Wild about macadamias - conserving a national icon

Michael Powell
Australian Macadamia Society Limited

Project Number: MC10005

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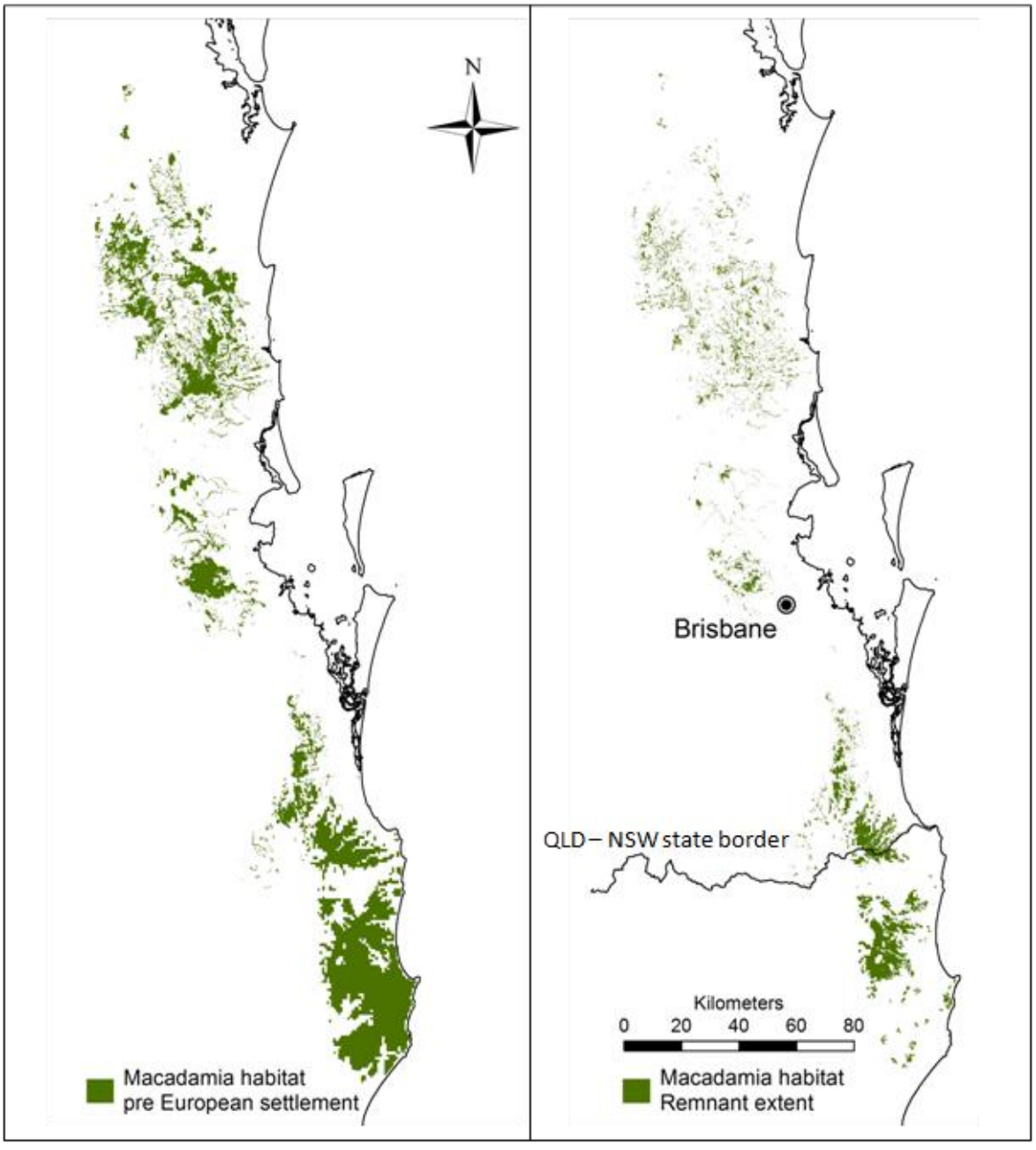
The Australian Macadamia Society



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Summary

Wild Macadamias are threatened with extinction over medium to long term timeframes due to historical land clearing, invasive vine weeds, pressure from human development and climate change. The 'Wild about Macadamias' (WaM) project was initiated by the Australian Macadamia industry and Horticulture Australia Limited in 2010 to implement the key aims of the then recently approved southern Macadamia species Recovery Plan. The overall objective of the WaM project is to protect wild Macadamia populations from decline, ensure their long-term viability, and raise awareness of flora conservation issues within the community.

The WaM project has focussed on carrying out a survey program of Macadamia populations to obtain baseline data on their conservation status together with raising public awareness of the threats facing Macadamias through development of a website, production of interpretation material, holding of public information sessions and provision of interpretation stalls at regional environment events. Additionally, a substantial quantum of research related to conservation of Macadamias has been carried out by members of the Macadamia Conservation Committee (MCC), who are the group responsible for overseeing implementation of WaM. The outcomes from this research has informed conservation planning and actions.

The major accomplishments are:

- Completion of a survey program of Macadamia populations and their habitats including their prioritisation for conservation action.
- Establishment of long term monitoring plots for the commercially important *Macadamia integrifolia* to assess the response to long term processes including habitat fragmentation and climate change.
- Production of a booklet entitled 'The Macadamia Story an overview', which outlines the history of Macadamias, their conservation status and information on their taxonomy and biology.
- Development of a website to inform the public of the conservation status of wild Macadamias and enlist their support (http://www.wildmacadamias.org.au);
- Holding of public information sessions and interpretation stalls at local environmental festivals and events.
- Publication of four research papers on aspects of conservation of wild Macadamia species in the peer reviewed scientific literature which are authored or co authored by members of the MCC.
- Substantial commencement of an introduction program for the endangered *Macadamia jansenii.*
- Completion of a post graduate research project using DNA analysis to ascertain whether *Macadamia tetraphylla* populations are being hybridised by pollen from industry or garden cultivars.
- The lineage of the named cultivars and advanced selections that are used in commercial Macadamia orchards have been traced back to the seedling populations from which they were derived.
- Production of a new Macadamia Species Recovery Plan (2014-2019), which builds on the knowledge and experience gained through implementation of WaM, together with the results of peer reviewed research papers on Macadamia species published in the life of the Plan.

The results suggest that Macadamia species will continue to decline unless a sustained appropriately resourced conservation program is continued. This will crucially entail formal identification and protection of those areas of remnant habitat that are essential to their persistence. The distribution of

genetic resources among Macadamia species including identification of populations containing rare or unique alleles is a key area for future research. It's clear that achievement of the goal of *insitu* conservation of Macadamias will require a sustained commitment from all stakeholders. The WaM program has laid the foundation for a science based approach towards ensuring the success of this objective.

Keywords

Macadamias; Australian Macadamias; Macadamia conservation; threatened species; Macadamia species recovery plan; Macadamia research

Introduction

Macadamia species occupy a unique intersect in the Australian ethos, being significant in economic, cultural and ecological spheres. *Macadamia integrifolia* and *M. tetraphylla* are commercially important on a global scale due to their edible nuts.

The four species of the genus Macadamia (Mast *et al.* 2008) are endemic to lowland subtropical rainforests of northern NSW and southeast QLD, which have undergone extensive clearing and fragmentation since European settlement. As a result, along with many similarly affected species, *Macadamia integrifolia, M. ternifolia* and *M. tetraphylla* are now rare and have been classified as vulnerable under the Federal government Environment Protection and Biodiversity Conservation Act (EPBC) (1999), categorising them as likely to become extinct within the next 20–50 years. The endangered *Macadamia jansenii* (Environmental Protection and Biodiversity Conservation Act 1999) is recorded from a single location more than 150km north of the nearest population of *M. integrifolia* (Shapcott and Powell 2011). There are significant areas of range overlap between *M. integrifolia* with *M. tetraphylla* and *M. ternifolia* (Hardner *et al.* 2009), with hybridisation recorded in populations where pairs of the species co-occur (Peace 2005).

Documented physical impacts of habitat loss and fragmentation on Macadamia species include habitat degradation through weed invasion, changed environmental conditions and increased susceptibility to fire. Population isolation arising from habitat fragmentation has reduced the capacity for dispersal and establishment of new populations, which has significant genetic consequences over the medium to long term. These include genetic isolation of populations, reduced frequency of optimal outbreeding distance among 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). The looming threat of climate change and the pressures arising from ongoing human development across the native distribution of Macadamia species increases the probability of continuing decline in numbers of individuals and populations.

The ongoing *in situ* persistence of all four Macadamia species in their natural habitat is an important goal for the Macadamia nut industry as a future source of cultivar germplasm. Moreover, Australia is a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO), adopted by consensus and as a binding international agreement at the Thirty-first Session of the Conference of the Food and Agriculture Organisation 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.

Previous projects had been carried out to address the situation, in particular the National Macadamia Germplasm Conservation Program (MC99029) (Hardner *et al*. 2004). Under this project a limited survey program was carried out and cuttings acquired from numerous populations, from which exsitu plots were set up for conservation and as a resource for cultivar selection. The results of the survey program revealed that many Macadamia populations were isolated, small, and/or occupied degraded habitats on private property. Consequently, their medium to long term outlook was poor. Overall, the weight of evidence suggested that, without action, Macadamia species will continue to decline, with progressive loss of individuals and populations to the point where they will eventually become extinct in the wild.

