicing, reducing the rate of loss of genetic diversity due to drift in small populations and partly explaining why Macadamias have retained relatively high levels of genetic diversity despite apparently naturally small population sizes. The effects of drift are likely to be slowly realised given the long generation times. Drift will lead to a loss of alleles and random differentiation between populations.

Macadamia populations could potentially maintain genetic diversity within fragmented small populations via gene flow due to pollen exchange if there is sufficient connectivity among populations within the landscape matrix. Interpopulation gene flow via pollen of 2.8 km has been documented for *M. integrifolia* (Neal 2007). Nearest neighbour distance calculations among recorded Macadamia populations show that for each species, many populations are located within 3 km of their two nearest neighbours, especially those located within areas of clusters of populations. Macadamia species appear to maintain themselves via a meta-population structure rather than acting as isolated independent populations.

Whilst pollen exchange between close populations may assist with maintaining genetic diversity, the available data for wild Macadamia species suggest that reproduction is inhibited by a lack of pollinators (Neal 2007; Pisanu et al. 2009). Macadamias are weakly self-compatible, but not capable of autogamy, i.e., they require a pollinator to effect fertilisation; further, outcrossed pollen results in greater seed production (Pisanu et al. 2009). The combined impact of these three factors is to limit seed production by Macadamias. When compounded by the impact of abundant seed predators, such as rats, the result is very low seed germination; this was evident in surveys of wild populations across SEQ undertaken for the Macadamia Conservation Trust during 2015–16 (L. Gould pers. comm. 2017). Further surveys and long-term monitoring are required to understand the likely impact on population persistence.

Macadamias belong to a group of regional subtropical rainforest tree species that produce large hard-shelled seeds and have limited dispersal ability (Rossetto et al. 2008). Whilst in-situ

Macadamia populations may 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 restored by neighbouring populations (typical of a meta-population structure). Actions which enhance or at least maintain connectivity between populations and facilitate pollinator movement, may improve interpopulation gene flow through pollen exchange, potentially mitigating some of the impacts of habitat loss and fragmentation (though as noted above, this may not be sufficient to redress the compounded effects of poor germination).

## Weed species

Weeds can displace native flora, compete for resources (such as pollinators, light, nutrients and water) and create habitats that are conducive to other exotic species. They can also alter the composition of vegetation communities, patterns of pollination and native seed dispersal. The interface between bushland and other land uses is particularly susceptible to the spread of exotic species that flourish in this altered environment.

Weed species that pose a direct and significant threat to Macadamia habitats are lantana (*Lantana camara*) and exotic vines such as cat's claw creeper (*Dolichandra unguis-cati*) and Madeira vine (*Anredera cordifolia*). All three species were introduced to Australia as garden plant and are now classified as weeds of national significance (WoNS). Cat's claw creeper and Madeira vine pose a significant medium-term threat to Macadamia species as they have the capacity to invade and establish within intact rainforest, forming a thick groundcover overwhelming understorey vegetation and eventually growing to canopy level, progressively smothering and collapsing mature trees. Currently, effective control is limited to mechanical and chemical methods that are expensive, requires specific knowledge about the site and a commitment to regular, long-term follow up. Biological controls for all species have been found and released, however, in most cases it will take years before their effectiveness can be properly assessed (Morin et al. 2009).

Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants is a Listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). Weeds are identified as a Key Threatening Process under the *Biodiversity Conservation Act 2016* (NSW).

Invasion of native plant communities by *Chrysanthemoides monilifera* (Bitou bush and boneseed) is a key threatening process under the *Threatened Species Conservation Act 1995* (NSW). *Macadamia tetraphylla* is thought to be at risk from this weed (DECC 2006).

## Fire

Rainforest communities are normally fire resistant and do not facilitate the spread of fire, however, Macadamias are fire sensitive (O'Hare et al. 2004). There is evidence that Macadamias, along with other rainforest species resprout strongly following fire (Rosedale 1969, Williams 2000, Clarke et al. 2013) and that rainforest elements found in wet sclerophyll forest can survive repeated low intensity fires (Donatiu 2007, unpublished data).

Fire is, however, a direct threat to rainforest remnants in situations where remnant edges are infested with flammable weeds such as lantana or exotic grasses, or where canopy cover has been reduced (such as through smothering of native tree species by cat's claw creeper and other vine weeds) enabling intrusion of more flammable plant species into remnant patches, thus

facilitating the spread of fire into the remnant. Remnants located upslope from grassy or weed-infested areas or from regional ecosystems reliant on a more frequent fire regime, are at increased risk of burning.

The Queensland Herbarium Regional Ecosystem Database (REDD) contains the following fire guideline for each of the four regional ecosystems in which Macadamias are predominantly found:

> STRATEGY: Do not burn deliberately. Protection relies on broad-scale management of surrounding country. May need active protection from wildfire in extreme conditions or after prolonged drought. Planned burns should not create a running fire into vine forest. Ensuring conditions of good soil moisture and moisture of litter in surrounding communities will limit fire behaviour/intensity. ISSUES: Fire sensitive and not normally flammable. Some preliminary work suggests rainforest seedling germination from planned burning activities will assist the establishment of seedlings in newly burnt areas, especially due to smoke. There may be issues with lantana (*Lantana camera*) and other weeds from fire and other disturbance. Remnants may be limited by frequent fire at the margins; this requires further research.

Fire regimes that cause declines in biodiversity is Listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

Fire is identified as a Key Threatening Process under the *Biodiversity Conservation Act 2016* (NSW).

## Unmanaged livestock

When access is available, livestock will utilise Macadamia habitat for shade, water (gallery and riparian rainforests) and grazing. Unmanaged this has the potential to:

- modify the vegetation structure and floristic composition,
- cause loss of habitat diversity,
- initiate and exacerbate soil erosion (with consequent effects on water quality),
- facilitate the introduction and spread of invasive weeds, particularly exotic pasture grasses and legumes, and
- alter the amount and distribution of fuel throughout the landscape, potentially increasing the incidence, intensity and extent of fires.

The impacts of livestock management activities, such as fencing, mustering activities, hard crossings, access roads and other infrastructure can also have an adverse direct impact.

## Climate change

It is widely predicted that climate change will significantly alter the distribution and composition of rainforest ecosystems in Australia (Hilbert et al. 2001; Williams et al. 2003; Hilbert et al. 2007). In south east Queensland, subtropical rainforest communities are predicted to experience upslope migration in range and increasing rates of turnover (Laidlaw et al. 2011). Mean annual temperature increases of up to 3°C and more variable precipitation regimes are predicted for the region occupied by Macadamia species. These changes will place additional

environmental stress on those Macadamia populations already under pressure from the impacts of habitat fragmentation, especially those located in areas of marginal soil moisture availability and/or in exposed locations which are at greater risk of fire.

Climate change is predicted to affect the phenology of Macadamias (Williams et al. 2006) including the initiation of flowering and the maturation of fruit, and potentially that of pollination vectors. Since both onset of flowering and maturation of fruit are known to be determined by climatic parameters, elevated temperatures in late autumn decreasing the probability of suitable conditions for flower bud initiation and/or decreased rainfall in summer affecting nut maturation, are likely to reduce the reproductive capacity of natural populations, especially those occupying the warmer drier end of climate gradients.

Climate change is also predicted to lead to a reduction in the extent of overlap of suitable environment among Macadamia species (Powell et al. 2014) thus potentially resulting in decreased hybridisation between Macadamia species. Research is required into the magnitude of change and the likely impacts on individual populations and species.

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 and pasture grasses at remnant edges, or result in vegetation changes within Macadamia habitat, leading to conditions more conducive to the spread of fire.

Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases is a Listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). Climate change is also identified as a Key Threatening Process under the *Biodiversity Conservation Act 2016* (NSW).

## Genetic pollution

DNA marker studies have confirmed hybrid genotypes (Peace 2005) of *M. integrifolia* and *M. ternifolia*, and *M. integrifolia* and *M. tetraphylla* hybrids occur in a 20 km overlap zone where both species co-occur within the same rainforest patch.

This natural predisposition for hybridisation has been found to be causing genetic ‘pollution’ of wild populations. A recent Honours level post graduate study identified gene flow between Macadamia nut cultivars (predominantly based on limited *M. integrifolia* germplasm) and nearby wild populations of *M. tetraphylla* (O’Connor 2013). There is a reasonable to high probability that the same phenomenon is occurring between cultivars and *M. integrifolia* and/or *M. ternifolia*. The study was, however, limited in scope and further research is required to identify thresholds of spatial proximity between cultivars and wild trees and to determine fitness (survival and reproductive potential) of hybrids among the affected wild populations. The major impact on wild Macadamia species is likely to be limited to the relatively few populations located in areas where Macadamia farms are a major agricultural activity such as the Alstonville Plateau in Northern NSW. In Queensland, the key Macadamia farming area is the Bundaberg region, which is well outside of the range of wild Macadamias. There are, however, numerous farms in south east Queensland and northern NSW within the range of *M. integrifolia* and/or *M. ternifolia* where gene flow between cultivars and wild Macadamia populations could potentially occur.

