



*A charity fostering scientific research into
the biology and cultivation
of the Australian flora*

Research Matters

Newsletter of the Australian Flora Foundation

No. 27, January 2018

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President's Report 2017



Delivered by Dr Peter Goodwin at the AGM,
November 2017

New grants

Three grants were awarded for research to begin in 2018:

Identifying the horticultural potential of rare and threatened Australian wildflowers

Sue Murphy, University of Melbourne

Sue will select and assess species (9 or 10) from a pool of rare and threatened herbaceous species indigenous to Victoria. She will propagate and grow a sample of 50 seedlings from each species within a conventional container nursery system, and expose species and selected individuals to public scrutiny within display beds, plant sales and ultimately, landscape use. The project will establish protocols for the on-going assessment of rare and threatened species for horticultural applications. This project will raise awareness of the horticultural potential of our rare and threatened flora, which is often overlooked in commercial horticulture. Successful outcomes for the species in this project will provide the impetus to tackle other rare and threatened flora.

A donation of \$10,000 received from the Australian Native Plants Society (ANPS) Canberra in 2016 will be applied at their request to this project.

Assessing the diversity and conservation of central Queensland rainforest using DNA barcoding

Alison Shapcott, University of the Sunshine Coast

Barcoding of plants involves looking at a small stretch of DNA whose sequence is unique for each species. This is a speedy and cheap process once the DNA barcodes have been established. In addition, species can be identified from small leaf samples, which is particularly valuable for rainforest trees. Alison has already developed DNA barcodes for the unique species in the temperate and subtropical southern Queensland rainforests (Shapcott *et al.* 2015) and Costion *et al.* (2016) have developed DNA barcodes for North Queensland wet tropic rainforests. This project will complete the barcodes for Queensland rainforests. They will be used to help identify the areas of high biodiversity and distinctiveness

in these and in related Australian rainforests, and to identify priority areas for conservation.

Development of molecular markers for resistance to myrtle rust to identify resistance genes against myrtle rust

Peri Tobias, Sydney Institute of Agriculture, University of Sydney

Myrtle rust was first found in Australia in 2010, and has since spread to Victoria and Queensland and has potential to spread to all states and territories. This disease is about as bad as it can get for biosecurity in Australia – a new disease attacking our dominant plants, including eucalypts, paperbarks and about 100 other species, including species important as garden plants, cut flowers, native food plants and species already on threatened lists. During her PhD, Peri was able to identify certain genes that are associated with natural resilience in *Syzygium luehmannii*. The aim of this project is to see if these genes provide molecular markers that signify resistant phenotypes in other Myrtaceae. If so, they may provide a genetic screening test to enable the selection and protection of endemic Myrtaceae flora.

New website

Thanks to our website manager, Jennifer Firn, the Australian Flora Foundation (AFF) website has recently been renewed. It is still located at <http://aff.org.au/>. Jennifer would appreciate your comments to Jennifer.firn@qut.edu.au.

Retirement of Professor Richard Williams

Richard was the last remaining foundation member of the Foundation. He was not only a member, but also a Councillor at the inaugural meeting of the Foundation at the University of Sydney on 14 August 1981. This year marks his 36th year as a Councillor. In May 1982, the Scientific Research Committee was formed, and Richard was a member, as he is still. In 1994 he took up the post of Vice President of the Foundation, and in 1998 became President, combining it with activities of a senior academic at the University of Queensland. Richard finally retired as President in 2005.

During his Presidency the size of grants was increased from between \$2,000 and \$4,000 to a more effective \$10,000 to \$20,000, a reflection of the stronger financial position that the Foundation had achieved. He also strongly encouraged the development of a website for the Foundation, which was finally launched in 2004. He was a farsighted and kindly President. During his subsequent time as Vice-President he continued to actively contribute to the work of the Foundation. We wish Richard a long, healthy and happy retirement.

The second Councillor to retire this year was Caroline Gillard. She joined in December 2015, and in her brief period made the valuable contribution of updating the Foundation membership brochure, which is passed out at meetings of associations whose members may be interested in joining us.

Thanks

A special note of thanks to the members of the Finance Subcommittee: Ian Cox, Charles Morris and Ross Smyth-Kirk for their work on reducing the annual deficit on our General Fund, primarily caused by the high costs of auditing and accounting. Firstly, Ian Cox has found a more affordable auditor. Secondly, they have recommended we charge grant applicants an administration fee. This is being implemented in 2018. Finally, members were invited to make a modest contribution to the administrative costs, as well as continuing to support the research funded by the AFF, and have responded very positively to this.

Finally I should like to thank each of you for your contributions over the year, whether as ordinary members, members of the executive, members of the Scientific Committee, and/or members of Council. A special thank you to all donors and benefactors of the Foundation: without you the Australian Flora Foundation could not continue. Particularly noteworthy are the generous donations of \$10,000 from the ANPS Canberra Group, mentioned earlier, two donations of \$1,000 from the Australian Plant Society Newcastle Group, and substantial donations from a number of other individuals.

Peter Goodwin, President
20 November 2017

Welcome to our New President – Charles Morris



Charles Morris has been on the Council/Board of the AFF for over 20 years. He served one stint as Treasurer (1996–2003, succeeding Janice Hughes) and returned as Treasurer at the end of 2014 (succeeding Jenny Jobling). At the end of 2017, he took over from Peter Goodwin as President, and as there has been no one to take on the Treasurer role, is currently filling that position as well.

