THE BOTANIC GARDENer

The magazine for botanic garden professionals

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Feedback and comments on the newsletter and articles are welcome. Please email: secretariat@bganz.org.au

COVER: Scented-top Grass *Capillipedium spicigerum* is a tall perennial native grass, occurring along the Australian east coast. A warm season grower, this grass is a great coloniser with attractive purple seed heads.
Photo credit: Peter Cuneo

CONTENTS

Book Review

Feature Garden

Professional Networks

The theme of the November 2016 issue is ***AMAZING Interpretation***. The deadline for contributions is Monday 26 September 2016. Please contact the Secretariat (secretariat@bganz.org.au) if you are intending to submit an article or have a contribution to other sections.

President's view

John Sandham, BGANZ President

John Sandham

Many things are certainly happening!

I am delighted with the outstanding support shown by member botanic gardens for the inaugural BGANZ Open Day. The public love their local botanic garden and people came out in great numbers to support the 76 botanic gardens and arboreta taking part. Eamonn writes more about this later in the magazine.

BGANZ has developed a Memorandum of Understanding with the American Public Gardens Association (APGA). One of the many positive outcomes is the benefit of one free (valued at approximately $1300 AUD $1450 NZD) registration annually for a BGANZ member to attend the APGA Conference. BGANZ Council believes that this gives great opportunity for professional development.

It may even be possible in some unique cases for members to combine this offer with the Study Research Grant ($2,000) or Young Professional of the Year ($500) awards announced at our congress every two years. Council will soon be calling for applicants for all of the above for 2017 so keep your eyes open as we will soon publish the selection criteria for these great opportunities.

We should congratulate Sharon Willoughby, Manager Public Programs, Cranbourne Botanic Gardens and the Chair of the BGANZ Botanic Gardens Education Network who was asked at late notice to deliver a paper at this year's APGA conference. Council recognized that Sharon would be a great ambassador for our organization and along with BGANZ Victoria and Royal Botanic Gardens Victoria we gave support for Sharon to attend.

In late April I attended the Australian Association of Friends of Botanic Gardens conference in Geelong Botanic Gardens. The theme was '*Botanic Environments and Their Survival in the Time of Global Warming* – a similar message to that of the BGANZ Open Day and truly underlining the importance that Friends' organisations play in getting our key messages to the visiting public. In countless cases they are the only contact we have with our customers.

As I travelled to Geelong by car I visited Horsham Botanic Gardens on the way and Werribee Park, Colac and Warrnambool botanic gardens on my return. It was great to see the vast and varied plant collections these gardens hold and it was also good to meet up with the hard working and passionate staff. Many things are certainly happening in our botanic garden world!

Editorial insights

Janelle Hatherly, Managing Editor

Janelle Hatherly

Having edited THE BOTANIC GARDENer for a few years now, I am seeing an interesting trend emerge. As well as a source of news and new ideas, members view their magazine as a good place to document conference presentations – that is, record and share their thoughts on all manner of contemporary issues. With the amount of research and preparation that goes into delivering conferences, many of those involved hope to make a lasting professional contribution.

The usual channel for doing this used to be in published papers but with increasing workloads, limited budgets and dwindling resources, formal conference proceedings are becoming a thing of the past. In addition social media, video conferencing and instant uploading of PowerPoint presentations provide immediate and easier communication of these events.

However, it's unclear to me if Twitter, Facebook, You-tube videos etc. can/will have a lasting presence. Professional magazines can and have been around for years and each issue records a snapshot in time and is a handy reference for the future.

Many of the articles in this issue are write-ups from the recent The Australian Seed Bank Partnership's National Seed Science Forum held at The Australian Botanic Garden Mount Annan. There is also one paper from The Australasian Association of Friends of Botanic Gardens' (AAFBG) 2016 conference held at the Geelong Botanic Gardens at the end of April. Also, Sharon Willoughby and Eamonn provide feedback on their experiences at the recent American Public Gardens Association (APGA) conference in Miami.

Obviously we don't want THE BOTANIC GARDENer to be inundated with this type of article but let's encourage the most interesting and innovative conference presentations to be recorded here for posterity. After all, the role of BGANZ is to provide its members with a forum for sharing expertise, information and best practice standards.