In response to the growing awareness of this situation, the Australian Macadamia Society and Horticulture Australia funded preparation of the Southern Macadamia Species Recovery Plan 2008-2012 (SMSRP), which was approved in 2009 by Federal under the provisions of the Environmental Protection and Biodiversity Conservation Act (1999). The Recovery Plan sets out a framework for

addressing the threats faced by Macadamia species, detailing the necessary actions required to protect them from decline and ensure their long term viability.

The 'Wild about Macadamias' (WaM) project is based on the key objectives/actions from the SMSRP. The initial timeline for carrying of WaM was 2010-2013, however an extension of one year was granted incorporating two additional objectives. The key components of WaM are:

- A field survey and monitoring program locating unrecorded populations of Macadamia species, surveying recorded populations for data deficiencies and setting up of monitoring plots to assess changes in habitat and population condition over time.

- A community awareness program of the conservation status of Macadamia species to be effected through holding of public information sessions and interpretation stalls at events, presentations to community groups together with development of information/interpretation material

- An information, liaison, resource provision to land owners and managers component aimed at ensuring known locations of Macadamia species are considered for protection when making development decisions and/or carrying out habitat rehabilitation activities.

- A research component including modelling the projected impact of climate change on the distribution of Macadamia habitat, together with identification and assessment of the loss of habitat from historical land clearing. Additionally to test whether hybridisation of wild *Macadamia tetraphylla* through *Macadamia integrifolia* cultivar pollen is occurring.

- To address the uncertainty in the domestication pathway of Macadamia

Methodology

1) Field survey

Survey areas and locations were derived from data obtained from previous project surveys, anecdotal information from land owners/managers, reference to state government vegetation mapping and predictions from habitat models. The location, and demographic attributes (height, number of stems, basal area) for each Macadamia tree in the survey area were recorded. In addition, habitat condition and a threat assessment was carried out, primarily in relation to presence of weeds, vulnerability to fire, presence of cattle etc. Populations were prioritised into three categories (very high, high, medium) for conservation action based on number of individuals, proximity to nearest populations, together with habitat type and condition.

Four long term monitoring plots were established at selected locations across the geographic range of *Macadamia integrifolia*. The objective of these sites is to resurvey the sites at appropriate frequencies over intervals measured in decades to assess changes in the Macadamia population and changes in canopy vegetation composition arising from fragmentation and climate change. Canopy vegetation composition was assessed employing the methodology described by Laidlaw et al (2011) in the Australian Journal of Botany entitled "The potential impacts of climate change on Australian subtropical rainforest". This entails identification of all species together with their abundance that are capable of reaching sub canopy level within a 20m x 20m plot in two categories: 1) those <5cm diameter at breast height (recruitment class) 2) those >=5cm diameter at breast height (adult class). We used a 25m x 25m plot and included the height and basal area of all Macadamia species both within the plot and a surrounding buffer 12.5m wide. (50m x 50m plot). In some plots the Macadamias were surveyed to a greater extent.

2) Community awareness

Early in the life of WaM, a series of public information sessions was held in community halls in strategic locations across the range of Macadamia species. These were located in areas where clusters of wild Macadamia populations are known to exist and included the Tweed Valley, Logan, the Scenic Rim, Moreton and Gympie districts. The aim of the sessions was to present information on the conservation status of Macadamias to interested members of the public, and where possible, elicit information from them of possible locations of Macadamia populations in the area.

Macadamia conservation interpretation stalls were present at community environment days. This included stalls at the annual Logan Eco Action festival (LEAF) (two years), the Greater Mary Association's community environment day, the Moreton Council Environment Festival, and the Sunshine Coast Council Community Environment Forum.

Presentations on the conservation status of Macadamias were given to the Society for Growing Australian Plants (SGAP), the Mary River Catchment Coordinating Committee (MRCCC), and regional councils including the Gold Coast City Council and the Sunshine Coast Council.

A presentation on the conservation status of wild Macadamias was given to attendees of the International Macadamia Symposium held in Brisbane in September 2012. A Macadamia conservation video was also produced for this event and subsequently has been distributed to the public as an information tool at community environment events.

Giftings of a seedling of each of the four Macadamia species together with interpretation signage was made to regional botanic gardens via public ceremonies. These include Rockhampton, Bundaberg, Sunshine Coast, Brisbane and Lismore Council Botanic Gardens. Thes events were well attended and received television and radio coverage.

A 22 page A5 size booklet entitled 'The Macadamia Story - an Overview' was produced. This booklet provides an overview of Macadamia history, evolution, biology, taxonomy, use by humans and the conservation threat they now face. Approximately six hundred copies have been produced and distributed to date.

A website aimed at providing information on the conservation status of wild Macadamias and seeking support has been developed and launched (http://www.wildmacadamias.org.au).

3) Informing and liaising with land owners or land managers
As managers of wild Macadamia populations, regional and local Councils were logically significant partners in the WaM project. The leaders of the environment departments of each council were initially contacted to seek a meeting to exchange information and obtain their support. A total of six Councils have provided financial support to WaM through VC contributions, and collectively, make up the VC largest sector. Officers from two Councils have participated in field surveys and provided data of wild Macadamia locations. The WaM project has contributed to Macadamia site or habitat rehabilitation projects in the Tweed LGA. Unfortunately the WaM project has made little progress in getting Councils to explicitly consider Macadamia habitats in development and planning instruments, probably due in part to a reluctance to favour a single genus over the scores of other threatened species inhabiting regional rainforests.

The WaM project has established a strong relationship with HQPlantations, who are the lessees of the QLD plantation forest estate, which contains a large proportion of recorded *Macadamia integrifolia* populations located in remnant patches of subtropical rainforest within its lease area. These areas are under threat from the invasive vine weed Cats Claw Creeper in the medium term to the extent that substantial areas of forest will become significantly degraded over the next few decades. Part of the consequences of this process will be local extinctions of Macadamia populations. In response, WaM has taken the lead in a partnership with HQPlantations and Gympie Landcare to develop and upscale Gympie Landcare's invasive vine weed bio control facilities with the aim of controlling or at least reducing the rate of the spread of these devastating weeds.

4) *Macadamia jansenii*
The genetic diversity of the single recorded population of *Macadamia jansenii* was assessed from DNA acquired from leaf samples of every adult individual using microsatellite techniques. The demographic structure of the population was ascertained by measurement of the height of each individual and their assignment to height classes. Cuttings were acquired from each adult individual and clones derived by a specialist nurseryman experienced in Macadamia conservation. Areas of suitable habitat for establishment of exsitu populations were identified from a habitat model and plantings carried out as clones became available from the nursery. A replicate cohort of clones was provided to Tondoon Botanic Gardens for establishment of a secure ex situ population to serve as a source of future clones as required.

5) Research
Four research papers on wild Macadamias which are authored or co authored by members of the MCC have been published in the peer reviewed scientific literature over the life of the WaM project. Two of these papers are derived from the results from PhD projects of the respective lead authors (Neal *et al.* 2010; Powell *et al.* 2010), and the third reports the results of investigations into demographic structure, genetic diversity and habitat distribution of the endangered *Macadamia jansenii* (Shapcott and Powell, 2011).

A fourth paper on Macadamias was recently published online in the Australian Journal of Botany (Powell *et al.* 2014 http://www.publish.csiro.au/journals/bt). This research employs in part data on

Macadamia locations acquired through the life of WaM which are used to develop statistical niche models to define and map the areas of habitat occupied by *Macadamia integrifolia, M. ternifolia* and *M. tetraphylla* respectively, together with the extent removed by historic land clearing. The research also investigates the impact of climate change on Macadamias and presents models predicting the change in geographic extent of climate niche between 1990 - 2070.

In response to concerns raised by local ecologists, a study was carried out in 2013 in northern NSW using DNA sampled from 10 wild *Macadamia tetraphylla* populations to ascertain whether they are being hybridised by pollen from nearby *M. integrifolia* based Macadamia nut farm cultivars. The results of this study are presented in an honours thesis (O'Connor, 2013), and are being condensed for publication in a peer reviewed science journal.

A research project tracing the domestication pathway of Macadamias was carried out by Dr Craig Hardner. This project involved locating the original plantings of seeds introduced into Hawaii in the late 19th century and the old seedling orchards that were established with progeny from these introductions. Leaf samples from each site were collected for subsequent paternity testing. A report to the Winston Churchill Memorial Trust of Australia on the results of this work has been produced on this work (Hardner, 2012).