Charles has worked as an academic at The University of Sydney, the University of New South Wales, and Western Sydney University, from whence he retired at the end of 2016. The research interests of Charles and his

postgraduate students included the study of plant competition (the 'self-thinning' phenomenon); plant carnivory; salt-spray damage to coastal plants; germination of seeds of Australian native plants (especially *Grevillea*) in response to fire-related cues such as smoke and heat shock; and restoration of Cumberland Plain woodland in western Sydney using fire and soil carbon addition as tools.

Young Scientist Awards

The Australian Flora Foundation awards prizes annually to encourage young scientists to continue studying the flora of Australia.

At the annual conference of the Ecological Society of Australia (ESA) held in December 2017 the Foundation's prizes were presented to:

Outstanding student spoken paper on the biology or cultivation of an Australian plant

Hannah Etchells, PhD candidate, University of Western Australia
Karri (Eucalyptus diversicolor) forest regeneration following catastrophic wildfire

Abstract: Wildfires in the forested regions of southwest Australia are predicted to increase in both frequency and severity with projected changes in climate. While Karri (*Eucalyptus diversicolor*) forests are considered relatively fire tolerant, there are few published studies of Karri forest response to high severity fire and their capacity to persist under future fire regimes is uncertain. In January 2015, the largest and most severe Karri forest fire on record burnt 98,000 ha near Northcliffe, Western Australia, including extensive areas of old-growth Karri forest. This study quantified the effects of differing fire severity on the recruitment and survival of Karri seedlings, the mortality of mature Karri trees, and the composition of the understory plant community following the fire. Mature Karri tree mortality was 87% greater at high fire severity sites than at other sites, indicating that Karri trees may have an upper limit to their fire tolerance. Burnt sites had significantly different understory community composition than unburnt sites, and dominant understory shrub, *Trymalium odoratissimum*, was entirely absent from one extremely high fire severity site. Fungal community composition also appeared to be considerably altered by extreme severity fire. These findings suggest that Karri forests may have a fire resilience threshold, which is consistent with recent studies undertaken in different fire-adapted forest types burnt by severe fire, both in Australia and elsewhere. This study further highlights the need for long-term research

into the effects of climate change and severe wildfire on forest ecosystems worldwide

Outstanding student poster presentation on the biology or cultivation of an Australian plant

Nicole Bezemer, PhD candidate, University of Western Australia

Sex on the rocks: consequences of recruitment after wildfire in a granite-endemic tree

Abstract: In south-west Australia, granite outcrops support hyper-diverse plant communities, some species of which persist as small, genetically insular populations for extremely long periods. Due to the fire-sensitivity and conservation status of some granite endemics, experimental burns are inappropriate. Thus, opportunities to study the impact of fire on plant population genetics seldom arise. Following a wildfire in a stand of the granite-endemic, lignotuberous tree *Eucalyptus caesia* at Boyagin Reserve, we surveyed genetic diversity, growth and survival, and parentage of seedlings. The entire adult stand ($n = 180$) plus all seedlings located ($n = 115$) were genotyped with 15 microsatellite loci. There was low heterozygosity and high fixation in seedlings compared to adults. Seedling mortality was high, with 32 seedlings still alive 2 years after the fire. Our data did not support expectations of post-germination selection against homozygous progeny. Based on height measurements, seedlings resulting from self-pollination ($n = 19$) could not be distinguished from outcrossed seedlings ($n = 69$). Whether these results can be explained by variability in seedling microsites, or purging of deleterious alleles, requires further investigation. Parentage analysis revealed limited seed dispersal (14.6 ± 3.8 m). By comparison, pollen movement was more extensive (67.8 ± 9.4 m), yet still restricted within the stand. Genetic mixing through wide pollen dispersal within stands, and extreme longevity of adults via lignotuber resprouting could retard extirpation in *E. caesia*. However, poor understanding of recruitment over the long-term, and lack of population age-structure data, represents a significant challenge to appropriate conservation management.



Left: Hannah Etchells receiving her award for Outstanding Student Spoken Paper from Associate Professor Dieter Hochuli; right: Nicole Bezemer receiving her award for Outstanding Student Poster Presentation (images from G Spina).

Thanks from the Ecological Society of Australia

The ESA was delighted to again have the opportunity to partner with the AFF in presenting student conference prizes at our 2017 conference. EcoTas17 was the 5th joint conference of ESA and the New Zealand Ecological Society and was held in Pokolbin, NSW, from November 26–December 1, 2017. The Foundation was promoted to a wide audience as AFF flyers were included in the conference program presented to all delegates.

Thank you again for the Foundation's ongoing support of the ESA's conference student prize programme and we look forward to working with you again in 2018.

Gail Spina
Executive Officer, ESA

The Bush Tomato: growth and propagation

Dr Angela Pattison

Introduction

Solanum centrale J.M.Black (Australian Bush Tomato or Desert Raisin) is a perennial sub-shrub found in arid areas of Australia. It is considered to be an important traditional food for Aboriginal people and is a current target for the Australian native food industry. It has cultural significance for Indigenous people, and has great potential as an income source for remote desert communities. The edible fruits form within a few months of favourable moisture conditions and dry on the plant and, hence, are naturally preserved.

Reproduction from seed has proven difficult (Ahmed *et al.* 2006; Vincent 2010; Lee 2012), however it is known that the species readily reproduces vegetatively from underground structures. These have been termed rhizomes, roots, suckers and laterals by various authors.