## Public perception

Public perception that Macadamias are a plentiful species and therefore not threatened is an issue. This perception is created by the lack of differentiation between the visual effect of rows of healthy Macadamias in a plantation, the number of non-wild Macadamias planted in backyards and roadsides, and largely hidden wild populations. Recent projects undertaken by the Macadamia Conservation Trust in partnership with Healthy Land and Water, such as 'Wild About Macadamias' and 'Still Wild About Macadamias', have made significant achievements with regard to raising community awareness, particularly amongst local governments, there is still a large section of the community, from landholders to policy makers, that are not aware of the threat of extinction of wild Macadamias and/or do not consciously make an effort to protect and conserve wild trees.

## Uncoordinated conservation

Macadamia species occur on a variety of land tenures throughout their range and within 15 local government jurisdictions across two States. Populations in both Queensland and NSW are recorded within conservation areas, on public lands such as road reserves and on private property. Given the diversity of land managers, conservation efforts are often limited to site management, the broader ecological needs of the species can be overlooked, and more strategic actions not coordinated.

Variations in legislation, resourcing and prioritisation of threatened species management between the States and local governments can also result in significant discrepancies in the ability of public agencies to assist in the management of populations of Macadamias on both public and private land or to undertake compliance activities. Threatened species data are often confined to point locations, with conservation planning and management prioritised partially on the diversity of rare or threatened species in any particular area or habitat type. This 'bang for the buck' approach has significant potential for oversight regarding Macadamia conservation and possibly many other threatened species whose ranges occur over multiple jurisdictions. Furthermore, a lack of information exchange between agencies and with relevant land holders can result in lost opportunities to improve overall management of Macadamia species, and a piecemeal approach to conservation.

A significant amount of research has been undertaken into the conservation status of Macadamia species (primarily due to their crop wild relative status), including studies on the effects of population loss, fragmentation and small population size.

This Plan recommends that an integrated approach that considers recent research findings is applied to conservation of Macadamia species across all jurisdictions.

## Phytophthora and other diseases

Phytophthora root rot is a major problem for the Australian Macadamia industry and is a serious threat to wild populations (Akinsami 2016). Of the Phytophthora species impacting Macadamia, *Phytophthora cinnamomi* is most widespread, has frequent impact and is the most devastating; *P. cinnamomi* causes stem canker, root rot, tree decline, dieback and tree death (if untreated).

Research is required to determine the extent and severity of *P. cinnamomi* infestation and the presence of other diseases within wild populations of Macadamia and explore further the variability in susceptibility between the four Macadamia species (Akinsami 2016). Strategies to

mitigate and/or prevent spread of *P. cinnamomi* to Macadamia populations and remnant wild trees are also needed.

Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*) is a Listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

### Feral pigs

Predation within Macadamia orchards by feral pigs (*Sus scrofa*) caused an estimated $500,000 loss in South East Queensland in 2012 (The Courier Mail, 2012). Given the widespread occurrence of feral pigs within the natural distribution of Macadamia, it is likely that feral pigs are having an impact on the survival of wild populations, either directly through predation on nuts or damage to trees or indirectly through the spread of *P. cinnamomi*; however, research is needed to determine the extent and severity of their impact.

Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs is a Listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

### Potential threats

#### Pests and Diseases from Commercial Orchards

Within orchards, the health and productive capacity of Macadamia is inhibited by a large range of insects and diseases, particularly flower caterpillar, spotting bugs, nutborer, blossom blight, husk spot and trunk canker.

Research is needed into the prevalence and impact of these insects and diseases on wild trees and populations.

## Species specific threats

The major threats facing Macadamias, outlined in the previous section, are shared by the rainforest communities that co-occur with the species. The following section deals with specific threats to individual species and populations.

### *Macadamia integrifolia*

Only a minority of recorded *M. integrifolia* sites is located within protected areas and these are often threatened by weeds and incursion by fire. Many populations on private land occur as individual trees dotted across paddocks left for their nuts when clearing occurred or small clusters of individuals in degraded remnants. The engagement and involvement of private landholders in conservation of this species is essential. The high urban growth zone from Beenleigh to the Gold Coast represents a major threat to local remnant wild *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).

Presence of the invasive vine weed cat's claw creeper is a significant threat to *M. integrifolia* populations in the northern part of the species distribution where, it is widely established within a diverse range of habitats. Smothering of native vegetation, including canopy trees, by invasive vine weeds results in significant mortality and degradation in the medium to long term. Cat's claw creeper is recorded in numerous *M. integrifolia* populations in the Amamoor and Bauple

clusters, with a further 25 populations located within 300 m of a mapped occurrence of cat's claw creeper in the Amamoor Valley (Powell and HQPlantations, unpublished data).

Modelling of the impact of climate change (Powell et al. 2014) suggests that *M. integrifolia* is likely to be more affected by the impacts of climate change relative to *M. ternifolia* or *M. tetraphylla*. This is because *M. integrifolia* occupies drier and warmer rainforests than the rainforest habitats occupied by the other two species.

## *Macadamia jansenii*

The major threat affecting *M. janensii* is that the known distribution is restricted to one population in an area less than a hectare. This makes the species highly susceptible to a catastrophic event, such as fire or disease. Significant recent effort has been made to reduce the vulnerability of the species through a research project to assess the genetic diversity of the species and identify suitable areas of habitat for establishment of ex-situ populations (Shapcott and Powell 2011). This project was supported by a Threatened Species Network grant and supervised by Associate Professor Alison Shapcott of University of the Sunshine Coast (USC), working in partnership with the local Gurang people and members of the Recovery Team. The research revealed a medium level of genetic diversity among the population, that the species was reproductively out crossing, and that recruitment occurred in pulses, probably commensurate with cycles of favourable environmental conditions such as La Nina events. Clones of the majority of adult individuals have been established through cuttings and are being used to establish four new populations on private land and within a National Park, that together with a fifth population at Tondoon Botanic Gardens in Gladstone which will act as an ex-situ gene bank for the species. However, full establishment and maintenance of these populations until they are self-sustaining is expected to take a decade or more. In the interim, wildfire, disease and inappropriate fire regimes remain as significant threats to the survival of *M. jansenii*. The increase in the numbers of wild pig in the Bulburin National Park and their destructive actions in rooting for food is also a threat to this species. Due to the isolation of this species from other Macadamia, seed collection for use in planting projects and storage in seed banks will aid conservation.

The impacts of climate change are predicted to be relatively severe for rainforest habitats in Bulburin National Park due to the area experiencing low precipitation and high temperature regimes relative to the same forest communities occupied by the other three Macadamia species (Powell, unpublished data). Extended drought conditions exacerbated by rising temperatures from climate change may facilitate conditions for more frequent and/or more intense fires that could lead to loss of 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*

The core distribution of *M. ternifolia* prior to clearing is located in the Sunshine Coast hinterland. These areas have been heavily cleared for agriculture with less than 20% of the species' former habitat remaining there (Powell et al. in press). Remnants are highly fragmented and often prone to weed invasion. In the remnant landscape *M. ternifolia* is also frequently found in riparian and riverine corridors, which themselves have been extensively cleared for agriculture and subsequent urban development, especially in the Sunshine Coast lowlands. Remnant riparian rainforests are prone to invasion by weed trees such as camphor laurel and weed vines

such as cat's claw creeper and Madeira vine on disturbed margins and edges. Many remnants are often too narrow to be mapped at 1:50,000 scale which places constraints on identification of habitat areas. Enhancing habitat linkages and providing appropriate management and protection of small linkage populations is considered important for maintenance of meta-population structure. Habitat in southern and western areas of the species distribution such as the Samford and upper Mary River valleys have also been extensively cleared for pasture, cropping and forestry, however, the species is present within reserve areas at elevations up to 700 m ASL in the Conondale National Park.

Excepting for those populations located within the Conondale National Park, there are no known large areas of contiguous habitat containing populations of *M. ternifolia*. Populations are generally small numbering less than 25 adult individuals and are more distant from each other compared with *M. integrifolia*, thus having lower connectivity among smaller more isolated populations in a landscape that is highly fragmented and subject to high pressures from ongoing human development.