Outputs

The outputs from the WaM project are varied and will be utilised by a diverse audience. These include conservation managers, land owners, researchers and the general public:

1) Conservation managers and/or researchers

MCC databases of Macadamia population locations and attributes

Macadamia integrifolia long term monitoring plot results

Macadamia jansenii reintroduction program (currently in progress)

Draft Macadamia Species Recovery Plan 2014 - 2019 (under review)

Research outputs on Macadamia species generated by members of the MCC over the life of WaM:

i. Neal JM, Hardner CM, Gross CL (2010) Population demography and fecundity do not decline with habitat fragmentation in the rainforest tree *Macadamia integrifolia* (Proteaceae). *Biological Conservation* **143**, 2591-2600

ii. Powell M, Accad A, Austin MP, Low Choy S, Williams KJ, Shapcott A (2010) Assessment of loss and fragmentation of a rare species habitat with niche models developed from compiled ecological data. *Biological Conservation* **143**, 1385-1396

iii. Shapcott A, Powell M (2011) Demographic structure, genetic diversity and habitat distribution of the endangered, Australian rainforest tree *Macadamia jansenii* help facilitate an introduction program. *Australian Journal of Botany* **59**, 215-225

iv. Powell M, Accad A, Shapcott A (2014) Where they are, why they are there, and where they are going: using niche models to assess impacts of disturbance on the distribution of three endemic rare subtropical rainforest trees of Macadamia (Proteaceae) species. *Australian Journal of Botany* Manuscript No. BT04156

v. O'Connor, K. (2013) Are genes from Macadamia cultivars being introduced into wild *Macadamia tetraphylla* populations through pollen transfer? Honours Thesis University of the Sunshine Coast

vi. Hardner, C. (2012) To trace the domestication pathway of macadamia. Report to the Winston Churchill Memorial Trust Of Australia

Presentations

Gold Coast City Council, November 2012, July 2014
Sunshine Coast Council, October 2012, August 2014
Mary River catchment Coordinating Committee, August 2010
Scenic Rim Regional Council, July 2014
Logan Regional Council, August 2014

2) General public , land owners and industry

Gifting of Macadamia seedlings to Council Botanical Gardens

Bundaberg Regional Council, August 2011
Rockhampton Regional Council, October 2011
Brisbane City Council, May 2012

Sunshine Coast Regional Council, June 2012
Lismore Regional Council, October 2013

Interpretation Stalls

Sunshine Council Environment Forum, October 2012
Greater Mary Environment Event, May 2013
Logan Eco Action Festival, June 2013
Moreton Council Environment Festival, August 2013
Logan Eco Action Festival, June 2014

Public Information Sessions:

Murwillumbah, November 2010
Gympie, December 2010
Logan, December 2010
Mt Tamborine, December 2010
Scenic Rim, March 2011
Gympie, June 2011
Logan, July 2011
Gympie, December 2011
Moreton, February 2012
Moreton, February, 2012
Cooroy, March 2012
Peachester, August 2013

Industry Presentations:

AMS Conference Gold Coast, November 2010
International Macadamia Symposium Brisbane, September 2012
Stahmann Farms breakfasts

- Bundaberg, October, 2010
- Gympie, October 2010
- Bangalow, October2010

Information Materials

Macadamia conservation website (http://www.wildmacadamias.org. au)
Macadamia conservation DVD
Macadamia Story Information Booklet
Macadamia conservation leaflet

Outcomes

A key activity of WaM (Action 1.1, 1.2) related to identification of the distribution and abundance of wild Macadamias in the remnant landscape through a field survey program. This program has been completed to a level where high confidence can be assigned to the outputs derived from these data. This includes prioritisation of Macadamia populations for conservation action, identification and mapping of their key habitats and quantification of the extent of loss and fragmentation of those habitats arising from historical land clearing. The results can be used by a range of audiences including land care and/or community groups in targeting conservation areas or carrying out on ground conservation works, planners in assessment of development applications and land owners/managers in development of Property Management Plans and/or in support of applications for grant funding for conservation.

The campaign to increase community awareness of the conservation status of Macadamia species has been successful in raising the general awareness that Macadamias are Australian and that they are under threat (Action 4.1). However, the majority of the audience were either those that either already had awareness and empathy for conservation, or had a direct connection with Macadamias through experiences in harvesting/eating nuts from a Macadamia tree in the backyard of their home, or a relatives home. There are a surprisingly large number of people/families who fit the latter profile, and they love the connection. Another cohort of the population who could potentially support Macadamia conservation were people who are interested in Macadamias as a food or product. These were frequent visitors to the interpretation stalls, availing themselves of the limited food related material on offer. Capturing this audience would be relatively easy if a properly developed and resourced program was effected. More generally, the acquisition of substantial public and support for Macadamia conservation is seen as a key objective going forward.

Outcomes related to provision of information to land owners and managers with the objective of having Macadamia species populations and habitats protected through Property Management Plans or incorporated into Council planning instruments (Actions 2.1 - 2.3) have been mixed. Many landowners with Macadamias on their properties have existing Property Management Plans developed in partnership with extension officers from their local Councils under conservation agreements such as Land for Wildlife. Others are more cautious; willing to have presence of Macadamias on their properties recorded, but are not willing to enter into conservation agreements.

The general approach of individual Councils to their conservation planning is based on assessment of biodiversity values among vegetation communities usually derived from state based vegetation mapping and their remnant extent within their respective geographic jurisdictions, with point location data of threatened species factored in. This approach has many advantages, however for threatened species such as Macadamia, which occur within 15 Regional or local Councils across two states, the absence of an integrated approach and lack of coordination of conservation among Council jurisdictions is problematic. This issue has been identified as a threat in the new draft Macadamia Species Recovery Plan (2014 - 2019).

A number of activities related to on ground conservation of Macadamia species have been carried out. (Actions 2.1 - 2.6). WaM has partnered with Tweed Shire Council in rehabilitation of several properties with Macadamias or Macadamia habitats in that shire. Mitigation of Cats Claw infestation in the Amamoor Valley, which contains a significant number of Macadamia integrifolia populations, has

been carried out in partnership with HQPlantations and the Burnett Mary Regional Group. However, without consistent follow up action to prevent reinfestation, the results are temporary. WaM is partnering with HQPlantations in supporting the up scaling of Gympie Landcare's invasive vine weed bio control nursery facilities as this approach is the only hope of controlling the spread of these devastating weeds. This project is underpinned by a grant from the Queensland state government, and its continuation is a major priority for Macadamia conservation.

More generally, the lack of funding programs available for conservation of individual species is problematic as governments address their conservation responsibilities through planning/activities at the level of vegetation community and/or focussing on particular regions such as the ranges on the QLD/NSW border, which are a biodiversity hotspot. Resourcing for conservation of Macadamia populations and habitats will largely be dependent on alignment with particular programs which capture those populations/habitats, together with supporting those landowners with Macadamias to obtain small grants for property scale rehabilitation.

The *Macadamia jansenii* introduction program has substantially commenced, is ongoing and will take a number of years before the introduced populations are established and maintained to the point where they are self sustaining. WaM is partnering with traditional owners and QLD Parks and Wildlife in this project. This has been the one project where WaM has managed to effectively engage with indigenous groups. Despite some setbacks in survival of the introduced populations due to extreme weather over the last few years, the stakeholders are strongly committed to its continuation and completion. As the project requires few resources, and the objectives are compelling, funding can reasonably be expected to be forthcoming from various providers such as the World Wildlife Fund, the Burnet Mary Regional Group or the Mohammed Bin Zayed Species Conservation Fund, all of whom have previously supported the project

The Executive Summary of the Southern Macadamia Species Recovery Plan identifies potential hybridisation of wild Macadamias with cultivars from commercial plantations as a significant potential threat. In response to concerns raised by regional ecologists and botanists, the scope of the extension of WaM provided for a post graduate study to ascertain whether wild *Macadamia tetraphylla* populations were being hybridised by pollen from *Macadamia integrifolia* based nut farm cultivars. The results identified presence of hybrids in 9 out of the 10 populations sampled in the study, however hybrids are restricted to the younger age classes in the population and its unclear whether this is due to lack of ecological fitness resulting in mortality, or the limited time of exposure to cultivar pollen. Further research is required to ascertain the full impact of this phenomenon and establish frameworks to mitigate the impact if the hybrids are found to be surviving and reproducing. As Macadamia nut farms in northern NSW are predominantly located in those areas where *M. tetraphylla* has been largely removed by historical land clearing, the impact on the species and the industry is likely to be relatively minor. However the precautionary principle suggest that establishment of new farms in areas where *M. tetraphylla* still exists in some numbers should take into consideration these findings.

The major learnings of the project tracing the domestication pathway are:
(i) improved knowledge of the domestication pathway of macadamia in Hawaii, particularly the lineage of cultivars and other commercial germplasm,

(ii) location and status of ancestral germplasm in the domestication pathway of macadamia and collection of leaf samples for subsequent research,

(iii) identification of uncertainty on the location, status and contribution to domesticated germplasm of the initial Purvis introduction and a possible additional unrecorded major introduction of macadamia in the early 20th century,

(iv) the production and selection environments differ between Hawaii and Australia,

(v) research on macadamia in Hawaii has declined, however, it may be possible to collaborate with the University of Hawaii through use of historic data to study genotype x environment,

(vi) it is likely that the opportunities for genetic improvement from *M. tetraphylla* and *M. ternifolia* have been underestimated in efforts to date.