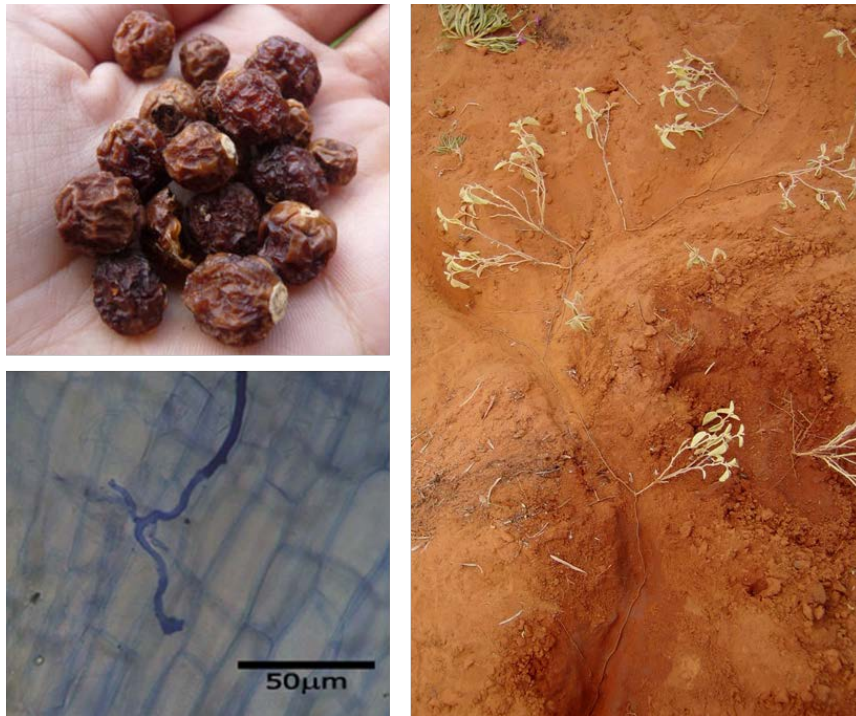
Studies of clonal growth

A study was undertaken to determine the precise nature of the underground parts of the species. The underground connections within seven clonal communities from Central and South Australia were documented over two sampling trips and samples of fine roots, thick lateral roots, stems and seeds were examined under both laboratory and glasshouse conditions. Shoot samples were taken along a 50 m transect at one site for DNA analysis to determine the extent of clonality. In addition, fine roots were sampled to determine if the species was able to form mycorrhizal associations and whether these associations would be beneficial to the plant.

Plants from all sites were defined as clones with individual ramets arising from lateral roots (root suckers) that ranged from 2–10 mm in diameter and located at a depth of 5–15 cm. Lateral roots have the capacity to accumulate large amounts of starch in parenchyma cells, and can rapidly resprout to form new clonal ramets. The ability to resprout from lateral roots is well-documented in many Australian species, and is an excellent general adaptation to disturbance such as fire or extended periods of drought as experienced in deserts.

Many individuals along the 50 m transect were found to be a single clone, hence the potential extent of a single plant must be considered to be at least that large (Waycott 2010). Furthermore, the species was found to readily form mycorrhizal associations, despite fine roots being ephemeral.

In glasshouse experiments, the addition of mycorrhizal fungi enhanced plant growth in low-phosphorus potting mix (Dennett *et al.* 2011).



Top left: Dried fruits from Bush Tomato (image from <http://en.foodlexicon.org/b0002960.php>); right: excavated clone of Bush Tomato showing individual ramets spaced evenly along lateral roots (image from A Pattison); bottom left: microscopic detail of hyphae of arbuscular mycorrhizal fungal (stained dark blue) within root tissues of Bush Tomato (image from Dennett *et al.* 2011).

Potential for propagation

Interestingly, root-suckering is documented in other species of *Solanum* from around the world, such as weedy *S. elaeagnifolium* (Silverleaf Nightshade; a Weed of National Significance in Australia) and *S. carolinense* (Carolina Horsenettle) (Cuda *et al.* 2002; NAPPO 2003). The descriptions of the root system of *S. carolinense* by Miyazaki and Ito (2004) and *S. juvenile* by Cosa *et al.* (1998), both of which are not desert species, are almost identical to that found for *S. centrale*. The seed plant in a colony of *S. carolinense* produced horizontal roots 5–10 mm in diameter. Like the roots of *S. centrale*, these laterals grew parallel to the surface and produced shoots at intervals or bent to vertical some distance from the seed plant (Miyazaki and Ito 2004).

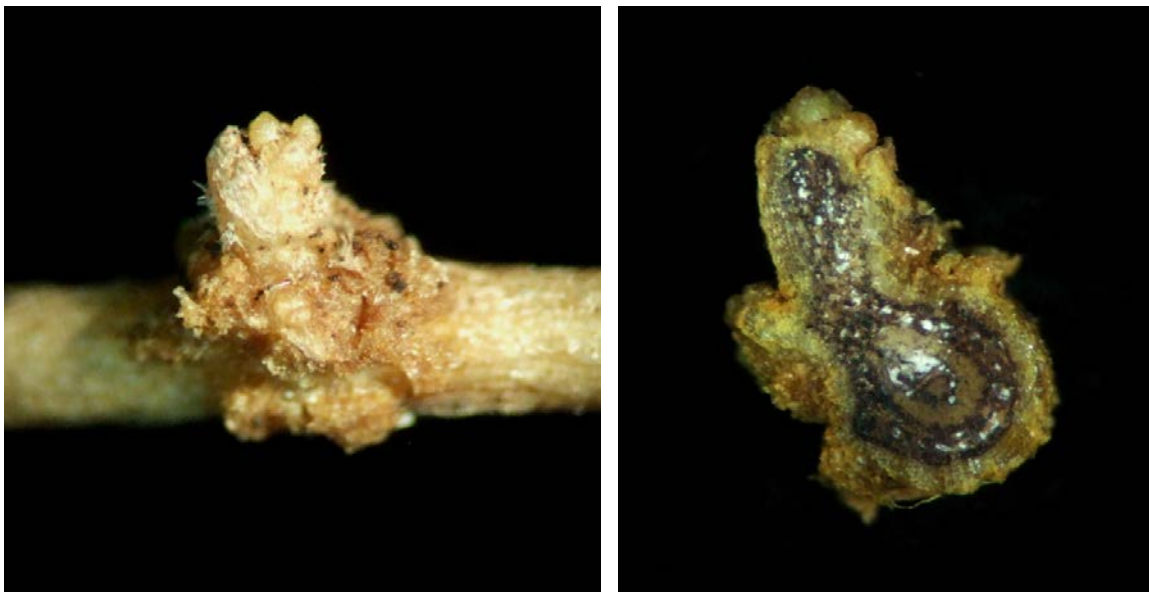
The features which allow the species to survive in deserts may prove challenging in cultivated plantations of *S. centrale* for the bushfood industry. *Solanum carolinense*, *S. elaeagnifolium* and other root-sprouters such as *Knautia arvensis* and *Centaurea scabiosa* are vigorous weeds in cropping regions (Symon 1981; Klimesova and Martinkova 2004). Colonies are very difficult to eradicate during crop rotation as the viability