Modelling of the change in distribution of *M. ternifolia* under climate change suggests that this species will be less impacted by current projections of future climate compared with the other three Macadamia species, however, areas of high suitability climate niche is predicted to shift to upland areas of the Maleny/Blackall Range and the Conondale Ranges (Powell et al. 2014).

### *Macadamia tetraphylla*

*Macadamia tetraphylla* has experienced a greater loss of habitat from land clearing relative to *M. integrifolia* or *M. ternifolia*, with the effective loss of the vast majority of the southern and central parts of its former range. *Macadamia tetraphylla* populations in these areas are generally small, isolated and at risk of hybridisation through pollination from nearby Macadamia nut farm cultivars, which are predominantly based on *M. integrifolia* germplasm (O'Connor 2013).

The species is now most frequently found on the core of Wollumbin (Mount Warning) and its caldera, along the Border Ranges and foothills between the coast and Numinbah, and along the coastal ranges and valleys from the NSW border to Beenleigh. The diversity of *M. tetraphylla* habitats and tenures through these areas presents complex challenges for planning and management, with a range of different practices required to effectively manage threatening processes.

The high urban growth zone from Beenleigh to the Gold Coast represents a major threat to local remnant wild *M. tetraphylla* populations which are subject to intense pressure from urban expansion and subdivision. Some roadside populations are at risk from road widening and ongoing maintenance activities, such as slashing and spraying.

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 habitats are also vulnerable to invasion by aggressive weeds, such as lantana and asparagus fern (*Asparagus* spp.), which can modify remnant vegetation structure and composition. In NSW, *M. tetraphylla* is identified as a species at risk from Bitou bush (*Chrysanthemoides monilifera*) (DECC 2006).

The relatively wet and cool conditions on the slopes of Wollumbin (Mount Warning), its caldera and along the Border Ranges, make it likely that populations in these areas are less vulnerable to the impacts of climate change (Powell et al. 2014). *Macadamia tetraphylla* populations located

outside these areas are more at risk to the potential consequences of climate change that include increased environmental stress and lowered reproductive potential.

# Prioritisation of threats

This risk assessment considers the likelihood of a threat occurring (Probability) and the level of significance of the threat (Consequence). The Probability of a threat occurring is evaluated on a sliding scale of five categories (from 'likely to 'remote'), and the Consequence of a threat is evaluated on a sliding scale of six categories (from 'negligible' to 'catastrophic'); definition of these categories used is provided in Appendix 2: Risk probability, consequence and impact analysis.

Probability and Consequence are combined in a matrix to provide an ordinal level of Risk associated with particular threatening process ranked from 0 (being circumstances where no threat exists) to 4 (where a catastrophic level of threat exists). See Appendix 2: Risk probability, consequence and impact analysis and Figure 2 for details. Threats are further classified according to the timeframe over which they are likely to have maximum impact on species survival: Short < 5 years, Medium (M) 5–15 years and Long term (L) >15 years. The derived table (Table 9) provides a basis for prioritisation of threats to guide management actions.

**Table 9. Threat prioritisation**

| Threat | Impacts | Probability | Consequence | Risk (0–4) | Time (S, M, L) |
|---|---|---|---|---|---|
| Habitat loss and fragmentation | Loss of individuals | Likely | Moderate | 2 | L |
| – | Loss of populations | Possible | Catastrophic | 4 | L |
| – | Reduced connectivity and gene flow with genetic consequences | Likely | High | 3 | M, L |
| – | Reduced habitat available for establishment | Likely | Moderate | 2 | M, L |
| – | Reduced ecosystem viability | Likely | High | 3 | L |
| Small populations | Isolation; loss of diversity | Likely | Very high | 4 | M, L |
| – | Degradation of habitat; change in environment | Likely | High | 3 | M, L |
| – | Reduction in pollinators | Likely | High | 3 | M, L |
| Weeds | Increased fire risk at ecotones | Likely | Moderate | 2 | S, M, L |
| Vine weeds | Change in habitat structure, composition, and function; loss of individual trees | Likely | Very high | 4 | S, M, L |

| Threat | Impacts | Probability | Consequence | Risk (0–4) | Time (S, M, L) |
|---|---|---|---|---|---|
| – | Reduced recruitment | Likely | Very high | 4 | S, M, L |
| Fire | Habitat degradation through inappropriate fire regimes | Likely | Moderate | 2 | M, L |
| – | Loss of populations through wildfire | Possible | Very high | 3 | M, L |
| – | Loss of only wild population of *M. jansenii* | Occasional | Catastrophic | 4 | S, M, L |
| Unmanaged livestock | Grazing and trampling | Likely | Moderate | 2 | S, M |
| Climate change | Environmental stress | Possible | Moderate | 2 | M, L |
| – | Reduced reproduction | Possible | High | 3 | L |
| – | Local extinctions | Possible | High | 3 | L |
| Genetic pollution | Hybridisation of *M. tetraphylla* or *M. ternifolia* from Macadamia nut farm cultivar pollen | Likely | High | 3 | M, L |
| – | Pollen transfer from cultivated *M. integrifolia* to wild *M. integrifolia* | Likely | Moderate | 2 | M, L |
| Disease | Loss of populations | Occasional | Very high | 3 | M |
| – | Loss of only wild population of *M. jansenii* | Possible | Catastrophic | 4 | S, M |
| Public perception | False sense of security through presence of cultivars | Likely | Moderate | 3 | S, M |
| – | Apathy | Occasional | Moderate | 2 | S, M |
| Uncoordinated conservation | Ad hoc conservation of Macadamia species | Possible | Moderate | 2 | S, M, L |

# 4 Evaluation of previous Recovery Plan

## Overview

The overall objective of the previous Recovery Plan, the Southern Macadamia Species Recovery Plan (SMSRP), was 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.

In the five years since the SMSRP was approved, significant progress has been made towards achieving these objectives. Many key actions have been implemented, through a logical sequence of field surveys to improve knowledge of the distribution and abundance of Macadamia in the remnant landscape and building scientific knowledge of the species' conservation status, whilst undertaking planning and on-ground actions and raising community awareness.

Significant improvement of the knowledge base has been made through publication of six papers in the science literature on wild Macadamia species, several of which were undertaken through the endeavours of Recovery Team members (Appendix 1: Recovery Team membership). Additionally, two research studies on the impact of climate change and potential for genetic pollution of wild Macadamia species have been completed and are either currently in preparation for publication or have been submitted for publication.

The threat profile facing Macadamia species has been refined through field survey and research. The impacts of habitat fragmentation may be mixed, at least in the short term; two research studies have shown that fecundity in Macadamia populations is higher in smaller fragments relative to those within intact habitats. However, the benefits may be outweighed by more pervasive medium term influences such as habitat degradation and isolation. Invasion of weeds into habitat remnants is a major threat, particularly vine weeds such as cat's claw creeper and Madeira vine. Modelling of the impacts of climate change, predicts that the geographic extent of suitable climate niche will contract to areas that are currently cooler and generally at higher elevation that the majority of extant populations. A recent Honours level study (O'Connor, 2013) has found that pollen from Macadamia orchard cultivars is being incorporated into nearby wild *M. tetraphylla* populations; however, more research is required to inform development of management guidelines.

Raising awareness of flora conservation issues within the community has been carried out in tandem with population surveys. This has been achieved through community information sessions at local halls and stalls at various environmental events hosted by local governments or community groups. Planting of specimens of each of the four Macadamia species and installation of interpretation signage has been undertaken in six Council Botanic Gardens with good media coverage. Workshops and presentations have been given to local government environment staff and interpretation material, including a DVD and 'The Macadamia Story' booklet, has been produced and disseminated as opportunities have become available. The Macadamia Conservation Trust has established a website with information about Macadamias and monthly updates on activities.

However, the SMSRP has not fully achieved its recovery objectives in implementation of on ground works. This has been due to a combination of factors including deficiency in the fundamental knowledge required to prioritise on ground works, resource limitations and the relatively short timeframe (8 years) since the SMSRP was written.

# Achievements against performance criteria

An overview of the outcomes achieved against each of the SMSRP performance criteria is provided below.

## 1.1: New populations of southern Macadamia species are identified and recorded on secure sections of State databases

In the five years since the original SMSRP was written, more than 100 surveys of populations of Macadamia species have been undertaken, nearly all of which were previously unrecorded. Voucher specimens were obtained from 26 Queensland populations and submitted to the Queensland Herbarium along with population and site details. Upload of population locations and details of all new sites to state government agency databases such as WildNet (Queensland DES) and BioNet (NSW) databases will be undertaken in 2014.