Evaluation and Discussion

Performance

A key objective of WaM was improved knowledge of the distribution and abundance of wild Macadamias in the remnant landscape through a field survey program. The outcomes of the population and habitat survey program have resulted in significantly increased knowledge of the distribution and abundance of Macadamias in the remnant landscape together with the key threats they face. More than 100 field surveys were carried out under the WaM program, within which the majority of Macadamia populations were previously unrecorded or unsurveyed.

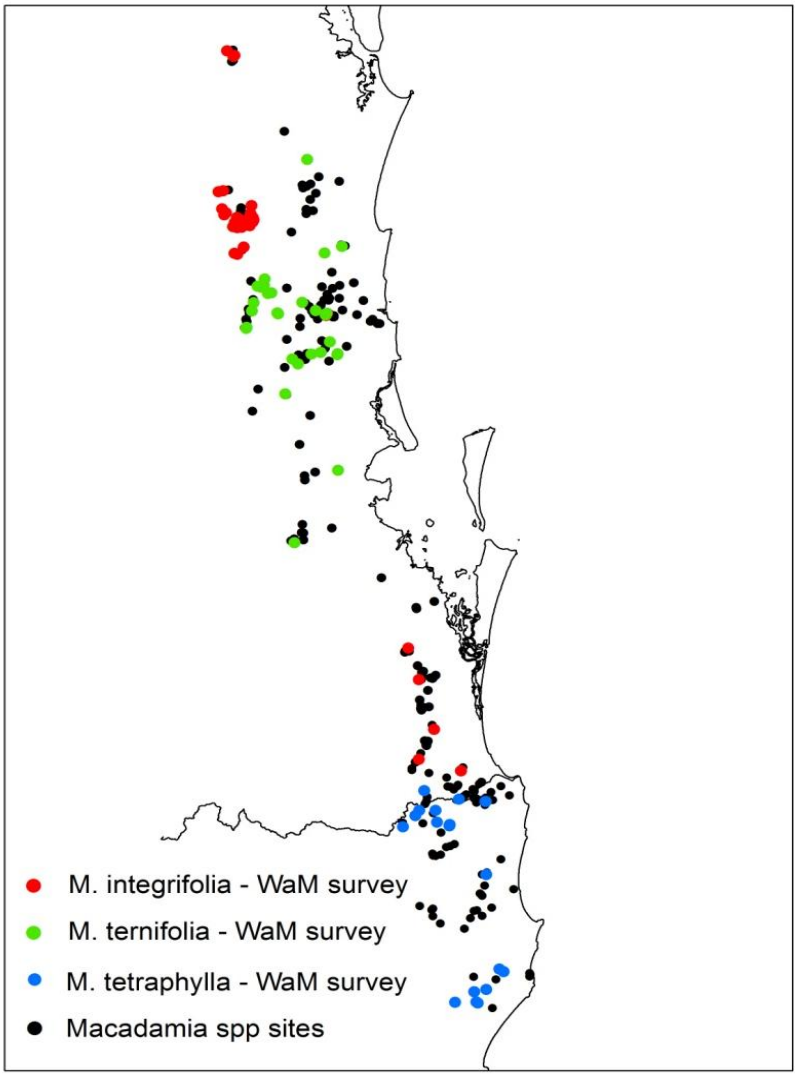

Figure 1. Macadamia species population locations showing those carried out under WaM in colour

These results are a significant addition to the number of recorded locations in the Macadamia database maintained by members of the MCC prior to commencement of WaM (Figure 1). Quantification of population demographics together with an assessment of the threat profile at each site, together with a subsequent habitat assessment and connectivity analysis carried out in a GIS have provided the essential baseline data required to prioritise populations for conservation action (Table 1; Figure 2). It is recognised that not all populations may be viable, or able to be conserved in the long term. However the identification of the pattern of geographic clusters of populations, the

number of individuals within those clusters, their connectivity and the condition of their habitats provide a robust basis for ongoing conservation of Macadamia species. These data can be used to inform a potential project to assess the distribution of genetic resources among Macadamia populations or to identify non viable populations, which can be sampled for ex situ conservation and genetic assessment.

Table 1. Macadamia species Population Prioritisation Criteria

Priority	Criteria
VERY HIGH	Populations with at least two neighbouring populations within 3km AND within 50m of remnant vegetation AND Population Class 26-49 or greater (Class refers to population size; see the Recovery Plan) OR Populations where two Macadamia species are recorded as present
HIGH	Populations with at least two neighbours within 3km AND within 50m of remnant vegetation AND Population Class 11-26 or greater OR Populations with at least two neighbours within 3km AND Population Class 26-49 or greater OR Populations within 50m of remnant vegetation AND Population Class 26-49 or greater
MEDIUM	all other populations

These data have also been employed to inform ecological niche models which have been used to define and map the respective areas of habitat occupied by *Macadamia integrifolia, M. ternifolia* and *M. tetraphylla*, the extent of prime habitat areas removed by historic land clearing, together with the impacts of climate change. The recent publication of the results of this analysis (Powell *et al*. 2014) provides a credible science based peer reviewed basis for improved protection of key habitats together with predictions of those populations and habitats are most vulnerable to the impacts of climate change.

Progression of the project

As the implementation of WaM progressed and new information about the distribution and abundance of wild macadamias in the current landscape came to light, it became apparent that the scope and complexity of the project had been under estimated, resulting in an overly optimistic timeline for its implementation. Accordingly an extension of time was requested and granted. Despite the extension, some activities are still not completed; eg the new Recovery plan is currently under review by the Federal government Department of Environment. Approval of the Plan is subject to assessment by the Technical Committee and a public consultation period, which may take up to 12 months in total. Results of research into hybridisation of *M. tetraphylla* by industry based *M. integrifolia* cultivars are still to be published. Actions related to ensuring Macadamia populations and habitats are considered in development and planning instruments are still largely incomplete.

It is apparent that Macadamia species are present in sufficient abundance in the remnant landscape to persist if their habitats are protected through appropriate planning instruments and from physical threats such as weeds, fire, climate change etc . Securing this protection is a large and complex task.

Its scope is well beyond the resources of the Macadamia nut industry and in any event, is the responsibility of the Australian community.

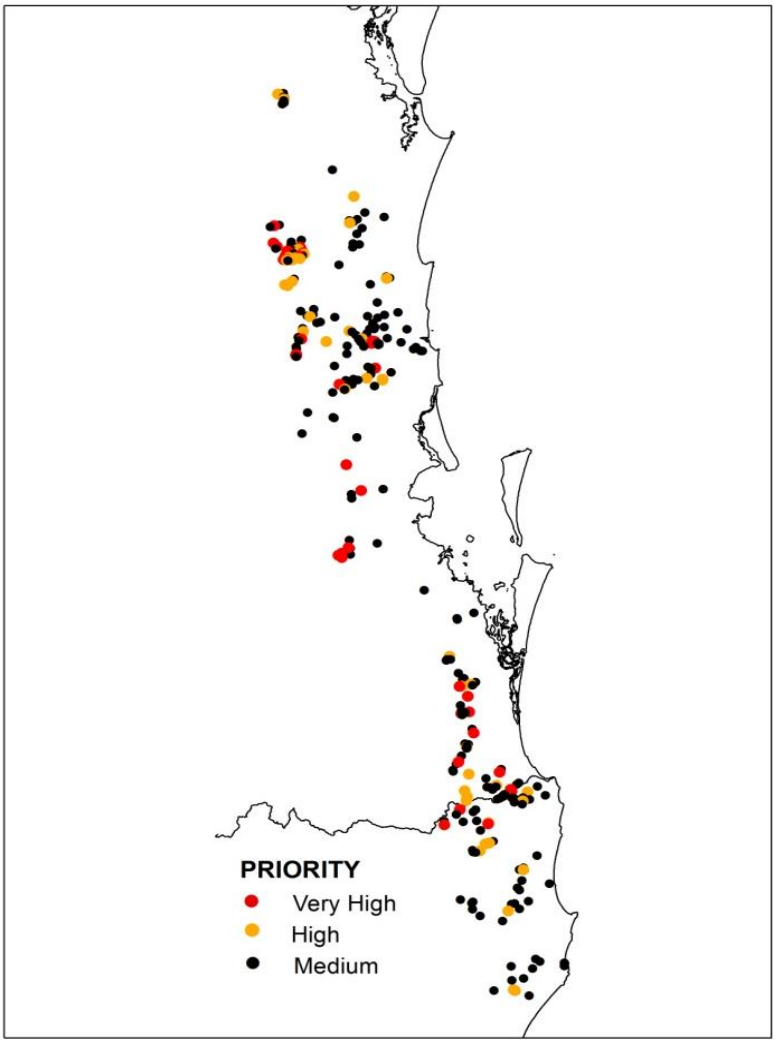

Figure 2. Macadamia species populations assigned priority for conservation

Effectiveness, efficiency of delivery mechanisms, appropriateness of methodology

Due to its nature, assessment of the effectiveness of the project is largely qualitative, however it is clear that much has been achieved given the relatively limited resources available to carry out a complex multi faceted project requiring engagement of multiple stakeholders including securing their financial support in matching funding where possible. The effectiveness of the outcomes are not currently apparent. For example approval and implementation of the new Recovery plan is a key criteria for assessment of effectiveness, as is publication of research papers.