The Welcome Reception for the National Seed Science Forum provided a wonderful opportunity for the 145 delegates to renew acquaintances and meet new colleagues, while enjoying the surrounding of the Australian PlantBank at The Australian Botanic Garden. (Photo: Adam Huttner-Koros, ASBP).

FEATURE INTERVIEW

Outstanding in the field

Janelle Hatherly interviews

Lucy Sutherland, National Coordinator
Australian Seed Bank Partnership

Thanks for agreeing to be our feature interviewee. I'm particularly interested to learn how you developed your career in plant conservation and, as this issue's about science and partnerships, to find out more about existing seed banking partnerships in Australia and abroad.

Dr Lucy Sutherland

How have you come to work in botanic gardens and what attracts you to this work environment?

I'm an ecologist and social scientist and I have worked in or with botanic gardens for a great part of my career. I'm passionate about these institutions because they bring together various disciplines from the science to the arts fields and work to connect people to plants and to improve our understanding of the world's flora.

Botanic gardens are both scientific and cultural institutions and as such they attract a diverse range of people including volunteers, who are passionate about plants and the environment. Because of this diversity and genuine interest and passion, I feel a real sense of place and belonging in these institutions. I feel that botanic gardens make an important contribution to our society from the knowledge that is generated, to the experience we create for people's learning, enjoyment and recuperation.

What is the ASBP and what is your role?

The Australian Seed Bank Partnership (ASBP) is a conservation program of The Council of Heads of Australian Botanic Gardens Inc., which is supported by the Australian National Botanic Gardens through providing leadership and secretariat services.

There are twelve partners making up the ASBP and we also collaborate with many associates on various conservation and knowledge sharing projects.

Relaxing at the Australian National Botanic Gardens cafe.

Our associates include the Australian Grains Genebank, the Atlas of Living Australia and the Society for Ecological Restoration Australasia.

Setting the scene at the National Seed Science Forum. Photo: Cathy Offord

My role, as the national coordinator, is to lead and manage the partnership in its national and international efforts in plant conservation through seed banking, research and knowledge sharing. Our goal is to share knowledge and engage people in the work of the Australian Seed Bank Partnership. ASBP's vision is for a future where native plant diversity is valued, understood and conserved for the benefit of all. The Australian Seed Bank Partnership's National Seed Science Forum 2016, held recently at The Australian Botanic Garden Mount Annan, aligns with our goal and vision.

Why is seed research and conservation so important?

Australia's rich flora is threatened by various processes such as Dieback *Phytophthora cinnamomi* and more recently Myrtle Rust *Puccinia psidii*. To maintain our biodiversity we need an integrated approach to conservation and seed science enhances knowledge of our native flora. The research aims to advance our understanding of seed biology and translate this into technologies for plant propagation, conservation and landscape restoration. Seed science also helps with ensuring we are able to store germplasm for long-term future use.

What seed partnerships exist and what is their value?

Over the last 16 years we have seen the growth of seed banking partnerships, with the Royal Botanic Gardens, Kew leading this process through its Millennium Seed Bank Partnership (MSBP). Australia has been a significant participant in Kew's global seed conservation program and the ASPB was established to grow national collaborations in seed collecting, banking, research and knowledge sharing.

The ASBP is a member of the Global Partnership for Plant Conservation, which is a collaboration of international, regional and national organisations working to contribute to the implementation of the Global Strategy for Plant Conservation (GSPC). This helps us to be part of the global plant conservation community and also communicate about our Australian efforts in ex situ conservation and research.

With rapidly reducing resources available for plant conservation in countries, including Australia, partnerships can be an effective way to do business and deliver a conservation mandate. As a collaborative we can identify gaps where new initiatives are needed.

Moreover, seed banking partnerships can pave the way for opportunities within botanical institutions to diversify how they undertake their conservation efforts, by assisting in the development and

dissemination of best practices and case studies in plant conservation and providing access to relevant scientific and technical information and facilities for plant conservation.

How does Australia 'stack up' to other countries with respect to achieving GSPC plant conservation targets?

There are 16 targets outlined in the GSPC and Australia is making important contributions to the global efforts. In terms of the work of the ASBP, we primarily contribute to five of these targets.