## 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

Identification of habitats critical to survival of Macadamia species requires knowledge of the distribution and abundance of Macadamia populations, identification of priority populations, habitats and threat assessment. These actions are underway, but yet to be completed.

However, some progress with has been made to reduce the impact of threatening processes on Macadamia habitats in several areas. For example:

- A partnership between the Macadamia Conservation Committee (MCC), HQ Plantations Pty Ltd (HQP) (lessees of the Queensland State Forest estate) and the Burnett-Mary Regional Group in 2012–13 to reduce the impact of cat's claw creeper in the Amamoor Valley through on ground mechanical and chemical control at strategic locations. In addition, the extent of cat's claw creeper infestation within HQ Plantations lease areas including those occupied by many Macadamia populations has been defined and mapped at a coarse scale. This work continued through a new partnership between HQ Plantations, Gympie Landcare and MCC, partially funded by a 2013–14 Queensland Government Everyone's Environment Grant, which aimed to increase community capacity in addressing this threat through production and deployment of biological controls for cat's claw creeper and Madeira vine by Gympie Landcare.
- Tweed Shire Council, Sunshine Coast Council, Logan City Council and City of Gold Coast have provided support to private landholders, particularly to Land for Wildlife members and those with voluntary conservation agreements, to undertake weed control and restoration of Macadamia habitats.
- Tweed Shire Council has undertaken restoration of Macadamia habitat on Council reserves.
- NSW DPIE has identified Wollumbin (Mount Warning) National Park as a key management site for *M. tetraphylla* under their Saving our Species program.

### 2b: Increase in landholder capacity to manage and conserve threatened southern Macadamia species populations

Increase in landowner capacity to manage and conserve threatened Macadamia populations has been largely affected through information dissemination during site visits, community information sessions and workshops, which generally have been well attended and received. Liaison with local government officers has encouraged support for private landholders through council grants and ongoing support programs for Land for Wildlife and voluntary conservation agreement landholders, such as Management Plans and on ground works. Queensland regional Natural Resource Management (NRM) organisations and NSW North Coast Local Land Services have been encouraged to prioritise funding support for Macadamia habitat conservation and promote this to their communities.

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

Whilst not been measured quantitatively, there has been a significant increase in the extent and number of on-ground projects to manage priority macadamia habitat. Evidence of this has been gained through consultation with local governments, NRM groups and community groups, such as Sunshine Coast Council, City of Gold Coast, Redland City Council, Scenic Rim Regional Council, Noosa Landcare, Gold Coast Catchment Association, Gympie Landcare, Big Scrub Landcare, Healthy Land and Water.

### 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

The Macadamia Conservation Research Network (MCRN) was a subset of the Macadamia Conservation Committee (MCC) tasked with development and oversight of Macadamia research, as well as ensuring the MCC was up to date with relevant research. The two priority research goals identified in the SMSRP – modelling of impact of climate change and investigation of potential of genetic pollution of wild Macadamia from orchard cultivar pollen – were developed into research programs and have been implemented; the results will be disseminated through publication in the peer reviewed science literature. NB. The MCRN was renamed in 2018 to become the Macadamia Conservation Research Committee.

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

During the five years of the SMSRP, six research papers have been published in the peer reviewed scientific literature, and two more are in preparation. The results of these studies will be integrated into future activities and information products.

### 4a: Increase in public awareness of the environmental, cultural and economic significance of threatened southern Macadamia species

Significant effort has been devoted to this achievement of this criteria, including the development of new information product, displays at local and regional events, media releases, public activities (such as ex situ plantings), although much remains to be done. A Macadamia conservation website was launched in 2014; this is a key element in achieving this goal.

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

As per 2b: Increase in landholder capacity to manage and conserve threatened southern Macadamia species populations.

## 5a: Progress made on the completion of Recovery Plan actions is reviewed annually

Implementation of the Recovery Plan is carried out under the supervision of the MCC, which meets 3–4 times annually to review progress and prioritise activities going forward. The MCC is comprised of a multi-disciplinary panel of people who collectively have unparalleled knowledge and expertise of Macadamia species and their conservation. Progress in implementation of the Recovery Plan is measured formally via biannual reports that are produced as part of the compliance requirements of the umbrella grant provided by Horticulture Australia Limited for implementation of the SMSRP.

# 5 Updated recovery objectives, performance criteria and actions

## Overall objective

Ensure the long-term viability of all four Macadamia species through maintaining existing populations and implementing measures to promote recovery.

**Table 10. Summary of specific objectives and threats addressed**

| Specific Objectives | Threats Addressed |
|---|---|
| 1. Continue to identify and evaluate the extent and quality of Macadamia species populations and their habitat | Habitat loss and fragmentation, Climate change, Uncoordinated conservation |
| 2. Reduce and manage the major threatening processes affecting Macadamia species and their habitat | Habitat loss and fragmentation, Weeds, Vine weeds, Fire, Unmanaged livestock |
| 3. Increase knowledge of Macadamia species and their ecology to affect their conservation and management | All |
| 4. Improve awareness and understanding of Macadamia species, especially the management requirements of these species and their major threats | Public perception, Uncoordinated conservation |
| 5. Manage, monitor and evaluate the National Recovery Plan for Macadamia Species | Uncoordinated conservation |

## Overview

Detailed knowledge of the distribution and abundance of Macadamia species has been acquired through field surveys conducted during the life of the previous Recovery Plan. This provides solid evidence that Macadamia species are sufficiently diverse, abundant and connected in the remnant landscape to persist in the short term if populations and habitats are protected and threats are mitigated through appropriate management. Key to achieving this is a coordinated, cross-tenure approach that ensures further loss of essential habitat within areas of key population clusters is avoided.

Weeds remain the single greatest threat to Macadamia species in the short to medium term, as they have the capacity to retard rehabilitation of degraded areas and in the worst cases, invade and transform intact rainforest habitats. In the longer term, impacts arising from habitat fragmentation including degradation, inbreeding and drift are likely to become more pervasive. These impacts will be exacerbated with further habitat clearing and loss of individuals or populations, particularly priority populations. Climate change is also highly likely to place many populations under additional threat through increased environmental stress and reduced reproductive potential. Loss of genetic diversity and/or hybridisation through pollen from orchard cultivars is also a potential medium to long term problem. Given these factors the recovery approach adopted in this Recovery Plan is to focus on outcomes that address short term goals whilst considering the medium- and long-term threats. For example, stratifying the identification of critical populations and habitats and the threats they face (based on short to

medium term considerations), to identify those which are likely to be most resilient to climate change and have lower risk of contamination from cultivar pollen.

# Performance criteria and management actions

## Objective 1. Continue to identify and evaluate the extent and quality of Macadamia species populations and their habitat

**Performance Criteria 1a. Population and site data for new and known populations of Macadamia are used to inform conservation and management priorities**

***Action 1.1*** *Determine whether additional populations of Macadamia species occur within southern Queensland and northern NSW*

Continue to carry out strategic searches for unrecorded populations of Macadamia species as opportunities or new information (such as essential habitat mapping) comes to hand. Searches will concentrate on areas highly likely to provide habitat for Macadamia species, especially those that link extant populations. All new information to be submitted to appropriate government databases, including the National Forest Inventory (ABARES), the Tree Seed Centre (CSIRO), Queensland's WildNet (DES), NSW BioNet (DPIE) Atlas of Living Australia (ALA) and relevant local governments.

Priority: Medium

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, botanists, community groups, landholders

***Action 1.2*** *Record data from previously unrecorded Macadamia populations, including population size and structure, distance to nearest population, reproductive viability, threats and management issues*

All new information collected to be submitted to appropriate government databases, including the National Forest Inventory (ABARES), the Tree Seed Centre (CSIRO), WildNet (DES), BioNet (DPIE), Atlas of Living Australia (ALA) and relevant local governments.

Priority: Medium

Potential Contributors: AG, MCC, DES, DPIE, LLS, local governments, regional NRM organisations, botanists, community groups, landholders

***Action 1.3*** *Survey known Macadamia populations for data deficiencies, including population size and structure, distance to nearest population, reproductive viability, threats and management issues*

Some records of Macadamia populations are data deficient. Others are dated, may have been lost to clearing, or are not true wild populations. An ongoing strategic survey program of selected populations where data is deficient or more than ten years old needs to be undertaken, concentrating on those populations that are large, important in linking the network of populations, in secure tenure, or at the ends of deterministic environmental gradients.