Delivery of WaM has been largely effected through employment of a part time Project Officer, who was responsible for implementation of the project under the direction of the MCC. Whilst the majority of the project outcomes were achieved to some extent, it may be that the range of skills required to effect the project in all its facets are unlikely to be possessed by any one individual. This was recognised in the MCC Business Plan (DeVos, 2013), which recommends employment of a person with expertise in communications and a second person suitably skilled in conservation. Moreover,

direct employment of expertise supervised by the MCC may not be the most effective approach. Contracting the role to an outside organisation which has a greater depth of expertise, resources available to it and ability to engage with the multiple stakeholders may achieve far more.

Recommendations

Its clear than achieving protection of Macadamia species will require an ongoing commitment from all stakeholders. The Draft Macadamia Species Recovery Plan (2014 - 2019) provides the framework for this going forward together with the following recommendations:

1) Some current tasks carried out under WaM are yet to be completed. These include ensuring approval of the draft Macadamia Species Recovery Plan (2014 - 2019), completion of the *Macadamia jansenii* introduction program and publication of completed research projects.

2) Protect Macadamia populations and habitats through planning instruments. This requires engagement and informing conservation planners within threatened species departments of the NSW and QLD State governments and key regional Councils who have Macadamia population clusters. Provide data on the distribution of Macadamia species and population details together with outputs from published modelling research to relevant parties to support this request.

3) Continue to work with and provide support to stakeholders in all areas of Macadamia conservation, in particular activities to mitigate the impacts of invasive vine weeds and carry out rehabilitation of key Macadamia populations and habitats.

4) Continue to raise the profile of the conservation status of Macadamia species in the public arena through the methods outlined in the new Still Wild about Macadamias Project and highlighting the link between wild Macadamias, industry cultivars and Macadamia nut products.

5) The unique status of Macadamias as crop wild relatives of industry cultivars, and their long history of human use are compelling reasons to favour conservation of these species. WaM has shown that there is substantial public support and empathy for Macadamia species conservation, however this support is not currently translated into their protection. The ongoing support of the Australian Macadamia Society and its members is an important component achieving this goal.

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Appendices

- Draft Macadamia Species Recovery Plan 2014 - 2019

Macadamia Species Recovery Plan 2014-2019

Macadamia integrifolia

Macadamia tetraphylla

Macadamia ternifolia

Macadamia jansenii

Title:
Macadamia Species Recovery Plan 2014-2019

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Disclaimer:
The Australian Government, in partnership with the Queensland Department of Environment and Heritage Protection, facilitates the publication of recovery plans to detail the actions needed for the conservation of threatened native wildlife.

The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved, and may also be constrained by the need to address other conservation priorities. Approved recovery plans may be subject to modification due to changes in knowledge and changes in conservation status.

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Executive Summary

This Recovery Plan replaces the former Southern Macadamia Species Recovery Plan. It contains considerable new information gathered during the course of 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. With the exception of *M. jansenii* (which is recorded from a single location approximately 150km 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 bodies 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 *Macadamia 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.

1. General Information

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 also under Commonwealth legislation (Table 1).

Table 1. Legislative status of Australian macadamia species

Scientific Name	Legislative Status		
	Queensland[1]	NSW[2]	Australia[3]
Macadamia integrifolia Maiden & Betche	V	N/A	V
Macadamia jansenii C.L.Gross & P.H.Weston	E	N/A	E
Macadamia ternifolia F.Muell.	V	N/A	V
Macadamia tetraphylla L.A.S.Johnson	V	V	V

[1]Queensland *Nature Conservation Act 1992;* [2]New South Wales *Threatened Species Act 1995;*
[3]Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

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), adopted by consensus and as a binding international agreement at the Thirty-first Session of the Conference of the Food and Agriculture Organisation 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.

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:

- Australian Government, including:
  - Department of the Environment
  - Department of Agriculture
- State Government agencies, including:
  - NSW Office of Environment and Heritage
  - NSW Local Land Services (North Coast, Northern Tablelands and North West)
  - NSW Trade and Investment
  - Queensland Department of Environment and Heritage Protection
  - Queensland Department of National Parks, Recreation, Sport and Racing (including Queensland Parks and Wildlife Service)
  - Queensland Department of Natural Resources and Mines
  - Queensland Department of Science, Information Technology, Innovation and the Arts (including the Queensland Herbarium

  - Queensland Department of Community Safety (including Queensland Fire and Rescue Service)
- Local Governments
- Industry, including:
  - Australian Macadamia Society
  - Growcom
  - Horticulture Australia Ltd
  - HQPlantations
- Non-government conservation organisations, including:
  - Brisbane Rainforest Action and Information Network
  - Landcare groups, eg. Big Scrub Landcare, Gympie Landcare, Noosa Landcare, Tamborine Mountain Landcare
  - Catchment associations, eg. Mary River Catchment Coordinating Committee, Gold Coast Catchment Association, Pine Rivers Catchment Association
  - Field naturalists groups
  - Society for Growing Australian Plants
  - Greening Australia
  - Environment groups, eg. Sunshine Coast Environment Council, GECKO, Queensland Conservation Council
- Queensland and NSW Natural Resource Management (NRM) bodies, including:
  - Burnett-Mary Regional Group
  - NSW Local Land Services (North Coast, Northern Tablelands and North West)
  - SEQ Catchments
- Research institutions, including:
  - CSIRO
  - Griffith University
  - University of the Sunshine Coast
  - University of Queensland
  - Southern Cross University
- Land managers, public and private
- Indigenous Land Councils and the Traditional owner groups they represent
- Northern Rivers Fire and Biodiversity Consortium, South East Queensland Fire and Biodiversity Consortium

Consultation with Indigenous People

During the development of the initial Plan, several Indigenous 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. Indigenous people have been and will continue to be encouraged to be involved in the recovery process through the implementation of recovery actions. For example, the Recovery Team is actively working with the Gurang people through the Gidarjil Corporation in the Bundaberg region to establish and maintain four ex-situ populations of the endangered *Macadamia 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 Queensland *Vegetation Management Act 1999* (VMA 1999) and others in threatened ecological communities listed in the NSW *Threatened Species Act 1995.* 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 Macadamia Species Recovery Plan

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

Biological Information

Introduction

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

The commencement of significant and permanent change in climate beginning about 40 million years ago resulted in 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.

The four species of the genus Macadamia (Mast et al. 2008) 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). Macadamias are genetically closely related and, except for *M. jansenii* which is known from a single location 150km north of the closest Macadamia population, have overlapping ranges (Figure 1). 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. Trees that display morphological characteristics of both *M. integrifolia* and *M. tetraphylla* are found in a hybrid zone up to 20km 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.

Macadamias have had a long association with humans – nut shells have been found in aboriginal middens near Brisbane and the first specimens were collected by the explorer Leichardt in 1843 about 60km north of Brisbane. From1860, settlers discovered the fine eating qualities of both *M. integrifolia* and *M. tetraphylla*, which were subsequently widely planted in farm yards and backyards as single trees grown from seeds of local wild stock.