of root fragments is not affected by standard cultivation and most herbicides. In fact, cultivation stimulates sprouting from root fragments (Urakawa and Koide 2004). The difficulty in eradicating colonies or preventing colony expansion has similarly been noted in *S. centrale* and *S. ellipticum*.

On the contrary, the ability of *S. centrale* to rapidly produce fruit following a disturbance event may be managed to increase production in cultivated situations by harvesting, slashing or burning shoots followed by irrigation to induce fruit production. Propagation by salvaged root fragments has been found to be a useful method of revegetation of the root-suckering species *Populus tremuloides* (Landhäusser *et al.* 2015). Furthermore, there is considerable potential to use material propagated vegetatively from root fragments of highly productive or flavoursome individuals to establish crops, given current difficulties with seed germination and high genetic variability within the species.

An important final note

The domestication of Australian native plants, including the Bush Tomato, involves not only agronomic and ecological considerations, but also the cultural heritage, totemic relationships and knowledge custodianship of the Australian Aboriginal people. The significance of the root sprouting ability of *S. centrale* and related species to food supply has been known and used by Aboriginal people for thousands of years. Domestication of this species should consider the knowledge held by Aboriginal people and involve discussions with the many groups who have contributed to the place the species has in food production and culture (Lee 2012).



Left: Vegetative ramet emerging from a meristematic bud region on a lateral root; right: transverse section through bud region stained with iodine to show copious amounts of starch (dark blue black region). The bud region is approximately 1 cm in width (images from A Pattison).

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About the author

Dr Angela Pattison (nee Dennett) is a plant breeder and agricultural scientist at the Plant Breeding Institute, School of Life and Environmental Sciences, University of Sydney. Her current role is pre-breeding chickpea for heat tolerance and developing tools to achieve this including the use of unmanned aerial vehicles (UAVs), molecular markers and interesting chickpeas from around the world. She is also involved in breeding and research related to field pea. Angela is passionate about the potential use of Australian native plant species for food, fuel and fibre production in environmentally- and socially-beneficial systems.

Banksia taxonomy: *status quo* remains?

Kevin Collins

Note: This article appeared in the Banksia Study Group Newsletter of the Australian Native Plants Association (Australia), Issue 20, Winter 2017, Volume 12, No. 1 and is reprinted with kind permission from the author. This version has been edited to comply with the format of the AFF newsletter. The original newsletter is available at: <https://protect-au.mimecast.com/s/YTdxCROAQot5B0GNF90TOV?domain=anpsa.org.au>. Kevin welcomes your feedback and opinions.

It is now 10 years, believe it or not, since the cladistics revision of the genus *Banksia* and the subsequent absorption of *Dryandra* by Mast and Thiele in 2007. Where do we now sit?

The respective *Banksia* and *Dryandra* Study Groups still remain separate entities steadfastly believing the amalgamation to be unnecessary. No one disputes the lineages regarding the evolution of *Dryandra* from *Banksia* but the removal of *Dryandra* is seen as an unnecessary step. Instead of adding new information about the species involved as promised by Thiele, it results in a 'dumbing down' of a separate group well described through Linnaean determination.

The new treatment retains sub-sections in the former genus recognised as *Banksia* but abandons this concept in the group formerly called *Dryandra*. This appears to be an inconsistency. The DNA findings clearly show dryandras to be in a separate group under the *Banksia*-umbrella, with no species interspersed amongst *Banksia* other than the unusual *D. subulata* which was formerly recognised as different, but was not placed in a separate genus at the time.

The strict adherence to cladistics principles which resulted in the sinking of *Dryandra* into *Banksia* is highly controversial in international botanical circles with the major issue being that it is a denial of evolution. The most criticised cladistics rule is the rejection of paraphyletic groups.

Paraphyletic groups occur where a group does not contain all the descendants of the most recent common ancestor. In the *Banksia/Dryandra* example, the most recent common ancestor of all banksias is also the most recent common ancestor of all dryandras. Under cladistics classification all of these descendants must be one genus (i.e. all *Banksia* or all *Dryandra*), or each lineage must be split to ensure no paraphyletic groups exist. Had this latter option been adopted, *Banksia* species such as *serrata*, *media* and *praemorsa* could have remained as banksias, but other species on a different lineage such as *integrifolia*, *grandis* and *brownii* could not be called banksias and would have to be allocated to a new genus. Under this option, dryandras would remain dryandras.