Target 8 aims for at least 75% of threatened plant species in ex situ conservation and in Australia around one third (34.2%; 6325) of the estimated 18,500 flowering taxa are banked in conservation seed banks. Of the 3,574 legislatively threatened plant taxa, 1,240 (34.7%) are held in conservation seed banks.

The National Seed Science Forum has contributed to Target 3 where information, research and associated outputs, and methods necessary to implement the GSPC are developed and shared. The forum did this by bringing together seed scientists, people working in the native and agricultural seed industries, and restoration practitioners to share the latest research and ideas, discuss issues being faced by industry and the conservation and restoration sectors that could be addressed through science.

> The National Seed Science Forum has contributed to Target 3 of the GSPC.

Furthermore, we contribute to Target 3 through our collaboration with the *Atlas of Living Australia* who has built the *Australian Seed Bank Online.* This publically accessible database contains detailed records for over 43,155 seed collections and draws on the ex situ collections data captured by eight conservation seed banks in Australia.

This information is integrated with other relevant data records such as Australia's Virtual Herbarium and the spatial layers available through the Atlas (http://asbp.ala.org.au). This distributed database provides us with the capability to export the data into other systems e.g. the Millennium Seed Bank Partnership Data Warehouse and the World Flora online.

What did you hope the recent National Seed Science Forum would achieve?

We wanted the forum to be an inspiring event where people came together to share the latest research and ideas, discuss critical issues being faced by industry that could be addressed through seed science, and form collaborations to advance future conservation, agricultural and restoration efforts.

The feedback from the evaluation process has been excellent – the vast majority of delegates found the forum valuable with 76% ranking it as 'good to excellent' for professional development, 93% for networking and collaborations and 95% for knowledge sharing.

Many delegates reported on the value of bringing the conservation, restoration and agricultural sectors together to discuss seed science and highlighted the rarity of this happening internationally. Keynote speaker Dr Christina Walters from the United States challenged the current seed banking paradigm and highlighted the need for those working in conservation seed banking to draw on the experience of the agricultural industry in relation to the behaviour of seed in storage.

Post-forum, I'm aware of conservation scientists meeting with agricultural scientists to discuss their work and look for synergies – and I'm so pleased to hear of these possible new collaborations. This can only benefit all our efforts.

Dr Christina Walters at the National Seed Science Forum. Photo: Zoe-Joy Newby

What is one bit of advice you would offer to an aspiring young scientist who is passionate about plant conservation?

Am I limited to only one bit of advice? Firstly, ***don't give up!*** It can be very difficult to break into plant conservation and it takes persistence and sometimes requires a willingness to travel to find work opportunities, or you may need to start off through volunteering.

Secondly, ***find a good mentor*** who can support your career development and help open doors to opportunities. Thirdly, ***build your networks*** this may happen by joining a relevant professional association or participating in gatherings that bring people together to discuss plant conservation.

What are you reading now?

I always have a pile of books 'on the go'. At the moment, several of these focus on business management and leadership such as the Harvard Business Review Must Read Series and Think One Team by Graham Winter. We are witnessing big changes in botanic gardens and ongoing challenges to sustain these institutions.

We need to lead and manage them so they can adapt to change, respond to society's needs and always be the 'go to' place for plant related expertise. Consequently, we need to challenge our own thinking and ways of seeing these institutions and how they operate to ensure that our efforts to manage these institutions are maintaining their relevance and value.

I'm also pouring over the literature to prepare a paper for the upcoming Australian Garden History Society National Conference in October 2016. I'm presenting a paper on '*Botanic gardens and seed banking: a journey through time*' and I want to examine botanic gardens from a historical and contemporary perspective and consider the social and scientific context, and subsequent impact, of their evolution. I'm still at the stage of being overwhelmed by the literature – I hope to fine a clear pathway very soon!

Botanic news: from home and abroad

Congratulations AALBG!

The South Australian Tourism Awards were announced recently in Adelaide and the Australian Arid Lands Botanic Garden (AALBG) was named South Australia's best ecotourism experience at the 2015 South Australian Tourism Awards.