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

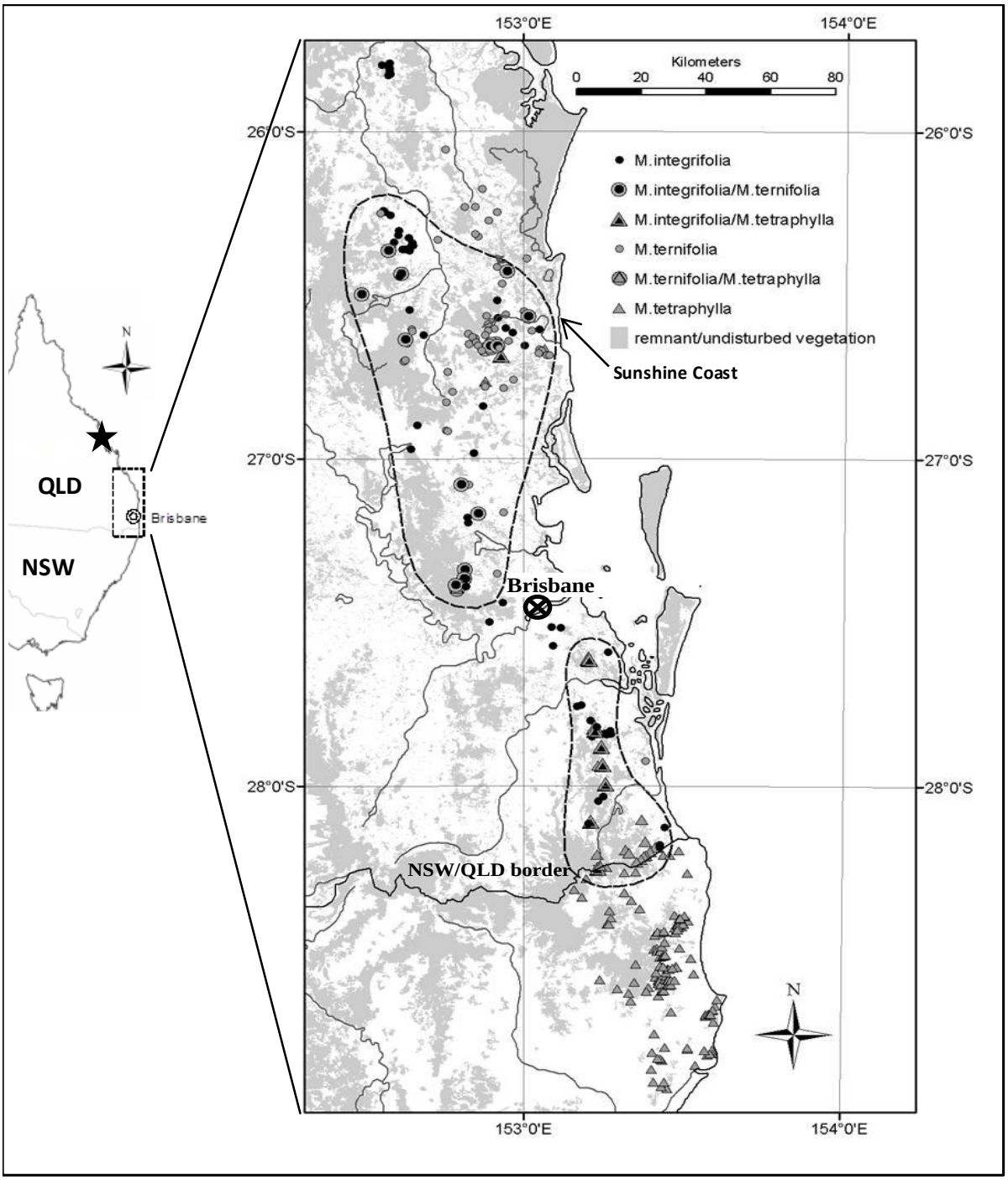

Figure 1. Natural distribution of *Macadamia integrifolia, M. ternifolia, M. tetraphylla* and natural hybrids. Areas of vegetation are those remnant in 2005 in NSW (NSW Department of Environment and Heritage) and 2006 in Queensland (Queensland Herbarium). Dotted lines show the extent of hybrid zones. Star represents the approximate location of *Macadamia 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 25m tall, with greyish branchlets dotted with raised lenticels (Hauser and Blok 1992). Individuals are often multi stemmed with small crowns. The simple obovate to narrowly oblong leaves are arranged in whorls of three or opposite, and 5.5cm to 14cm long by 2.5cm to 6cm wide (Stanley and Ross 2002). Blade tips are rounded and finish in a short sharp point; the base tapers to petioles 5 to 10mm long. Axillary creamy-white flowers are arranged in brush-like hanging racemes 10 to 30cm long. Rounded fruits are green, 2.5 to 3.5cm wide with a hard brown inner shell protecting the edible nut. Flowering period is August to October with kernel maturation from December to March, with mature nuts falling to the ground thereafter.

Life history and ecology

Both introduced European honey (*Apis mellifera*) and native bees appear to be the main pollinators, with native bees *Trigona* spp. being superior pollinators. Seed dispersal is by small rodents and gravity fall, probably with some assistance from local stream flooding. Hybridization 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). Results for *M. integrifolia* indicate some differentiation between populations in northern and southern regions however overall genetic differentiation between populations is moderate to low and increases with increasing distance between populations (>50km) indicating considerable past gene flow between populations. 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.

Distribution

Macadamia integrifolia is distributed along the foothills and coastal ranges of South east Queensland from the NSW border to Mt Bauple near Maryborough, a distance of approximately 300km, 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 favorable climate (Powell et al. in press). The largest number of recorded populations and individuals are located in an area centered 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). The balance of population clusters collectively contain 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 to 600m.

The currently recorded extent of occupied habitat is approximately 1,500 hectares and the modelled extent of available habitat is approximately 30,000ha within an area of 6,800km^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. 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 2). 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. in press).

A substantial number of populations occur in non-remnant areas; areas where stands of *M. integrifolia* have been preserved, but other native vegetation has been cleared.

Table 2. 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 <600m	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 Queensland *Vegetation Management Act 1999*; 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 50m of remnant vegetation is assumed to be located within remnant vegetation.

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

Priority	Criteria
	of remnant vegetation AND Population Class 11 - 26 or greater OR Populations with at least two neighbours within 3km AND Population Class 26 - 49 or greater OR Populations within 50m 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 3. Information is provided on the site identifier (Site Id: MGA northing), location, tenure, habitat (cleared, RE or unknown; REs in bold are Endangered under the *VMA 1999*, those in italics are Of Concern), population size (Pop Size), and conservation priority (Priority: very high, high or medium).

Table 3. 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
7086980	Amamoor	Forest lease area	12.11.10	6 - 10	High

Site ID	Location	Tenure	Habitat	Pop Size	Priority
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
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

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

Life history and ecology

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

Distribution

Endemic to the northern part of the SEQ bioregion, *Macadamia jansenii* is known only from a 6000m^2 area restricted to the upper catchment of Granite Creek in Bulburin National Park (Gross and Weston 1992; Shapcott and Powell 2011).

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 150m 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 20m of a tributary of Granite Creek, Bulburin National Park. *Macadamia jansenii* is identified as occurring in Regional Ecosystem 12.12.13 (see Table 4). This form of simple notophyll vine forest is characterised by *Araucaria cunninghamii* (Hoop pine), *Alangium villosum* (Canary muskheart), *Argyrodendron trifoliatum* (Brown tulip oak), *Baloghia inophylla* (Scrub bloodwood), *Brachychiton discolor* (Scrub bottletree), *Dendrocnide photinophylla* (Shiny-leaved stinging tree) and *Harpulia pendula* (Tulipwood).

Priority populations

The only known population of *M. jansenii* is summarised in Table 4. Information is provided on the site identifier (Site Id: MGA northing), location, tenure, habitat (cleared, RE or unknown; REs in bold are Endangered under the *VMA 1999*, those in italics are Of Concern), population size (Pop Size), and conservation priority (very high, high or medium).

Table 4. 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	60	Very high

Macadamia ternifolia (Gympie nut)

Description

Macadamia ternifolia is a perennial lower to mid storey evergreen subtropical rainforest tree to 18m tall, with brown branchlets dotted with raised lenticels (Hauser and Blok 1992). The simple, narrow-oblong to narrow-elliptical leaves are arranged in whorls of three, and 10-12cm long; new growth is pinkish red. Blade tips are pointed and the base tapers to petioles 3 to 13mm long (Stanley and Ross 2002). Axillary pinkish or cream flowers are arranged in brush-like hanging racemes 4-20cm long. Compressed rounded fruits are greyish, 1.5-2cm long with a hard inner shell protecting the nut. The seed kernel is cyanogenetic and not edible. Flowering period is June to August with fruiting occurring from March to April

Life history and ecology

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

Distribution

Macadamia ternifolia is endemic to southern coastal Queensland, with a known national distribution of scattered populations extending from Goomboorian (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 15-700m 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. in press). 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 600m ASL (Powell unpublished data). A finger of populations extends northward along coastal foothills to Goomboorian, a distance of approximately 50km. *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.

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 4), though it is also frequently found in RE 12.8.3, 12.11.10, 12.12.1 and 12.12.16 (Powell unpublished data). The occupied habitat is approximately 1,350 hectares and the modelled extent of available habitat is approximately 22,000ha within an area of 3,100km^2. Total population size is estimated to be between 1,500 – 2,500 mature individuals within approximately 60 key populations with 5 - 25 mature specimens at each locality. 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.

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 5.

Table 5. 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
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

Site ID	Location	Tenure	Habitat	Pop Size	Priority
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
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
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

Site ID	Location	Tenure	Habitat	Pop Size	Priority
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 18m tall, with greyish-brown branchlets dotted with pale elongated lenticels (Hauser and Blok 1992). The simple oblong lanceolate leaves are arranged in whorls of three to four, 6-20cm long and 2-4cm wide. Blade tips are pointed, margins sharply serrated and petioles are 2-8mm long (Stanley and Ross 2002). New leaves of *M. tetraphylla* are bright red in colour, whereas those of *M. integrifolia* are light green. Axillary pinkish purple flowers are arranged in brush-like hanging racemes 15-45cm long. Compressed rounded fruits are greyish-green, 2-3.5cm wide with a hard inner 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

Very little is known about the life history and ecology of this species. Similar to other Macadamia 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. A recent 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. An optimal outbreeding distance of 2km 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).

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 30-800m 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 Mt Warning and in the Border Ranges from the coast to Numinbah;
- within the area of the former Big Scrub, including the western and southern footslopes of the Nightcap Ranges and Whian Whian State Forest, extending north along the east facing slopes and foothills and adjacent lowland areas of Mt Jerusalum 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 40km.

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 interplanted 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 hectares and the modelled extent of available habitat is approximately 48,000ha within an area of 2,400km^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.

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* occurs in the following seven vegetation classes and four Endangered Ecological Communities (*TSA 1995*):

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 has been 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 6; 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).