Critics of the rejection of paraphyletic groups under strict cladistics classification believe that this is a simplistic rule of convenience and is a denial of evolution. The *Banksia/Dryandra* case is a perfect illustration of this denial where, despite the marked evolutionary divergence of dryandras from banksias, the extent of this evolutionary divergence is ignored in cladistics classification where paraphyletic groups cannot be accepted.

A recent paper by Aubert (2015) concludes that cladism is based on biologically unrealistic assumptions that have been empirically falsified. He argues that paraphyletic groups should be acceptable. However, he recognises the strong intransigence between the proponents of the two philosophies in the botanical world, cladists versus evolutionists, and proposes the co-existence of two classifications reflecting the two philosophies.

Further controversy due to the strict adherence to the paraphyly rule under cladistics classification is now looming with the possible absorption of most *Grevillea* into the genus *Hakea*. The cladistic findings indicate that *Grevillea* may be split into different genera or absorbed into *Hakea* as this genus was the first named. Once again there is concern that these

proposed changes will not be well advertised and that no attempt will be made to achieve a broad consensus of approval prior to adoption of any change.

Perhaps we need to elect a panel of experts from a broad sphere of interests to discuss and consider the ramifications for all interested parties before any further taxonomy is abandoned or revised. Surely there are public, historical, business, non-science academia and preservation implications that need to be considered in line with the scientific findings and approaches.

A consensus was claimed amongst a small group of peers for the removal of *Dryandra* and not approved from a wider audience of *Dryandra* enthusiasts, predominantly from Western Australia, who are familiar with their history and traits. *Dryandra* is a genus endemic to Western Australia. They have different seed-holding mechanisms, fire ecology, inflorescence shape and structure, flower configuration, more prominent and persistent inflorescence bracts, different soil type requirements and provenance and are mostly smaller in habit to that of *Banksia* species.

It is still strongly evident that the general public wish to, and still do, refer to them as dryandras with their former names, as do many nurserymen, seed collectors, wildflower tourism operators, study group and plant association members and some academics. Nurserymen find it incredibly difficult to show purchasers any characteristics that show that dryandras can justifiably be called banksias. Botanist, Alex George, clearly stated that we are under no obligation to use the new names (George 2008). He believes the science to be preliminary and logically flawed at best.

The unfortunate reality of adopting cladistics for taxonomic determination is that it places plant recognition out of the realm of the people who work with them. At the end of the day it is these people, often volunteers, who grow, appreciate, adopt, study, preserve and treasure them.

On reflection, cladistic analysis is admirable in that it confirms ancestry, however no boundaries appear to have been set as to how far back you delve... 100 million, 1000 million years. The outcomes would be dramatically different. All genera and species may well have evolved from a single plant. Wouldn't that make life easier as they are all plants?

Further, the recent phenetic determination of a clonal group of *spinulosa* named *B. vincentia* begs the question. What are the parameters? How much separation should a clonal group have before it can be recognised as a separate species? To my knowledge these parameters haven't been established and the botanical treatment is *ad hoc*. The determination adopted for *B. vincentia* could lead to at least 30 or more new species of *Banksia* in Eastern Australia where some species are distributed over

thousands of kilometres with local provenance adaptation, continuing evolution and much hybridisation. Many Western Australian species, particularly in the Abietinae series, would likewise be split. This brings us back to the old dichotomy of “lumpers versus splitters”. This is very relevant in the Orchidaceae family as, due to promiscuity of species possibly brought on by indiscriminate pollination by European honey bees, new species are identified on a regular basis. The taxonomic nightmare is cleverly summarised by Barrow (2016).



Examples of some of the specimens in Kevin Collins' *Banksia/Dryandra* arboretum. Top left: *Dryandra drummondii* ssp. *macrorufa*; top right: *Banksia lemmaniana*; bottom left: the ground creeping species, *B. chamaephyton*; bottom right: *B. tricuspis* (images from K Collins).

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About the author

Kevin Collins was born on a farm at Pemberton in south west Western Australia. After working for 20 years with Telecom in radio and television transmission, he changed profession to accommodate his love of botany. He and wife Kathy collected seed, grew plants and established the world's first and only complete arboretum of banksias in the small country town of Mount Barker, Western Australia. The arboretum at Mount Barker includes a complete collection of all taxa of *Banksia* (112) and over half the 135 taxa of *Dryandra*.

Kevin is a self-taught botanist who has contributed data to the Western Australian Agricultural Department related to growing banksias for horticulture and floriculture. He has consulted on the genus in Western Australia and in California and lectures across the world on the genus. Kevin is currently assisting ANBG Canberra with a new banksia garden project. He co-authored with botanist AS George the book titled *Banksias* – a 376 page bible on the genus.



The author Kevin Collins near a dwarf specimen *Banksia praemorsa* at Cheyne's Beach headland, Western Australia (image from K Collins).

AFF-Funded Project: Can the native Rusty Fig, *Ficus rubiginosa*, beat climate change?

David Mackay

Introduction

Environmental changes are likely to impact on *Ficus rubiginosa* directly through phenological responses to climatic variation and indirectly through behavioural responses by its pollinators and avian visitors to climatic and habitat alteration. Many of these changes could reduce individual fitness and population viability in this species. Some of these environmental pressures at least, such as habitat fragmentation, fires and drought, are predicted to increase for this species across the region of this study and are likely to become long-term changes under the influence of climate change (CSIRO 2016) and a growing human population (Halpern *et al.* 2015). Similar environmental changes and stresses are being faced by most species globally (Cochrane 2001; Laurance and Williamson 2001; Cochrane and Laurance 2008). The primary aim of this study was to determine if climate change was impacting on reproductive success in *Ficus rubiginosa* and/or was likely to impact in the future.