Australian orchid expert awarded

Leading Australian orchid expert Dr Mark Clements has been awarded a prestigious award, the Westonbirt Orchid Medal, from the Royal Horticulture Society in the United Kingdom. Mark works at the Centre for Australian National Biodiversity Research, a joint initiative between Parks Australia's Australian National Botanic Gardens and CSIRO.

Landscape Succession Strategy for Melbourne Gardens 2016–2036

Adapting a world-renowned botanical landscape to climate change, Royal Botanic Gardens Victoria has released a Landscape Succession Strategy that will guide the management of Melbourne Gardens into the next century. It was launched 170 years to the day when land for Melbourne's much-loved botanic gardens was set aside on the south bank of the Yarra River. More details here

BGCI: Communities in Nature Webinars

Communities in Nature supports botanic gardens to grow their social role and work with their communities on common issues of social and environmental importance, for the enduring benefit of those communities, the gardens themselves, and towards a sustainable future for our planet.

Upcoming free webinars: *Bringing organisational change* with Jennifer Schwarz-Ballard, Chicago Botanic Garden, *Fundraising for social inclusion* with Sharon Willoughby, Royal Botanic Gardens Victoria, and *Working with diverse audiences* with Poppy Szaybo, Diversity: Heritage Group.

Would you like to buy and own your own botanic garden?

Princeville Botanical Garden is a world-class botanical garden and residence located on the North Shore of the island of Kauai. The garden has been placed on the market for sale, and the full offering summary can be viewed at Princeville Botanic Garden.

BGCI's Big Picnic: Big Questions

BGCI is pleased to announce the launch of its new project *Big Picnic Big Questions – engaging the public with responsible research and innovation on food security.* As part of Big Picnic, the public across Europe and in Uganda are invited to sit down with scientists, policy makers, industry and others to learn from each other and share ideas about food security. Food security, or lack of it, is one of the most pressing challenges facing the planet.

BGCI will coordinate this brand new project, brought to you through an international partnership of botanic gardens, universities, a science shop, an institute for art, science and technology and an international NGO. Big Picnics will take place in 12 countries across Europe and one in Africa.

Garden gurus in ASA lecture series

Founded in 1977, Australians Studying Abroad (ASA) is Australia's oldest educational and cultural tour company. All ASA tours reflect a belief that learning is as much an act of imagination and experience as a garnering of information, based on the assumption that an intimate relationship exists between geography, history and culture. Now ASA is hosting garden lectures in both Sydney and Melbourne. Lecturers include John Patrick on '*Gardens, art and fall foliage in the USA*', Jim Fogarty on '*Drawing on Japanese influences in garden design*' and Richard Heathcote on *An Englishman's home is a Welsh castle*. Find out more at ASA tours.

Complementary organisations

The Australasian Association of Friends of Botanic Gardens (AAFBG) held its 2016 conference at the Geelong Botanic Gardens at the end of April. They have already produced a special conference edition of their newsletter viewable at AAFBG Newsletter.

Vale Allan Dale Correy landscape architect

My friend of a lifetime has gone! But what a lifetime we have had in the great horticultural industry, especially botanic gardens. Allan and I started work in the Royal Botanic Gardens Sydney back in 1946, just after the end of WW2, as Junior Outdoor Attendants. As such we started at the bottom!

Allan and I attended the Sydney Technical College and completed our horticultural training. While doing that we took up bushwalking and had many walks and climbs in many areas of Australia and many discussions on development of horticulture – particularly how Australian landscapes should develop. Allan went off to England and USA and became one of Australia's first university trained landscape architects.

Allan at Fountain Falls Lamington NP in 1952.

Always interested in botanic gardens Allan came back to Australia and did the master plan for Mt Lofty Botanic Garden in South Australia.

We have kept in touch over the whole of our lives, fostered our families, kept up walking in the bush in our home areas, played our parts in the horticultural industry and both became Volunteer Guides in our home botanic gardens: Allan at the Royal Botanic Gardens Sydney and myself in Brisbane's botanic gardens.

Mates for life.

In our retirement years we walked and talked our way through our careers and life in general. Allan has made a mark on the landscape of Australia, which will continue with all the landscapers he has influenced in our 'wide brown land'.

The Volunteer Guides in Sydney's botanic gardens and I will remember Allan, for his quality walks, and his great interest in plants that remained with him to the end of his life.