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

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	Reserve	Non remnant	12 - 25	Very high

Site ID	Location	Tenure	Habitat	Pop Size	Priority
	Park				
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
Mt 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
6876161	Bilambil	Private property	Non remnant	11 - 25	Medium
6876088	Duroby	Public land	Non remnant	11 - 25	Medium
6875592	Bilambil	Reserve	Subtropical	61 - 75	High

Site ID	Location	Tenure	Habitat	Pop Size	Priority
			Rainforest		
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
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

Site ID	Location	Tenure	Habitat	Pop Size	Priority
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. in press). 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). The majority of extant populations of *M. tetraphylla* occur along the fringes of this area and the foot slopes of Mt Warning and its caldera.

Whilst a number of populations of Macadamia occur in protected tenures, e.g. 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, however, ensuring the long term persistence of these populations 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.

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 are able to 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 2.8km 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 3km 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 (Pisanu et al. 2009).

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, mitigating some of the impacts of habitat loss and fragmentation.

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 camera*) and exotic vines such as Cat's claw creeper (*Dolichandra unguis-cati*) and Madeira vine (*Anredera cordifolia*). All three species are 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).

Fire

Rainforest communities are normally fire resistant and do not facilitate the spread of fire. There is evidence that some rainforest species resprout strongly following fire (Williams 2000) and that rainforest elements found in wet sclerophyll forest can survive repeated low intensity fires (Donatiu 2007, unpublished data).

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 (e.g., 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.

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^{o}C and more variable precipitation regimes are predicted for the region occupied by Macadamia species (http://www.climatechange.gov.au/climate-change/climate-science/climate-change-impacts/queensland). 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. in press) thus potentially resulting in decreased hybridization 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.

Genetic Pollution

A recent Honours level post graduate study (O'Connor, 2013) has identified presence of gene flow between Macadamia nut cultivars which are predominantly based on *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*. However the study was 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. Whilst the current 'Wild About Macadamias' project has 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 with regard to 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 takes into account recent research findings is applied to conservation of Macadamia species across all jurisdictions.

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 300m 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. in press) 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 the Bulburin nut tree 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 favorable 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.

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 700m 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. in press).

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 hybridization 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 Mt 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, e.g., slashing, 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* has been identified as a species at risk from Bitou bush *(Chrysanthemoides monilifera)* (DECC 2006).

The relatively wet and cool conditions on the slopes of Mt 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. in press). *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 Consequences 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.

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 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 provides a basis for prioritisation of threats to guide management actions.

Table 7. 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
	Reduced recruitment	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
	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. jansen*ii	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 from Macadamia nut farm cultivar to wild *M. integrifolia or M. ternifolia*	Possible	Moderate	2	M,L
Disease	Loss of populations	Occasional	Very High	3	M
	Loss of only wild population of *M. jansen*ii	Possible	Catastrophic	4	S,M
Public perception	False sense of security through presence of	Likely	Moderate	3	S,M

Threat	Impacts	Probability	Consequence	Risk (0-4)	Time (S,M,L)
	cultivars				
	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. 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. A website is under development.

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 (5 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 DSITIA WildNet (Queensland) and OEH 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 a number of areas. For example:

- A partnership between the Macadamia Conservation Committee (MCC), HQPlantations 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 HQPlantations lease areas including those occupied by a large number of Macadamia populations has been defined and mapped at a coarse scale. This work is continuing through a new project partnership between HQPlantations, Gympie Landcare and MCC, partially funded by a 2013-14 Queensland Government Everyone's Environment Grant, which aims 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.

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 effected 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. Natural Resource Management (NRM) bodies and Catchment Management Authorities (CMAs) have been encouraged to prioritise funding support for Macadamia habitat conservation and promote this to their communities.

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 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.

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.

4. 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 (e.g., ex situ plantings), although much remains to be done. The development of a Macadamia Conservation website is well progressed and will be launched in 2014; this is seen as a key element in achieving this goal.

5. 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 Macadamia Conservation Committee (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 Southern Macadamia Species Recovery Plan.

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.

Specific Objectives

1. Continue to identify and evaluate the extent and quality of Macadamia species populations and their habitat
2. Reduce and manage the major threatening processes affecting Macadamia species habitat
3. Increase knowledge of Macadamia species and their ecology to effect their conservation and management
4. Improve awareness and understanding of Macadamia species, especially the management requirements of these species and their major threats
5. Manage, monitor and evaluate the Macadamia Species Recovery Plan

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 taking into account 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 (e.g. 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 will be submitted to appropriate government databases, including Queensland's WildNet (DSITIA) and The SPRING (The Species Recovery Information Gateway, DEHP), NSW BioNet (OEH) and relevant local governments.

Priority: Medium

Potential Contributors: MCC, DEHP, NPRSR/QPWS, DSITIA, OEH, NSW.NPWS, local governments, NRM bodies, 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 WildNet (DSITIA), The SPRING (DEHP), BioNet (OEH) and relevant local governments.

Priority: Medium

Potential Contributors: AG, MCC, DEHP, OEH, DSITIA, local governments, NRM bodies, 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, DEHP, OEH, DSITIA, 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 (e.g., 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, DEHP, OEH, DSITIA, local governments, NRM bodies, botanists

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

Performance Criteria 2a Priority Macadamia populations are protected

Action 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*
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 (DSITIA), The SPRING (DEHP), BioNet (OEH) and relevant local governments.

Priority: High

Potential Contributors: MCC, AG, DEHP, DSITIA, OEH, local governments, NRM bodies, researchers

Action 2.2 *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 actively targeted and encouraged to enter into voluntary conservation agreements, e.g., Land for Wildlife, or conservation covenants, e.g., a Nature Refuge, through local or state governments or non-government organisations, such as the Australian Wildlife Conservancy (AWC), Bush Heritage Trust (BHT), Queensland Trust for Nature, NSW Nature Conservation Trust (NCT). 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, DEHP, OEH, local governments, AWC, BHT, QTfN, NCT, NRM bodies, community groups, landholders

Action 2.3 *Establish ex-situ populations for* Macadamia jansenii *at multiple sites*
The known distribution of this species is restricted to one population. Continue to work with stakeholders to complete establishment, monitoring and maintenance of four new populations of the species at ex-situ sites in Bulburin National Park and Thornhill Station and a fifth population at Tondoon Botanic Gardens, Gladstone.

Priority: High

Potential Contributors: MCC, DEHP, NPRSR/QPWS, USC, Gladstone Botanic Gardens, Gidarjil Development Corporation, landholders

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

Action 2.4 *Provide information to public and private land managers (including landholders, Macadamia growers, etc.) 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 publically accessible databases, e.g., WildNet, The SPRING, BioNet, publications and media.

Priority: High

Potential Contributors: MCC, AG, DEHP, OEH, local governments, NRM bodies, community groups, botanists

Action 2.5 *Support land managers to develop property management plans that include wild Macadamia conservation*
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

Priority: High

Potential Contributors: MCC, DEHP, OEH, local governments, NRM bodies, 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 2.6 *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. Provenance protocols (for seed and tube stock) need to be developed to guide Macadamia plantings aimed at enhancing existing populations and establishing new populations in appropriate habitats. Land managers should be encouraged and assisted to develop submissions to funding bodies for resources to protect Macadamia species and their habitats. Local and state governments, community and industry groups, NRM bodies and research institutions should collaborate in funding applications to bodies for strategically important objectives such as landscape scale projects eg invasive weed management or rehabilitation of important Macadamia populations or their habitats.

Priority: High

Potential Contributors: AG, MCC, DEHP, OEH, local governments, NRM bodies, community groups, land managers

Action 2.7 *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 come to light 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 harboring priority populations. Identify populations and habitats at particular risk and encourage those land owners to carry out mitigation measures to protect the affected Macadamia population.

Priority: High

Potential Contributors: MCC, DEHP, DSITIA, OEH, local governments, NRM bodies, Fire and Biodiversity Consortiums, community groups, land managers

Action 2.8 *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, DEHP, DSITIA, DAFF/Biosecurity Queensland, OEH, local governments, NRM bodies, community groups, land managers

Action 2.9 *Establish long-term monitoring programs for priority Macadamia populations and disseminate the results*

Use an accepted methodology to monitor changes in habitat composition and condition, population dynamics (including population size and structure) and threat profile of priority Macadamia population over medium to long term timeframes. Provide results to land managers and land use planners to guide protection of Macadamia populations.

Priority: Medium

Potential Contributors: MCC, DEHP, DSITIA/Queensland Herbarium, OEH, local governments, NRM bodies, researchers, land managers

Action 2.10 *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 (e.g., flowering, fruit maturation), hybridization 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, DEHP, DSITIA/Queensland Herbarium, OEH, local governments, NRM bodies, researchers

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

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

Action 3.1 *Identify gaps in the current understanding of Macadamia species ecology and develop research priorities for conservation priority research needs*
All Macadamia species in this plan are affected by one or more threatening processes. The absence of information on mechanisms to address some of these threatening processes will direct the selection of research priorities (for example, determining 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 and identifying opportunities to reintroduce populations within and between population clusters to maintain connectivity and enhance diversity). The Macadamia Conservation Committee (MCC) will work with land managers and the Macadamia Conservation Research Network (MCRN) to determine research aims for progression by the MCRN.

Priority: Medium

Potential Contributors: MCC, DEHP, OEH, local governments, NRM bodies, researchers, land managers

Action 3.2 *Ongoing liaison with research institutions to address prioritised research gaps*
MCRN will continue to generate and resource research priorities aimed at improving knowledge of the consequences of the impacts of the key threats facing Macadamia species.