Priority: High

Potential Contributors: MCC, DPIE, LLS, DES, local governments, botanists, community groups, landholders

***Action 1.4*** *Use the results of Macadamia population surveys together with research outcomes to systematically prioritise populations for conservation, management and research purposes within an adaptive framework*

Prioritisation will enable strategic allocation of limited resources to conservation of populations that make a significant contribution to the long-term viability of a species. Elements to be considered in prioritisation will be defined by the MCC, but could include factors such as unique genotypes, genetic diversity, population size, reproductive viability, level of protection, location within overall species distribution (such as edge of range), extent of habitat important to survival, proximity to habitat linking populations, landscape connectivity and threat mitigation ability.

Priority: High

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, botanists

## Objective 2. Reduce and manage the major threatening processes affecting Macadamia species and their habitat

**Performance Criteria 1a. Priority Macadamia populations are protected**

***Action 2.1*** *Provide information on the habitats critical to the survival of priority Macadamia populations to government agencies at all levels to assist with legislative and planning protection*

Macadamia populations are found throughout the fastest growing region in Australia. Land managers and land use planners require detailed information about the location and priority of remnant populations to improve decision-making with regard to activities that may impact on Macadamia populations or exacerbate the threatening processes that they face. Macadamia population data together with peer reviewed published habitat models will be used to develop essential habitat mapping and climate change projections for Macadamia species. All information collected on Macadamia populations will be submitted to appropriate government databases, including WildNet (DES), BioNet (DPIE), Atlas of Living Australia (ALA) and relevant local governments.

Priority: High

Potential Contributors: MCC, AG, DES, DPIE, LLS, local governments, regional NRM organisations, researchers

***Action 2.2*** *Mitigate climate change impacts on Macadamia through planning protection and on ground implementation*

Modelling of the impact of climate change on Macadamia habitat was undertaken in 2013 (Powell et al. 2013). The resultant mapping needs to be made more widely accessible and, particularly, governments need to be encouraged to incorporate outcomes into planning schemes and policies. Further dissemination of the outcomes to the wider community, particularly regional NRM organisations and Landcare and conservation groups, will assist with implementation of climate change mitigation strategies.

Priority: High

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, community groups, landholders

***Action 2.3*** *Negotiate appropriate agreements with private landholders to establish greater long-term security for wild Macadamias*

Private landholders with priority populations of wild Macadamias will be encouraged to enter into voluntary conservation agreements (such as Land for Wildlife) or establish conservation covenants (such as nature refuge) through local or state government. Landholders with wild Macadamia trees or non-priority Macadamia populations will also be encouraged to participate in conservation partnership programs.

Priority: Medium

Potential Contributors: MCC, DES, DPIE, LLS, local governments, Queensland Trust for Nature (QTfN), NSW Biodiversity Conservation Trust (BCT), regional NRM organisations, community groups, landholders

***Action 2.4*** *Establish ex-situ populations for M. jansenii at multiple sites*

The known distribution of this species is restricted to one population. Ex-situ populations have recently been established at five sites: Bulburin National Park and Thornhill Station and a fifth population at Tondoon Botanic Gardens, Gladstone. Continue to work with stakeholders to complete establishment, monitoring and maintenance of ex-situ populations.

Priority: High

Potential Contributors: MCC, DES, USC, Gladstone Botanic Gardens, Gidarjil Development Corporation, landholders

***Action 2.5*** *Establish seed banks and/or seed orchards*

Identify appropriate source trees, based on the outcomes of genetic research into the diversity of wild populations, and establish seed banks or seed orchards from representative populations of all species.

Priority: High

Potential Contributors: MCC, AG, state governments, local governments, Botanic Gardens, regional NRM organisations, community groups, researchers

***Action 2.6*** *Develop provenance protocols (for seed and tube stock) to guide Macadamia propagation and planting*

Hybridisation and pollination by cultivars are a threat to wild trees and populations of three Macadamia species (not *M. jansenii*). Development of provenance protocols (for seed and tube stock) to guide Macadamia plantings will reduce the threat to wild trees and inform actions to enhance existing populations and establish new populations in appropriate habitats.

Priority: Medium

Potential Contributors: MCC, AG, DES, DPIE, LLS, local governments, regional NRM organisations, community groups, researchers, native plant nurseries

**Performance Criteria 2b. Increase in land manager capacity to manage and conserve wild Macadamias**

***Action 2.7*** *Support land managers to develop property management plans that include wild Macadamia conservation and threat mitigation*

Property management planning is an important tool to help land managers improve understanding and management of their land. Land managers with wild Macadamia habitat on their properties will be strongly encouraged to develop property management plans that:

- achieve long-term protection appropriate to the tenure of Macadamia habitat
- reduce the impact of weed species
- reduce the impact of fire
- manage livestock
- enable habitat expansion
- improve connectivity of Macadamia habitat with other vegetation communities.

Land managers are also encouraged to include the above activities in existing management plans for properties containing wild Macadamia. Additionally, land managers are encouraged to consider collaboration with neighbouring land managers for the purpose of developing strategic plans to undertake the above activities.

Priority: High

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, community groups

**Performance Criteria 2c. Increase in the extent and effectiveness of on-ground works undertaken by land managers to manage wild Macadamia habitat**

***Action 2.8*** *Source and provide resources and incentives to land managers for long-term protection of Macadamia habitat appropriate to the tenure of the habitat*

Protection and rehabilitation of Macadamia habitats requires practical resources including materials and labour to remove invasive weeds, erect fences and manage fire and livestock. All levels of government, philanthropic and commercial organisations and the Macadamia industry, are to be encouraged to provide financial and other support for the management and/or rehabilitation of important Macadamia populations or their habitats, particularly given likely benefits provided to other threatened flora and fauna species and threatened vegetation communities. Land managers should be encouraged and assisted to develop submissions to funding bodies for resources to protect Macadamia species and their habitats.

Priority: High

Potential Contributors: AG, MCC, DES, DPIE, LLS, local governments, regional NRM organisations, community groups, philanthropic organisations, commercial organisations, Macadamia industry, land managers

***Action 2.9*** *Identify, monitor and manage weed, fire and livestock threats for priority populations*

Use the results of population surveys to assess the extent and severity of weed, fire and livestock threats and to develop a targeted threat mitigation strategy.

- The potentially significant impact of weeds on Macadamia populations and their habitats has become known through implementation of the previous Recovery Plan. Invasive vine weeds cat's claw creeper and to a lesser extent, Madeira vine are specific threats to wild Macadamia species. Cat's claw creeper is well established in the northern part of the geographic distribution of *M. integrifolia* where it directly threatens the largest cluster of extant populations. Continue to work with stakeholders to acquire resources and expertise to address this serious threat. Monitor selected populations of *M. integrifolia* where cat's claw creeper is present, or nearby.
- Fire is a risk to rainforest at ecotones between dry fire adapted sclerophyll forests and rainforest communities and/or edges of rainforest fragments where weeds have established, especially where those fragments are located upslope of areas subject to fire. Identify populations and habitats at particular risk and work with stakeholders to minimise weed build up at rainforest margins.
- When access is available, livestock will utilise rainforest fragments for shade, resulting in soil compaction and trampling of the ground layer, severely retarding recruitment. Work with land managers in affected areas to exclude cattle and other livestock from rainforest patches, especially those harbouring priority populations. Identify populations and habitats at particular risk and encourage those landowners to carry out mitigation measures to protect the affected Macadamia population.

Priority: High

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, Fire and Biodiversity Consortiums, community groups, land managers

***Action 2.10*** *Undertake release of biocontrol agents for weeds such as cat's claw creeper and Madeira vine at appropriate sites and monitor results*

Cat's claw creeper and Madeira vine are threatening Macadamia trees and their habitat in many locations. Resource limitations often prohibit the control of these weeds through physical or chemical methods and biocontrol release may be appropriate to reduce weed impacts at these sites. Work with Biosecurity Queensland, community groups and other organisations raising biocontrol agents to undertake biocontrol release in partnership with land managers and implement appropriate monitoring.

Priority: High

Potential Contributors: MCC, DES, DAF, DPIE, LLS, local governments, regional NRM organisations, community groups, land managers

## Objective 3. Increase knowledge of Macadamia species and their ecology to affect their conservation and management

**Performance Criteria 3a. Priority research benefiting wild Macadamia conservation is undertaken**

***Action 3.1*** *Encourage research to address gaps in the current understanding of Macadamia species ecology and conservation requirements*

The following gaps in knowledge of Macadamia ecology and conservation requirements need to be addressed in order to mitigate threats:

- determining impacts of fragmentation on genetic diversity and reproductive biology including identification of populations containing rare or unique alleles
- examining the potential impact of climate change on flowering period and pollinators
- identifying opportunities to reintroduce populations within and between population clusters to maintain connectivity and enhance diversity.