Ray Steward, Retired Director Parks and Recreation Brisbane City.

Pollinating great ideas

Global Seed Conservation Challenge

Katherine O'Donnell, Seed Conservation Coordinator, BGCI

Botanic Gardens Conservation International (BGCI) launched the Global Seed Conservation Challenge (GSCC) to support and challenge botanic gardens involved in seed banking.

The online seed conservation 'hub' has a range of collated resources from around the world with information on a range of topics. In order to address gaps in resources, this year BGCI will be launching online seed banking modules, with knowledge testing components, for participants to learn the basics of seed banking.

One of the aims of the GSCC is to strengthen networks at the national, regional and global level, facilitating the sharing of experiences and resources in seed banking. Participants of the Global Seed Conservation Challenge have access to the seed conservation Listserv where over 150 institutions are connected through email. This is a great place to share advice, experience and expertise and information on upcoming events.

As well as supporting gardens in their seed banking efforts, BGCI wants to challenge botanic gardens to conserve more threatened species. Working together towards Target 8 of the Global Strategy for Plant Conservation, which calls for '75% of threatened species in ex situ collections… by 2020'.

At BGCI's next Global Botanic Gardens Congress we will be celebrating the successes of seed banking botanic gardens. Prizes will be awarded to gardens that bank the most threatened species, the most difficult to collect or the most useful. In order to enter the competition gardens should upload seed collection data now to PlantSearch.

BGCI's PlantSearch provides a unique tool for measuring progress towards Target 8 of the GSPC. By uploading collection data to BGCI's PlantSearch database, data is cross-referenced with conservation-related information including the IUCN Threatened Species Red List, CITES appendices, Crop Wild Relative Genera and Invasive Species Compendium fact sheets.

If your garden is interested in being part of the GSCC get in touch with me at katherine.odonnell@bgci.org. More information can be found at BGCI Plant Conservation.

Plant importation alert

Warren Worboys, Curator, Horticulture Royal Botanic Gardens Victoria

On 12 May 2016, the Post Entry Plant Industry Consultative Committee (PEPICC) held a biannual meeting which I attended at the new Post Entry Quarantine (PEQ) facilities at Mickleham, on Melbourne's outer northern suburbs edge.

This committee has representatives from significant plant material importers in the horticultural industry from across Australia, including cut flowers, strawberries, potted colour, bulbs, seeds, trees and shrubs, fruit and nuts, as well as Federal Government representatives from the Department of Agriculture and Water Resources (DAWR). The PEQ facility now consolidates the operations of numerous older and out of date plant and animal government quarantine sites from across the country (which have been closed down) into a single state-of-the-art quarantine facility.

Of particular concern to the DAWR, and for Australian and New Zealand botanic gardens and the horticultural industry in general, are the threats of the importation of Sudden Oak Death *Phytophthora ramorum* and Xylella *Xylella fastidiosa*, both of which could cause havoc in ornamental horticulture and food production. The latter in particular due to the extensive range of species which it infects, e.g. it is already devastating olive groves in southern Italy where nearby almond trees and oleanders are also infected. Any BGANZ members who import plant material should be very wary about where they are sourcing their material prior to going through all the hoops of the importation.

Factsheet and further reading here.

Pha Tad Ke – a really great idea

Rik Gadella, Pha Tad Ke Botanical Garden

> 'Who would have thought that a week's stay in Laos would have turned my life around so much!'
> Rik Gadella Founder

We have been working on the creation of the first botanic garden of Laos for seven years now and have finally found the financing to finish and open the first part of Pha Tad Ke Botanical Garden to the public this November! Please find some documentation here. We have very tight links to Australia and New Zealand professionally and are now reaching out to secure the last 10% of the funding with an Indiegogo crowd funding campaign. Please help to spread the news through your gardens' social media and Friends.

Urban tree management strategies for climate change

Greg Moore, Senior Research Associate, University of Melbourne, Burnley College

Overview

The impacts of climate change on urban trees and ecosystems may be described as generally deleterious, but the real scenario will be subtle[1]. Some species will benefit from climate change and others will be disadvantaged. Urban trees will be impacted in many ways, the most apparent of which will be the direct effects of higher day and night temperatures on the trees of the urban forest and their associated biota. In many places there will be reduced water availability due to lower rainfall and higher evaporative losses or a combination of both. Climate change will bring a mixture of outcomes both good and bad for urban tree managers.