Ficus rubiginosa, the Rusty Fig, is a widespread, keystone, dry-rainforest species with a 3,000 km range from Cape York, Queensland, to south-eastern NSW. *Ficus rubiginosa* is the only tree on the western side of the

Great Dividing Range that produces large quantities of fleshy fruit (syconia) throughout the year, supporting large numbers of frugivores, insects and insectivores.



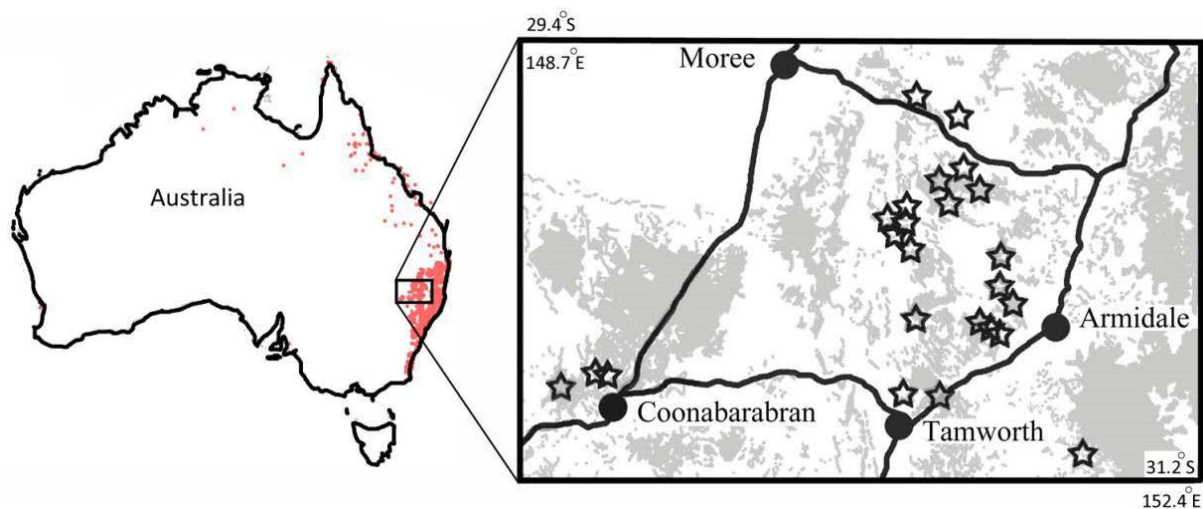
Left: An example of *Ficus rubiginosa* growing in typical isolated, rocky-outcrop habitat. Ten mature fig trees grew at this site near Delungra in northern NSW; right: developing syconia of *F. rubiginosa* with a pollinator insect, *Pleistodontes imperialis*, entering the ostiole at top (yellow arrow) (images from D Mackay).

Field studies

Field work for this study concentrated in the western half of the range of *F. rubiginosa* range in northern New South Wales, Australia, with a smaller number of coastal populations in northern NSW included in the study for comparison with inland populations. Four key areas of population ecology relating to phenology, pollination, avian visitation and genetic variation were addressed in the study. Environmental factors impacting on the fitness of *F. rubiginosa* in these four areas were identified and measured over the three-year period between January 2014 and January 2017. Further field work was conducted over the range of the species in July to October 2015 to collect genetic samples for Next Generation Sequencing and Single Nucleotide Polymorphism (SNP) analysis to determine current and historic patterns of genetic variation across the fragmented distribution of the species.

Results and discussion

The major findings from this study were that phenology was impacted by seasonal variations in temperature and by irregular, unpredictable variations in rainfall. Low winter temperatures caused syconium and pollinator-wasp development to slow down and go into stasis. Low rainfall stimulated the extension of male and female phenophases in fig trees through staggered syconium development. This staggered syconium development increased reproductive assurance by increasing overlap of male and female phenophases among trees. However, it also reduced the number of ripe fruit on trees at any one time, thereby reducing the attractiveness of a tree to frugivore seed-dispersers.



Left: Distribution of *Ficus rubiginosa* in Australia (red dots; including islands off the Queensland coast); right: locations of the 24 study sites (stars) within the 50,000 km² study area in northern New South Wales. Remaining areas of woody vegetation in the region are marked in grey on the map of the study area, based on satellite imagery (Google Earth 2017).

Pollination success was reduced in drier parts of the range of *F. rubiginosa* compared with that in more mesic environments. Extreme fragmentation – single trees – provided pollinators with refuge from parasitoids leading to increased male and female fitness in *F. rubiginosa*. Retention of unpollinated fruit on trees increased female fitness by increasing apparent crop size and attracting greater visitation by frugivores.



Two birds commonly associated with *Ficus rubiginosa*. Left: Brown Thornbill, an insectivore; right: Wompoo Pigeon, a frugivore (images from CL Gross).

Ficus rubiginosa is a pivotal and keystone resource for twice as many insectivorous bird species as frugivore species. Drier climates during the last ice age led to contraction of *F. rubiginosa* populations to four probable refugia, scattered over 22° (2,500 km) of latitude. Dry coastal zones that functioned as biogeographic barriers to gene flow during the

last ice age have functioned as corridors facilitating gene flow between inland and coastal populations more recently.

Signals of early population decline can be difficult to recognise in long-lived species such as large *Ficus* trees. However, several factors that impacted on pollination success and seed production and dispersal in *F. rubiginosa* were identified during this project. Among these factors were fire, rainfall, aridity in intervening habitat matrices, crop size in individual trees and the population size of *F. rubiginosa*.