The MCC will work with the Macadamia Conservation Research Committee (MCRC) to prioritise, resource and undertake research.

Priority: Medium

Potential Contributors: MCC, MCRC, DES, DPIE, LLS, local governments, regional NRM organisations, researchers, land managers

***Action 3.2*** *Increase knowledge of the structure of genetic diversity in wild populations to assist prioritisation of populations for conservation*

Undertake research to improve knowledge of the distribution of genetic diversity among Macadamia populations, targeting those that are under threat, geographically isolated, at the edge of range or deterministic environmental gradients, or identified as a priority population within this Recovery Plan. The results to be used to assist with prioritisation for conservation and identifying the need for specific management actions to maintain genetic diversity, including establishment of ex-situ populations.

Priority: Low

Potential Contributors: MCC, MCRN, researchers

***Action 3.3*** *Improve understanding of the consequence of pollination of wild Macadamia populations from domestic germplasm and impacts on long-term conservation*

Pollination of wild *M. tetraphylla* by industry cultivars and garden specimen has been identified in a recent honours level post graduate study. However, the scope of the study was limited, and the extent of hybridisation found to be restricted to seedling and juvenile cohorts in the affected populations. Further research is required to establish the extent of the phenomenon across the three Macadamia species affected, the extent of survivorship of hybrid individuals and to develop of a mitigation strategy. Liaise with the Australian Macadamia Society (AMS) and DAFF to investigate opportunities to reduce this threat, such as incorporating appropriate measures in the Macadamia industry Code of Sound Orchard Practice.

Priority: Low

Potential Contributors: MCC, MCRN, AMS, DAF, Macadamia growers, researchers

***Action 3.4*** *Facilitate the use of traditional ecological knowledge in the recovery of Macadamia species*

Traditional owner groups have highlighted the importance of conserving threatened Macadamia species. Macadamia nuts have been recorded as a valuable food, trading and cultural resource to Aboriginal people (SEQTOLSMA members pers. comm.). The MCC will work with Traditional Owners and other Aboriginal stakeholders to appropriately document and share knowledge and stories that improve conservation outcomes for Macadamia species.

Priority: Medium

Potential Contributors: MCC, LLS, regional NRM organisations, Aboriginal and Traditional Owner groups

***Action 3.5*** *Establish long-term monitoring programs for priority Macadamia populations and disseminate the results*

A long-term monitoring program has been initiated for four *M. integrifolia* sites in South East Queensland. The methodology is based on Laidlaw et al. (2011), and encompasses changes in habitat composition and condition, population dynamics (including population size and structure) and threats. This program requires expansion to include representative sites for all Macadamia species. Results to be provided to land managers and land use planners to guide protection of Macadamia populations.

Priority: Medium

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, researchers, land managers

***Action 3.6*** *Update models of the projected impact of climate change on Macadamia ecology, extent of habitat and threatening processes and disseminate the results*

Climate change will affect the phenology (for example, flowering and fruit maturation), hybridisation between, and reproductive capacity of Macadamia species. Increasing temperatures and variable rainfall patterns may also affect the distribution of these species, the composition and integrity of their rainforest habitats, the impact of current and sleeper weeds, and the intensity, seasonality and frequency of fire. Climate models of predicted impacts of climate change will be updated on a regular basis as new information comes to hand and the results disseminated to land use planners and land managers, as well as incorporated into Recovery Plan review and implementation.

Priority: Low

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, researchers

**Performance Criteria 3b. Outcomes of priority research are integrated into wild Macadamia conservation**

***Action 3.7*** *Research outcomes are promoted and made easily accessible to land managers, land use planners and the wider community*

Priority research results will be published in the peer reviewed scientific literature. The MCC in partnership with the MCRN and research partners will disseminate and promote of research outcomes through media and networks to facilitate inclusion of latest ecological research in management and planning for Macadamia conservation.

Priority: Medium

Potential Contributors: MCC, MCRN

## Objective 4. Improve awareness and understanding of Macadamia species, especially their conservation management requirements and major threats

**Performance Criteria 4a. Increase in public awareness of the environmental, cultural and economic significance of Macadamia species**

***Action 4.1*** *Develop community education tools that build understanding of Macadamia species and their conservation management requirements*

Misconceptions regarding the status of Macadamia and information of the conservation management requirements needs to be built within the broader community and with land managers. The MCC will investigate opportunities to: distribute Macadamia species profiles to landholders, install signage at significant roadside remnants, profile species in local newspapers, and develop fact sheets on threatening processes. A website devoted to Macadamia conservation has been established and is managed by the Macadamia Conservation Trust. Monthly articles are contributed to the Australian Macadamia Society e-newsletter which links to the website. Continue to raise the profile of Macadamia conservation in the public arena through giftings of each species along with interpretation signage to botanic gardens, media releases and other measures.

Priority: Medium

Potential Contributors: MCC, DES, DTMR, DPIE, LLS, local governments, regional NRM organisations, land managers

***Action 4.2*** *Provide information to public and private land managers (including landholders and Macadamia growers) on known locations of wild Macadamia species to ensure they are considered when making land management decisions*

Disseminate and promote the results of Macadamia population surveys, through media, information products, targeted engagement and the inclusion of data in publicly accessible databases, such as WildNet, BioNet, publications and media.

Priority: High

Potential Contributors: MCC, AG, DES, DPIE, LLS, local governments, regional NRM organisations, community groups, botanists

***Action 4.3*** *Continue to develop opportunities for promotion of Macadamia species conservation status*

Ongoing promotion of Macadamia conservation issues through local, regional and international media and events will improve community awareness of the status of Macadamias.

Priority: Medium

Potential Contributors: MCC, DES, DPIE, LLS, local governments, regional NRM organisations, community groups

***Action 4.4*** *Liaise with state government agencies, local governments, and regional NRM organisations in order to incorporate Macadamia conservation into their biodiversity conservation and natural resource management strategies*

The distribution of Macadamia species spans 15 local government areas, three regional bodies and two state governments. Whilst many are taking a proactive role in Macadamia conservation and management, with the exception of planning for wildlife corridors, each is primarily focussed on the geographic extent of their respective jurisdictions. Conservation of Macadamia species requires a coordinated approach that accounts for individual actions and facilitates implementation of broader initiatives that spans the species' geographic distribution, to ensure that optimum outcomes are achieved. The MCC has a lead role in this coordinated conservation, ensuring that past activities supported through substantial investment by the Australian Macadamia industry on behalf of the community are built upon in the ongoing development and implementation of this Recovery Plan.

Priority: High

Potential Contributors: MCC, MCRN, DES, DPIE, LLS, local governments, regional NRM organisations, researchers, land managers

***Action 4.5*** *New ecological information is incorporated into information products and materials*

The MCC will undertake a review of information products, including online materials, it develops as required to ensure the latest ecological research is incorporated.

Priority: Medium

Potential Contributors: MCC, MCRN

## Objective 5. Manage, monitor and evaluate the National Recovery Plan for Macadamia Species

**Performance Criteria 5a. Progress made on the completion of Recovery Plan actions is reviewed biennially**

***Action 5.1*** *Maintain the role of the Macadamia Conservation Committee as the coordinating body for the Recovery Plan*

In 2013, the Macadamia Conservation Trust, in consultation with the MCC and with the support of the AMS (trustees for the MCT), commissioned the development of a Business Plan to guide the activities and operations of both the MCT and MCC to assist in maximising conservation

outcomes (deVos Consulting 2013). The Business Plan includes Terms of Reference for both the MCT and MCC and confirms the role of the MCC to:

- provide advice and recommendations to the MCT and AMS on all matters related to Macadamia conservation
- develop and undertake/manage activities to promote Macadamia conservation
- act as a reference/advisory committee for the 'Wild about Macadamias' project and any subsequent similar projects
- undertake activities to raise funds for the Trust.

Members of the MCC are appointed by the AMS on recommendation from the MCC on the required mix of skills and background and may include Macadamia growers, scientists and researchers, conservation specialists NRM and community groups, together with representatives of government departments and instrumentalities. The composition of the MCC is comprised of individuals who collectively possess the range of skills, expertise and experience required to oversee implementation of the Recovery Plan and is reviewed annually.