Many commonly planted urban trees have wide temperature and water tolerance ranges and so are unlikely to be impacted by early climate change and for some genera there are ecological displacement series where, as temperatures warm and rainfall decreases, one species within the genus is replaced by another. There will still be a wide palette of species with which to plan and plant cities and there is much that can be done to mitigate some of the consequences of climate change on a city-wide or regional scale at a time of climate change.

> Botanic gardens, in particular, have a significant role to play in evaluating species for future use in urban forests.

Botanic gardens, in particular, have a significant role to play in evaluating species for future use in urban forests. Often native and exotic tree have been planted in botanic gardens for decades or even centuries, under conditions that have been far from ideal for their growth and development. Diverse plantings in botanic gardens also provide a significant source of data on tree performance under these conditions and, as climate changes, may provide indications of tree performance that will inform planting and tree management practices.

Because so many of our botanic gardens are located close to major points of entry to the continent – ports and airports – they also have a role to play in the early detection of exotic pests and diseases, a role which is more likely to bear fruit as staff are well-trained and have expertise in the detection of unusual symptoms. An understanding of tree biology and physiology and observing how long-established trees are responding at present will make it possible to take advantage of some of the changes wrought by climate change and adaptively manage urban trees more efficiently.

Some strategies for managing urban forests as climate changes

One of the more obvious strategies in dealing with climate change is to do nothing. Our urban forests may be more resilient to climate change than we think and we may not need to do anything, or at least avoid an uninformed knee-jerk reaction. Many species that are widely planted in cities, from genera such as *Platanus, Linden, Pittosporum, Betula, Ulmus* and some coniferous genera, are renowned for their wide tolerance ranges.

They have become great urban trees because of their environmental resilience and tolerance of a wide range of soil, rainfall and temperature conditions and most should cope with the changes in temperatures and rainfall that are projected for many cities[2]. However, some such as *Betula* species and perhaps *Platanus* x *acerifolia* may be approaching the limits of their tolerance in south-eastern Australia, if their performance as ornamental trees during the dry period from 1997-2010 is considered.

Other common urban trees come from populations that have wide and extensive natural distributions. This is the case for many species from Australia's two largest genera, *Eucalyptus* and *Acacia*, where there are large numbers of related species occupying a broad range of habitats. *Lophestemon confertus* occupies a wide-range of habitats and differences in the provenances of the species are well-known for their different characteristics.

Similarly *Acmena smithii* and *Tristaniopsis* species show a wide-range of environmental tolerances. Careful provenance selection and breeding, which source specimens growing on appropriate soils but from lower rainfall or warmer regions could ensure that there are suitable intraspecific selections to meet urban planting demands.

Even if species' ranges are limited, there may be the option of selecting different but closely-related species from within a genus where displacement series of species exist. A displacement series consists of often related species, which replace each other over an ecotone that could be related to aridity, rainfall, soil nutrition, altitude or temperature.

Of particular interest for informing tree selection for climate change are displacement series of increasingly arid or warmer environments. Species show characteristics that adapt them to the drier conditions or generally more stressful environments, which could be used as a guide for which species might be successful for urban planting in drier conditions. Often species that are tolerant of one environmental stress may be more generally stress tolerant, or perhaps capable of withstanding a related stress.

It is not only abiotic stresses that can be dealt with via displacement series, but also biotic stresses, such as susceptibility to insect or fungal attack. Within the eucalypts, species from different genera and subgenera show different general tolerances to fungal pathogens such as *Phytophthora cinnamomi.*

While growth and arboricultural data on Australian amenity trees grown in urban areas is generally unavailable, there have been studies on provenances of *Lophostemon confertus*, *Tristaniopsis laurina* and *Corymbia maculata*. There are often good provenance data for important forestry and crop tree species, which can also inform decisions.

A role for botanic gardens

Horticulturists are adept at establishing, growing and managing trees outside their natural ranges and under adverse conditions. The role of botanic gardens in trialling plants through their various acclimatization plantings in the mid-1800s should not be undervalued. Many of these plantings were properly constructed trials that were well documented, and in the gardens in Melbourne for example von Mueller trialled plants for shelter, fibre and drought hardiness[3]. While many of the plantings and trials were short-lived, the remnant trees that have survived could prove to be invaluable in making informed plant selections as climate changes.