1. Fire is projected to keep increasing in frequency and intensity under the influence of climate change. Flower and fruit production were delayed by up to 5 years and more in many trees across the study area, as trees recovered (resprouted) after fire.
2. Lower rainfall resulted in slower and reduced fruit production and smaller fruit with fewer seeds. Smaller crops of ripe fruit in trees attracted lower avian visitation and, hence, reduced seed dispersal.
3. Lower pollination success was recorded during drier conditions.
4. Gene flow was obstructed by dry areas between populations.

All of these factors and events are consequences of deteriorating rainfall and increasing temperatures, which have been experienced across the study area over the last few decades. Further decline is likely and local population extinctions are possible in those parts of the range of *F. rubiginosa* where climate change will result in continued reduction in rainfall and ongoing increases in temperature. This will negatively impact on communities of *F. rubiginosa* and on the ecosystem services provided by plants and animals associated with these communities and within the local and surrounding environments.

Ficus rubiginosa would be an important species to use in restoration efforts as it provides a year-round food resource for frugivores and, as found in this study, a year-round and unique food resource for insectivorous woodland birds, many of which are in decline in this and others regions globally.

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About the author

This report presents the results from a PhD study conducted by K David Mackay between 2014 and 2017. The study culminated in a dissertation submitted in November 2017 for the award of Doctor of Philosophy at the University of New England, Armidale. Congratulations David!

The full report was provided to the AFF in fulfilment of the conditions of a grant awarded to the author and can be found at: <http://aff.org.au/results/grant-summaries/>.

AFF-Funded Project: Clinal variation in seed dormancy, germination and regeneration of *Boronia*

Mark Ooi and Berin Mackenzie

Introduction

Seed banks are a key life-history stage of plants, yet data are often limited or missing from predictive models developed to determine population persistence (Menges 2000; Walck *et al.* 2011; Ooi 2012). Plasticity and heritability of dormancy traits, seedling survival and recruitment have direct consequences on population persistence and are all critical factors in determining seed bank dynamics. Understanding the mechanisms of key traits such as these, that drive plant population dynamics, can contribute to strategies addressing threats to biodiversity, such as from climate change.



Typical four-petal arrangement of members in the genus *Boronia*. Species in the genus are found in all states and mostly grow in open forests or woodlands (image from M Ooi and B Mackenzie).

The Rutaceae are a significant component of understorey species in Australian sclerophyll vegetation. A total of 78 native taxa occur in the Sydney region in heaths and woodlands on nutrient-poor soils (Auld 2001). Fifteen species are rare or threatened at the NSW or national level (Benson and McDougall 2001). Despite this, the ecology of the Rutaceae remains poorly understood and their seeds are considered difficult to germinate (Dixon *et al.* 1995; Martyn *et al.* 2009). This limits effective management of species within the family, and the ability to utilise *ex situ* seed collections for conservation and horticultural purposes (Auld 2001). The overall aim of this project was to understand how key traits, including seed dormancy, seed bank longevity and seedling growth and survival, vary for species from the poorly understood genus *Boronia* (Rutaceae).

Dormancy and germination of *Boronia* – Intra-specific variation

The role of seasonal temperatures as germination cues in fire-prone habitats is often overlooked due to a focus on direct fire cues such as heat shock and smoke (Ooi *et al.* 2006; Mackenzie *et al.* 2016). Additionally, little is known about the combined effects of multiple fire-related cues and environmental cues as these are seldom assessed in combination. We aimed to improve our understanding of the germination requirements of species with physiological dormancy in fire-prone floras, and to determine the level of variation at the intra-specific level, by investigating germination responses across members of the Rutaceae from south eastern Australia. We used a fully factorial experimental design to quantify the individual and combined effects of heat shock, smoke and seasonal ambient temperatures on germination of freshly dispersed seeds of seven species of *Boronia*.

Inter-specific variation in response to smoke

In this study, we focused on a single species, *Boronia floribunda*, to assess how much variation occurs among individuals. It is currently unknown whether within-population variation in germination response to smoke, at the individual level, occurs for species in fire-prone systems.

Variation in germination response to fire cues is hypothesised to contribute towards species coexistence and has been identified for physically dormant species, where heat is the main cue breaking dormancy. This ensures that some germination can occur in response to the variation of heat produced by fire in the soil (Auld 1986; Penman and Towerton 2008), with a proportion of seeds able to germinate under either high or low soil temperatures (Trabaud and Oustric 1989; Ooi *et al.* 2014). The results from our study show that this variation can also occur in smoke responsive species, and highlights a similar mechanism.

Conclusions

Species with physiological seed dormancy are dominant throughout the world, however an understanding of their ecology in Australian fire-prone ecosystems is still surprisingly limited. While perhaps not unexpected, this study has clearly shown that variation in dormancy-breaking requirements and/or in response to germination cues occurs at both the inter- and intra-specific level for taxa from the genus *Boronia* in the family Rutaceae. This is a similar finding to that reported for numerous hard-seeded species which display variation in response to heat shock for overcoming dormancy. Although these dormancy types have vastly different mechanisms, and therefore evolved independently, we consider that the similarity in their response to fire cues represents convergent evolution (Keeley and Bond 1997). Less clear from our results is any evidence for strong local adaptation of dormancy cues for populations from different climatic maternal environments. While germination varied, considerably more work is required to identify potential maternal effects.

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About the authors

Dr Mark Ooi is a widely-published plant ecologist in the Centre for Ecosystem Science, School of Biological Earth and Environmental Sciences, University of New South Wales. Berin Mackenzie is a PhD candidate based in the School of Biological Sciences, University of Wollongong. Berin was awarded the AFF-sponsored prize of 'Outstanding student spoken paper on the biology or cultivation of an Australian plant' in 2016. Part of the research done using the AFF funding has been published as:

Mackenzie BDE, Auld TD, Keith DA, Hui FKC, Ooi MKJ (2016) The effect of seasonal ambient temperatures on fire-stimulated germination of species

with physiological dormancy: a case study using *Boronia* (Rutaceae). *PLoS ONE* 11, e0156142.