Priority: Medium

Potential Contributors: AMS, MCC, State agencies, local governments, regional NRM organisations, researchers, industry, community groups

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

This Recovery Plan provides the guiding document for the MCT and MCC, with implementation discussed and reviewed during regular meetings of the MCC. Biennial monitoring and evaluation will be undertaken by the MCC in consultation other appropriate stakeholders, and the results distributed to stakeholders.

Priority: Medium

Potential Contributors: AMS, MCC, State agencies, local governments, regional NRM organisations, researchers, industry, community groups

# 6 Summary of recommended management practices

Management prescriptions necessary for the maintenance and protection of Macadamia species include:

- prevent further loss of vegetation communities that provide habitat for Macadamia species
- manage the impact of environmental weeds through appropriate control programs that mitigate the impact of established weeds and prevent or slow the establishment of new weed species
- provide appropriate encouragement support to private land holders with to protect important populations on their properties
- manage fire regimes (frequency, intensity, and seasonality) in Macadamia habitat and neighbouring vegetation communities to ensure that Macadamia populations are not affected by fire-based disturbance events
- manage the impact of commercial and private plantations and planted specimens on the genetic diversity of wild populations through information dissemination and adoption of appropriate measures by the Macadamia industry.

## Table 11. Summary of actions to mitigate threats

| Threat | Current Actions | Future Actions |
|---|---|---|
| **All Species** | – | – |
| Habitat loss and fragmentation | • Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and regional NRM organisations<br>• Provision of Macadamia population data to relevant government authorities (local, state and federal) to assist with legislative and planning protection and guide public land management | • Provision of new Macadamia population data to relevant government authorities (local, state and federal) to assist with legislative and planning protection<br>• Liaison with local governments, regional NRM organisations, Fire and Biodiversity Consortiums and other relevant organisations to access resources for conservation of Macadamia habitat on private properties<br>• Liaison with public land managers to encourage conservation of Macadamia habitats on their properties<br>• Sourcing of additional resources to assist land managers with conservation of Macadamia habitat<br>• Re-survey Macadamia populations to assess changes in population number structure and threat profile<br>• Undertake population viability analysis and investigate differences in genetic diversity between juvenile and adult cohorts<br>• Further investigation (building on current knowledge) into genetic changes to Macadamia populations arising from habitat fragmentation and implementation of key outcomes |
| Small populations | • Studies of genetic characterisation of Macadamia species and impact of habitat fragmentation on the population viability (UQ and USC)<br>• Development of ex-situ gene banks | • Targeted research on population genetics<br>• Continue investigation building on current knowledge into genetic changes to Macadamia populations arising from habitat fragmentation |

| Threat | Current Actions | Future Actions |
|---|---|---|
| Weeds | • Work with stakeholders to reduce the impact of cat's claw creeper and Madeira vine<br>• Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and regional NRM organisations | • Assessment of Macadamia populations to determine level of weed impact and particularly the presence of transformer weed species, such as cat's claw creeper and Madeira vine<br>• Liaison with local governments, regional NRM organisations and other relevant organisations to access resources for conservation of Macadamia habitat on private properties<br>• Provision of resources to land managers to reduce the impact of specific weed species in areas of known essential habitat<br>• Liaison with public land managers to encourage conservation of Macadamia habitats on their properties<br>• Sourcing of additional resources to assist land managers with conservation of Macadamia habitat<br>• Identify sites suitable for release of biocontrol agents<br>• Work with stakeholders to set up monitoring sites to assess the impacts of cat's claw creeper on Macadamia populations |
| Fire | • Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and regional NRM organisations | • Liaison with local governments, regional NRM organisations, Fire and Biodiversity Consortiums and other relevant organisations to reduce the threat of fire to Macadamia habitats |
| Unmanaged livestock | • Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and regional NRM organisations | • Provision of resources to land managers to reduce the impact of livestock in areas of known essential habitat |
| Climate change | • Modelling of the projected impact of climate change on the ecology, distribution, and habitat of Macadamia species<br>• Work with stakeholders to set up four long term monitoring sites occupied by Macadamia species | • Resurvey long term monitoring plots at suitable intervals to assess change in vegetation composition and Macadamia population demographics over time<br>• Provide results of modelling to land use planners<br>• Identify appropriate mitigation measures and develop action-oriented implementation strategy<br>• Use modelling results for targeted engagement of land managers for implementation of mitigation actions |

| Threat | Current Actions | Future Actions |
|---|---|---|
| Genetic pollution | – | • Improve understanding of the consequence of pollination of Macadamia species from domestic germplasm and impacts on long-term conservation |
| Public perception | • Production of species profile leaflet for Macadamia species. Production of Macadamia Story Booklet. Development of a Macadamia conservation website. Gifting of Macadamia species along with interpretation signage to local, regional and state capital botanic gardens. Host interpretation stalls at selected community and environment events | • Continue to develop opportunities for promotion of Macadamia status, for example, through local and regional media, events, social media<br>• Development of community education tools for land managers that build understanding of the conservation management requirements of Macadamia species |
| Uncoordinated conservation | • Coordinated implementation of recovery actions by the MCT in partnership with Councils and regional NRM organisations through the Wild about Macadamias project | • Build partnerships in *Wild about Macadamias* to encompass and support a wider range of land managers<br>• Encourage local and state government involvement in the Recovery Team |
| ***Macadamia jansenii*** | – | – |
| Lack of ex-situ gene bank | • Establishment of four ex-situ wild populations and secure population at Tondoon Botanic gardens is underway | • Completion of establishment of an ex-situ gene bank for *M. jansenii* at Tondoon Botanic Gardens, Gladstone. Continue to establish, monitor and maintain all ex-situ wild populations until self-sufficient |

# 7 Costs of recovery

The indicative costs of recovering species identified in this plan are detailed in Table 12. Some of these actions are already underway (or planned) in existing management plans and programs. Integration of this plan with existing programs will result in the most efficient and effective use of resources for the conservation of Macadamias.

## Table 12. Costs associated with recovering species in the National Recovery Plan for Macadamia Species

| Action | Cost estimate ($) Yr 1 | Cost estimate ($) Yr 2 | Cost estimate ($) Yr 3 | Cost estimate ($) Yr 4 | Cost estimate ($) Yr 5 | Cost estimate ($) Total |
|---|---|---|---|---|---|---|
| 1.1 Determine whether additional populations of Macadamia species occur within southern Qld and northern NSW | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 1.2 Record data from previously unrecorded Macadamia populations, including population size and structure, distance to nearest population, reproductive viability, threats and management issues | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 1.3 Survey known Macadamia populations for data deficiencies, including population size and structure, distance to nearest population, reproductive viability, threats and management issues | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 1.4 Use the results of Macadamia population surveys together with research outcomes to systematically prioritise populations for conservation, management and research purposes within an adaptive framework | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 12,500 |
| 2.1 Information on the habitats critical to the survival of priority Macadamia populations is provided to government agencies at all levels to assist with legislative and planning protection | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 2.2 Negotiate appropriate agreements with landholders to establish greater long-term security for priority areas on private property | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 75,000 |
| 2.3 Establishment of ex-situ populations for *M. jansenii* at multiple sites | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 12,500 |

| Action | Cost estimate ($) Yr 1 | Cost estimate ($) Yr 2 | Cost estimate ($) Yr 3 | Cost estimate ($) Yr 4 | Cost estimate ($) Yr 5 | Cost estimate ($) Total |
|---|---|---|---|---|---|---|
| 2.4 Establish seed banks and/or seed orchards | – | – | – | – | – | – |
| 2.5 Develop provenance protocols (for seed and tube stock) to guide Macadamia propagation and planting | – | – | – | – | – | – |
| 2.6 Provide information to public and private land managers (including landholders and Macadamia growers) on known locations of wild Macadamia species to ensure they are considered when making land management decisions | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 2.7 Support land managers to develop property management plans that include wild Macadamia conservation and threat mitigation | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 125,000 |
| 2.8 Source and provide resources and incentives to land managers to seek long-term protection of Macadamia habitat appropriate to the tenure of the habitat | 240,000 | 240,000 | 240,000 | 240,000 | 240,000 | 1,200,000 |
| 2.9 Identify, monitor and manage weed, fire and livestock threats for priority populations | 40,000 | 40,000 | 40,000 | 40,000 | 40,000 | 200,000 |
| 2.10 Undertake release of biocontrol agents for weeds such as cat's claw creeper and Madeira vine at appropriate sites and monitor results | 5,000 | 7,500 | 10,000 | 12,500 | 15,000 | 50,000 |
| 2.11 Establish long-term monitoring programs for priority Macadamia populations and disseminate the results | – | 15,000 | – | – | 15,000 | 30,000 |
| 2.12 Update models of the projected impact of climate change on Macadamia ecology, extent of habitat and threatening processes | – | 5,000 | – | 5,000 | – | 10,000 |