> The role of botanic gardens in trialling plants through their various acclimatization plantings should not be undervalued.

Furthermore, many of the capital city and major regional botanic gardens have been much photographed for over a century, especially for postcards that are still accessible. It is often possible not only to identify particular trees, but also quite accurately estimate their heights and canopy spreads, especially if there are structures still present.

I have used postcards from Victorian botanic gardens such as Ballarat, Bendigo, Melbourne and Daylesford among others showing certain specimen trees from the early 1900s when inspecting the same trees in recent years for redwood dieback and other tree performance assessments.

Redwoods at Ballarat Botanical Gardens (circa 1908 and 2014)

The range of microclimates and microhabitats that exist within urban environments can be used to advantage. Trees that are more sensitive to warmer temperatures could be grown in parts of cities that are subject to permanent shade, while frost-sensitive species may be grown more easily. In the urban environment, restricting water availability to trees which may limit growth or foliage density may also restrict the benefits that trees provide, such as their capacity for providing shade, sequestering carbon and transpirational cooling.

Many Australian tree genera are sclerophyllous and maintain cellular volume as conditions dry. It is often assumed that sclerophylls are low water users, but paradoxically many have poor stomatal control and will use whatever water is available until they start wilting[4]. However, there are many other native species that do have the capacity for surviving in environments where water is limited, and managers could proactively minimise the supply of water in low water environments using sclerophyllous trees.

Many people advocating the use of species with high tolerances of low rainfall do so failing to appreciate that their use may come at a cost. Some native trees, such as *Allocasuarina littoralis, Eucalyptus calophylla, Eremophila macgillivrayii, Pittosporum phylliraeoides and Myoporum floribundum* show effective stomatal control and efficient water use. However, if water is limiting their growth rates slow to the point where they are ineffective for urban planting.

Similarly species, such as *Acacia melanoxylon* or *Eucalyptus grandiflora,* reduce water use through reduction in leaf surface area, and so would lack the canopy density required of an effective urban tree. The same can apply when considering *A. dealbata* and *A. mearnsii* for urban planting. *A. mearnsii* has a greater capacity for withstanding lower soil water levels than *A. dealbata*, but its canopy density is often too low for effective urban use. Coping with lower rainfall in the urban forest may require more sophisticated and efficient irrigation that balances limited water availability against the need for an effective urban forest canopy.

As climate changes, there will be a demand from landscape architects and urban planners for native winter deciduous trees, which provide the benefits of shade during summer but allow access to light and warmth during winter. Such species are in demand from the perspective of sustainability which seeks to maximise the efficient use of energy and other resources.

However, winter deciduous Australian native trees are relatively rare, with *Melia azedarach, Nothofagus gunnii,* and *Brachychiton acerifolius* being notable examples and even their performance can be poor in some urban contexts. Furthermore a few northern species including some eucalypts, such as *E. clavigera, E. grandiflora* and *E. brachyandra*, are facultatively deciduous during dry periods. Sadly, there has been very little breeding and selection of these native winter deciduous tree species for urban use, and even less research on whether breeding might allow deciduousness to apply to southern winters, expanding the potential use of any of these or related species.

Our island status has spared Australia many of the pests and diseases that have affected native and exotic tree species in other parts of the world, but as conditions warm and dry periods extend there has been an increase in tree deaths from biological causes. During the dry period that has been called the millennium drought, there was a fourteen year period (1997-2010) of below average rainfall and above average temperatures experienced in parts south eastern Australia.

Many older conifers such as *Pinus radiata* and *Cupressus macrocarpa* died, urban populations of *Platanus* x *acerifolia* were deleteriously affected and thousands of the most widely-distributed eucalypt, *Eucalyptus camaldulensis* died.

When this period ended, some trees such as *Ulmus* species recovered and the surviving *E. camaldulensis* rapidly refoliated, but Cypress Canker has been steadily taking a toll on older stressed conifers. There has been an increase in the number of pines succumbing to the fungus *Diplodia pinea* and more recently there have been outbreaks of the exotic insect, Giant Pine Scale. Myrtle Rust has also cut a swathe down the east coast of Australia.