Priority: Medium

Potential Contributors: MCC, MCRN, DEHP, OEH, local governments, NRM bodies, researchers, land managers

Action 3.3 *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 3.4 *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, DAFF, Macadamia growers, researchers

Action 3.5 *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 indigenous stakeholders to appropriately document and share knowledge and stories that improve conservation outcomes for Macadamia species.

Priority: Medium

Potential Contributors: MCC, NRM bodies, indigenous and traditional owner groups

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

Action 3.6 *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

Action 3.7 *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 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 the conservation management requirements of Macadamia species*
Land managers require additional information about the native flora found on their properties, particularly threatened species. The MCC will investigate opportunities to: distribute Macadamia species profiles to local landholders, sign significant roadside remnants, profile species in local newspapers, and develop fact sheets on threatening processes. Develop, launch and maintain a website devoted to Macadamia Conservation hosted by the Australian Macadamia Society. 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, DEHP, DTMR, OEH, local governments, NRM bodies, land managers

Action 4.2 *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, EHP, OEH, local governments, NRM bodies, community groups

Action 4.3 *Liaise with state government agencies, local governments, and regional NRM bodies 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, DEHP, NPRSR/QPWS, OEH, local governments, NRM bodies, researchers, land managers

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

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; and
- 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, NRM bodies, 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, NRM bodies, 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 8. 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 NRM bodies ❖ 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 ❖ Liaison with local governments, NRM bodies, Fire and Biodiversity Consortiums and other relevant organisations to access resources for conservation of Macadamia habitat on private properties ❖ Liaison with public land managers to encourage conservation of Macadamia habitats on their properties ❖ Sourcing of additional resources to assist land managers with conservation of Macadamia habitat ❖ Re-survey Macadamia populations to assess changes in population number structure and threat profile ❖ Undertake population viability analysis and investigate differences in genetic diversity between juvenile and adult cohorts ❖ 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) ❖ Development of ex-situ gene banks	❖ Targeted research on population genetics ❖ Continue investigation building on current knowledge into genetic changes to Macadamia populations arising from habitat fragmentation
Weeds	❖ Work with stakeholders to reduce the impact of Cat's claw creeper and Madeira vine	❖ Assessment of Macadamia populations to determine level of weed impact and particularly the presence of transformer

Threat	Current Actions	Future Actions
	❖ Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and NRM bodies	weed species, e.g., Cat's claw creeper and Madeira vine ❖ Liaison with local governments, NRM bodies and other relevant organisations to access resources for conservation of Macadamia habitat on private properties ❖ Provision of resources to land managers to reduce the impact of specific weed species in areas of known essential habitat ❖ Liaison with public land managers to encourage conservation of Macadamia habitats on their properties ❖ Sourcing of additional resources to assist land managers with conservation of Macadamia habitat ❖ Identify sites suitable for release of biocontrol agents ❖ 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 NRM bodies	❖ Liaison with local governments, NRM bodies, Fire and Biodiversity Consortiums and other relevant organisations to reduce the threat fire to Macadamia habitats.
Unmanaged livestock	❖ Resources to conserve and restore rainforest habitat provided to private landholders through local government, community groups and NRM bodies	❖ 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 ❖ 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 ❖ Provide results of modelling to land use planners ❖ Identify appropriate mitigation measures and develop action-oriented implementation strategy ❖ 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, e.g., through local and regional media, events, social media ❖ 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 NRM bodies through the *Wild about Macadamias* project	❖ Build partnerships in *Wild about Macadamias* to encompass and support a wider range of land managers ❖ 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 *Macadamia 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 9. 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 9. Costs associated with recovering species in the Macadamia Species Recovery Plan.

	Cost Estimate $					
Action	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**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	15,000	15,000	15,000	15,000	15,000	75,000

		Cost Estimate $					
Action		**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Total**
	private property						
2.3	Establishment of ex-situ populations for *Macadamia jansenii* at multiple sites	2,500	2,500	2,500	2,500	2,500	12,500
2.4	Provide information to public and private land managers (including landholders, Macadamia growers, etc.) 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
2.5	Support land managers to develop property management plans that include wild Macadamia conservation	25,000	25,000	25,000	25,000	25,000	125,000
2.6	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
2.7	Identify, monitor and manage weed, fire and livestock threats for priority populations	40,000	40,000	40,000	40,000	40,000	200,000
2.8	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
2.9	Establish long-term monitoring programs for priority Macadamia populations and disseminate the results		15,000			15,000	30,000
2.10	Update models of the projected impact of climate change on Macadamia ecology, extent of habitat and threatening processes		5,000		5,000		10,000
3.1	Identify gaps in the current understanding of Macadamia	2,500	2,500	2,500	2,500	2,500	12,500

		Cost Estimate $					
Action		**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Total**
	species ecology and develop research priorities for conservation priority research needs						
3.2	Ongoing liaison with research institutions to address prioritised research gaps	12,500	12,500	12,500	12,500	12,500	62,500
3.3	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
3.4	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
3.5	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
3.6	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
3.7	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
4.3	Liaise with state government agencies, local governments, and regional NRM bodies in order to incorporate	5,000	5,000	5,000	5,000	5,000	25,000

		Cost Estimate $					
Action		**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Total**
	Macadamia conservation into their biodiversity conservation and natural resource management strategies						
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 monitor the progress and delivery of the Macadamia Species Recovery Plan 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. Interim reviews may also be undertaken to meet reporting requirements of funding providers, e.g. HAL.

The Recovery Plan will be evaluated by members of the MCC at the end of the five-year period in 2019. Implementation of all management actions will be assessed against the designated performance criteria in Section 5.

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Ken Dorey	Maria Matthes
John Gillett	Dr Jodi Neal
Liz Gould	Dr Michael Powell
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Acronyms

AG	Australian Government
AMS	Australian Macadamia Society
ASL	Above Sea Level
BRAIN	Brisbane Rainforest Action and Information Network
BMRG	Burnett-Mary Regional Group
CA	Conservation Area
E	Endangered
DAFF	Queensland Department of Agriculture, Fisheries and Forestry
DEHP	Queensland Department of Environment and Heritage Protection
DTMR	Queensland Department of Transport and Main Roads
EPBC Act	Commonwealth Environment Protection and Biodiversity Conservation Act 1999
FR	Forest Reserve
HAL	Horticulture Australia Limited
LA	Lease Area
MCC	Macadamia Conservation Committee
MCRN	Macadamia Conservation Research Network
MCT	Macadamia Conservation Trust
MGA	Map Grid of Australia
NC Act	Queensland Nature Conservation Act 1992
NHT	Natural Heritage Trust
NP	National Park
NR	Nature Refuge
NRM	Natural Resource Management
NPRSR	Queensland Department of National Parks, Recreation, Sport and Racing
NSW	New South Wales
OEH	New South Wales Office of Environment and Heritage
QPWS	Queensland Parks and Wildlife Service
QTfN	Queensland Trust for Nature
RAF	Radioactive Amplified DNA Fingerprinting
RE	Regional Ecosystem
REDD	Regional Ecosystem Description Database
SEQC	SEQ Catchments Ltd
SEQFBC	South East Queensland Fire and Biodiversity Consortium
SEQTOLSMA	South East Queensland Traditional Owner Land and Sea Management Alliance
SF	State forest
SMSRP	Southern Macadamia Species Recovery Plan
SPRING	(The) Species Recovery Information Gateway
TAP	Threat Abatement Plan
TSC Act	NSW Threatened Species Conservation Act 1995
USC	University of the Sunshine Coast
V	Vulnerable
VCA	Voluntary Conservation Agreement

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Appendix 1: Recovery Team Membership

Name	Position	Organisation
Ian McConachie (AM)	Macadamia Grower	MCC
Liz Gould	Biodiversity Conservation Manager	SEQ Catchments
Dr Michael Powell	Macadamia Conservation Coordinator	MCC
Associate Professor Alison Shapcott	Senior Lecturer	University of the Sunshine Coast
Dr Jodi Neal	Plant Industry Scientist	DAFF

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 tabled below:

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 tabled below:

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. – no recovery time needed
Low	Possibly detectable but little impact on population size and none on dynamics. – rapid recovery would occur if stopped – measured in months
Moderate	Level of interaction/impact at maximum acceptable level. Long-term recruitment/dynamics not adversely affected. – recovery probably measured in months to years if stopped
High	Level of impact above maximum acceptable level. Would affect recruitment levels of the species or their capacity to increase in numbers. – recovery measured in years if stopped
Very High	Likely to cause local extinctions if continued. – recovery period measured in years to decades if stopped
Catastrophic	Local extinctions are imminent/immediate. – long-term recovery period to acceptable levels will be greater than decades or never, even if stopped

Risk evaluation matrix – potential impacts

Probability of event	Negligible	Low	Moderate	High	Very High	Catastrophic
Likely	0	1	2	3	4	4
Occasional	0	1	2	3	3	4
Possible	0	1	2	3	3	4
Unlikely	0	1	2	2	2	3
Rare	0	1	1	2	2	2
Remote	0	0	0	1	1	2

Significance of consequences