| Action | Cost estimate ($) Yr 1 | Cost estimate ($) Yr 2 | Cost estimate ($) Yr 3 | Cost estimate ($) Yr 4 | Cost estimate ($) Yr 5 | Cost estimate ($) Total |
|---|---|---|---|---|---|---|
| 3.1 Encourage research to address gaps in the current understanding of Macadamia species ecology and develop research priorities for conservation | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 12,500 |
| 3.2 Increase knowledge of the structure of genetic diversity in wild populations to assist prioritisation of populations for conservation | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 50,000 |
| 3.3 Improve understanding of the consequence of pollination of Macadamia species from domestic germplasm and impacts on long-term conservation | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 50,000 |
| 3.4 Facilitate the use of traditional ecological knowledge in the recovery of Macadamia species | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 50,000 |
| 3.5 Research outcomes are promoted and made easily accessible to land managers, land use planners and the wider community | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 3.6 New ecological information is incorporated into information products and materials | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 12,500 |
| 4.1 Develop community education tools that build understanding of the conservation management requirements of Macadamia species | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 | 30,000 |
| 4.2 Continue to develop opportunities for promotion of Macadamia species conservation status | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 60,000 |

| Action | Cost estimate ($) Yr 1 | Cost estimate ($) Yr 2 | Cost estimate ($) Yr 3 | Cost estimate ($) Yr 4 | Cost estimate ($) Yr 5 | Cost estimate ($) Total |
|---|---|---|---|---|---|---|
| 4.3 Liaise with state government agencies, local governments, and regional NRM organisations in order to incorporate Macadamia conservation into their biodiversity conservation and natural resource management strategies | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 25,000 |
| 5.1 Maintain the role of the Macadamia Conservation Committee as the coordinating body for the Recovery Plan | 16,000 | 16,000 | 16,000 | 16,000 | 16,000 | 80,000 |
| 5.2 Monitor and evaluate the outcomes of the Recovery Plan using an adaptive management framework | – | 10,000 | – | 10,000 | – | 20,000 |
| **Year/Grand Totals** | **446,500** | **479,000** | **451,500** | **469,000** | **471,500** | **2,317,500** |

# 8 Evaluation of Recovery Plan

The Macadamia Conservation Committee will endeavour to monitor the progress and delivery of the National Recovery Plan for Macadamia Species throughout the life of the Recovery Plan. The MCC will review the Recovery Plan biennially to include new knowledge – whether from research generated as a result of the plan or derived from work undertaken within specific actions – and revise priorities if required.

Resources permitting, the Recovery Plan will be evaluated by members of the MCC at the end of the five-year period in 2028. Implementation of all management actions will be assessed against the designated performance criteria in Section 5.

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Contributors to this Recovery Plan:

- Denise Bond
- Jolyon Burnett
- Ken Dorey
- John Gillett
- Dr Craig Hardner
- Brice Kaddatz
- Ian McConachie AM
- Maria Matthes
- Dr Jodi Neal
- Dr Catherine Nock
- Associate Professor Alison Shapcott
- Associate Professor Bruce Topp

Contributors to previous Recovery Plan (SMSRP):

- Jolyon Burnett
- Ken Dorey
- John Gillett
- Paul Grimshaw
- Dr Gordon Guymer
- Dr Craig Hardner
- Brice Kaddatz
- Ian McConachie
- Maria Matthes
- Ann Moran
- Dr Jodi Neal
- Rosemary Niehus
- Michael Powell

- Dr Alison Shapcott
- Associate Professor Bruce Topp

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# Acronyms

| Term | Definition |
|---|---|
| AG | Australian Government |
| AMS | Australian Macadamia Society |
| ASL | Above Sea Level |
| BCT | Biodiversity Conservation Trust |
| BRAIN | Brisbane Rainforest Action and Information Network |
| BMRG | Burnett-Mary Regional Group |
| CA | Conservation Area |
| E | Endangered |
| DAF | Queensland Department of Agriculture and Fisheries |
| DES | Queensland Department of Environment and Science |
| DPIE | New South Wales Department of Planning, Infrastructure and Environment |
| DTMR | Queensland Department of Transport and Main Roads |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* (Cth) |
| FR | Forest Reserve |
| HAL | Horticulture Australia Limited |
| LA | Lease Area |
| MCC | Macadamia Conservation Committee |
| MCRC | Macadamia Conservation Research Committee |
| MCT | Macadamia Conservation Trust |
| MGA | Map Grid of Australia |
| NHT | Natural Heritage Trust |
| NP | National Park |
| NR | Nature Refuge |
| NRM | Natural Resource Management |
| NSW | New South Wales |
| QAAFI | Queensland Alliance for Agriculture and Food Innovation |
| QTfN | Queensland Trust for Nature |
| RAF | Radioactive Amplified DNA Fingerprinting |
| RE | Regional Ecosystem |
| REDD | Regional Ecosystem Description Database |
| SEQFBC | South East Queensland Fire and Biodiversity Consortium |
| SF | State forest |
| TAP | Threat Abatement Plan |
| SEQTOLSMA | South East Queensland Traditional Owner Land and Sea Management Alliance |
| SMSRP | Southern Macadamia Species Recovery Plan |
| USC | University of the Sunshine Coast |
| V | Vulnerable |
| VCA | Voluntary Conservation Agreement |

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# Appendix 1: Recovery Team membership

The Recovery Team consists of members of the Macadamia Conservation Committee and the Macadamia Conservation Research Committee.

These committees were established by the Macadamia Conservation Trust (MCT) in 2018. Members are appointed by invitation and have a term of three years; the full Terms of Reference for each Committee is available from the MCT.

In 2018, appointed members of each Committee were as shown in Table 13 and

Table 14.

**Table 13. Macadamia Conservation Committee**

| Name | Organisation |
|---|---|
| Denise Bond | Macadamia Conservation Trust (Executive Officer) |
| Jolyon Burnett | Australian Macadamia Society (CEO) |
| Andrew Burnside | Community member |
| Ken Dorey | Community member |
| Graeme Fleming | Australian Macadamia Society (Board Member) |
| Liz Gould | Healthy Land and Water |
| Dick Harding | Save our Waterways Now (SOWN) |
| Brice Kaddatz | Community member |
| Ian McConachie AM | Community member |
| Paul O'Hare (Chair) | Community member |
| Trevor Steinhardt | Australian Macadamia Society (Board Member) |

**Table 14. Macadamia Conservation Research Committee**

| Name | Organisation |
|---|---|
| Andrew Burnside | Macadamia Conservation Committee |
| Dr Catherine Nock | Southern Cross University |
| Dr Craig Hardner | University of Queensland |
| Ian McConachie AM (Chair) | Macadamia Conservation Committee |
| Dr Katie O'Connor | University of Queensland |
| Dr Chris Searle | Industry consultant |
| Associate Professor Alison Shapcott | University of the Sunshine Coast |
| Associate Professor Bruce Topp | University of Queensland |

# Appendix 2: Risk probability, consequence and impact analysis

## Probability assessment (defining the probability of the issue occurring)

Terms used to describe the probability of an event occurring are:

- Likely: Event is known to occur or would be expected to occur
- Occasional: Event may occur
- Possible: Event would be unlikely to occur (evidence to suggest it is possible)
- Unlikely: Event would occur rarely (uncommon but known to occur elsewhere)
- Rare: Event would occur very rarely (in exceptional circumstances)
- Remote: Chance of event occurring is so small it can be ignored in practical terms (never heard of but not impossible)

## Consequence assessment (defining the consequences of the issue occurring)

Terms used to describe the severity of the expected impacts (level of significance) are shown in Table 15. These terms are used in the risk evaluation matrix for potential impacts shown in Figure 2.

**Table 15. Levels of impact and their ecological consequences**

| Level | Ecological consequence |
|---|---|
| Negligible | Insignificant impacts to populations. Unlikely to be measurable against background variability. Interactions may be occurring, but it is unlikely that there would be any change outside of natural variation. |
| Low | Possibly detectable but little impact on population size and none on dynamics. |
| Moderate | Level of interaction/impact at maximum acceptable level. Long-term recruitment/dynamics not adversely affected. |
| High | Level of impact above maximum acceptable level. Would affect recruitment levels of the species or their capacity to increase in numbers. |
| Very High | Likely to cause local extinctions if continued. |
| Catastrophic | Local extinctions are imminent/immediate. |

**Figure 2. Risk evaluation matrix – potential impacts**