The full report was provided to the AFF in fulfilment of the conditions of a grant awarded to the authors and can be found at:

<http://aff.org.au/results/grant-summaries/>.

What research were we funding 30 years ago?

Note: See <http://aff.org.au/results/grant-summaries/> for further details of these and other research projects funded by the AFF.

Floral biology of *Macadamia integrifolia* (Macadamia nut)

Dr Elizabeth Exley, The University of Queensland, funded in 1988 for \$1,500

An investigation of the diversity and abundance of pollinating insects in Macadamia orchards in Queensland and New South Wales showed that more than 90% of insect visitors to flowers belonged to two species of social bees, Honey bees (*Apis mellifera*) or Trigona bees (*Trigona carbonaria*). At one study site, Honey bees and Trigona bees were present through the entire flowering season. Other insects were rare at the beginning of the flowering season (July) but common later in the season (October).

Whereas Honey bees foraged for nectar, Trigona bees visited flowers mainly for pollen. This resulted in Trigona bees coming into contact with the stigma of the Macadamia flower more often than Honey bees, suggesting that they are more efficient pollinators. Foraging preferences showed that both Honey bees and Trigona bees foraged equally actively in sunny and shady positions. Macadamia racemes visited only by Trigona bees showed high initial nut set suggesting these bees are the more effective pollinators than Honey bees.

This research led to a number of publications (e.g. Heard 1988, 1991, 1993, Heard and Exley 1993, and see Wallace 1999) and, eventually, provided important information for the Macadamia growing industry in Australia. There are more than 850 Macadamia growers in Australia with a total of 6,000,000 trees producing an average of 40,000 tonnes per year. In 2017, growers produced a crop of 46,000 tonnes (in-shell) (<http://australian-macadamias.org/industry/>).

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Bee pollinators of Macadamia. Left: Honey bee (image from www.uhbeeproject.com/images/bee_on_macadamia.jpg); right: native bee (image from macadamiahouse.files.wordpress.com/2013/09/bees_flower.jpg).

Investigation of the cultural requirements for the development of *Helichrysum diosmifolium*

Dr Sandra Lacey, Queensland Department of Primary Industry, funded in 1988 for \$1,790

Cutting material and/or seed was collected from *Ozothamnus* (*Helichrysum*) *diosmifolium* (Rice Flower, Sago Flower) from over 80 sites in Queensland to evaluate the variability of horticulturally-desirable traits including stem and flower head form, involucre colour and flowering time. In general, flower heads arranged in a flat topped corymb are suitable for mixed bunches whilst those in finer sprays are more suitable as dried flowers. Pure white involucres are desirable and it is necessary to extend

the flowering period for trade purposes. This material was used for propagation trials.

Prior to the 1980s, *O. diosmifolium* was harvested from wild populations in central Queensland through to southern NSW. It is now cultivated throughout Australia and has national and international markets as a cut flower (Beal *et al.* 2001). Flower colour ranges naturally from white to pink with cultivars capturing a range of subtle colours (e.g. 'Benfers Pink Bouquet', 'Pretty Pink' and 'Jim's Pink' have pink flowers; 'True White' and 'Windles White Bouquet' have white flowers; 'Royal Flush' has purple buds opening to pink flowers). This species is also a popular garden and landscaping plant. Within its natural distribution, *O. diosmifolium* can grow to 2.5 m but cultivars have reduced the size of commercially-available plants (e.g. 'Petite' or 'Radiance' growing to 1 m).



Natural variation in *Ozothamnus diosmifolium*. Left: pink-flowered form (image from anpsa.org.au/o-dio.html); right: white-flowered form (image from anpsa.org.au/jpg/921309.jpg).

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Financial Report

These statements are summarised from the Foundation's audited accounts for the year ending 30 June 2017.

Income	\$
Donations	19,294
Administration contributions	1,176
Membership subscriptions	1,680
Interest	5,196
Fund distributions	52,650
Imputation credits refunded	7,506
Total income	87,502
Expenses	\$
Grants	64,505
Decrease in market value of investments	10,578
Accounting and audit fees	4,740
Website costs	2,000
Bank charges	180
Postage and printing	463
Administration	443
Total expenses	82,909
Surplus for the year	4,593
Assets	\$
Investments and bank accounts	912,501
Debtors	30,026
Tax credits receivable	7,506
GST receivable	4,114
Total assets	954,147
Liabilities	\$
GST payable	168
Grant commitments	71,653
Total liabilities	71,821
Net assets	882,326
Accumulated funds	
Accumulated funds from last year	877,733
Current year surplus	4,593
Total accumulated funds	882,326

About the Australian Flora Foundation

The Australian Flora Foundation is an Australian not-for-profit charity dedicated to fostering scientific research into Australia's flora. It is totally independent. All members of the Council and the Scientific Committee give their time freely as volunteers.

Each year the Australian Flora Foundation provides funding for a number of grants for research into the biology and cultivation of the Australian flora. While the grants are not usually large, they are often vital in enabling such projects to be undertaken. Many of the researchers are honours or postgraduate students, and their success with an Australian Flora Foundation grant hopefully stimulates their interest in researching Australia's unique and diverse plants throughout their careers.

This work is only made possible by the generous support of donors and benefactors.

The Foundation is currently calling for applications for projects to commence in December 2018. The Foundation expects to support between two and four projects at \$5,000–\$15,000 per year each in 2018 with possible extension into 2020. See the AFF website for application details (<http://aff.org.au/grants/>).

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