The role of botanic gardens in early detection and in providing information on species' susceptibilities to these pest and diseases is invaluable. Because of the location of many botanic gardens in Australia (near the major cities and ports) they can act to some extent as the 'canary in the mine' as part of early warning systems of climate-related pest and disease attack. This role is more likely to bear fruit as the staff working in botanic gardens are usually well-trained and have expertise in particular species and so are likely to detect unusual symptoms early.

The role of botanic gardens in early detection and in providing information on species' susceptibilities to pest and diseases is invaluable.

There may also be the need for action in relation to insect grazers. As temperatures increase the numbers of insects attacking street trees are likely to rise and the period over which they graze is likely to be extended. Such insect predation could have a devastating effect of individual trees leading to significant increases in tree mortality and a reduction in urban forest canopies. However, very high temperatures and extended heat wave conditions can impact on insect life cycles and survival rates which can significantly reduce insect numbers. This highlights the need for careful monitoring of insect pests and adopting an adaptive management approach to pest management in the urban forest.

There will be tree species that benefit from a warmer drier climate. Trees that may have been restricted in their planting due to frost sensitivity may be considered for planting or planted at an earlier age as the frequency of frosts and their intensity reduces. For species with temperature dependent fruit or seed set, higher temperatures may result in trees that flower but which do not produce fruits which are a nuisance in cities.

For many tree species higher temperatures will allow more rapid and easier tree establishment and growth if water is available, which will be an advantage for municipal street tree planting. The warmer temperatures should also allow more rapid root growth, either from more rapid growth rates or from longer growing seasons. So for newly planted trees, root systems should extend into the surrounding soil more rapidly. This would be beneficial for street trees where rapid early growth and establishment are considered advantageous as trees have an earlier landscape impact and planting would be more cost-effective.

Conclusion

As climate changes and cities expand, the pressure that development will place upon urban trees and forests will increase, but so too will their role in providing environmental services essential to the sustainability and liveability of those cities. The ameliorating benefits provided by trees will be seen as essential urban infrastructure and their economic worth will be established. To capture the major benefits that the urban forest can afford requires a cover of between 30-35% which may be more difficult to achieve as climate changes.

Urban forest managers must have the skill and expertise to achieve such levels of cover and will have many tree selection options available to them, if they are prepared to use the data that are available on the root, foliage and physiological adaptations of many tree species to warmer, drier environments. The role of botanic gardens and arboreta in providing such data over a long period of time and where there is a history of growing species beyond their normal ranges of growing conditions cannot be over-valued.

The role of botanic gardens in providing data over a long period of time cannot be over-valued.

References – Full list on our website

‘A leopard can’t change its spots’ but maybe Melbourne’s Spotted Gums can

James Shugg, Arborist, Royal Botanic Gardens Victoria

It was a breathlessly still autumn morning and I was dangling, perhaps 25 metres above the ground, suspended in the canopy of a large eucalypt. Picking its mature capsules by hand and dropping them into a bag attached to my climbing harness was the relatively less damaging method chosen to collect its seed. The tree was a fine example of the species *Corymbia maculata* commonly known as Spotted Gum.

I paused to take in my surroundings. I was aloft in a big tree standing in the midst of a tall East Gippsland forest. The tree rises above a ridge that is some 300 metres above sea level and yet I couldn’t detect the slightest movement amongst the multitude of gum leaves around me. Stem and branches clad in visually pleasing smooth, purple and grey mottled bark took my eyes on a journey.

This specimen appeared to be largely free of deadwood, broken branches and other structural defects. This is remarkable for a bush tree and is a characteristic that can make the Spotted Gums, and particularly those from certain populations, rather well suited for urban planting.

Stem and branches clad in visually pleasing smooth, purple and grey mottled bark took my eyes on a journey.

I pondered my luck at being employed in the field of arboriculture and in the more specialised area of botanic gardens arboriculture – a job which had delivered us to this agreeable location. My colleague Peter Berbee and I were on assignment for the Royal Botanic Gardens Victoria (RBGV). We were visiting the Mottle Range Flora Reserve 25 km north-west of Orbost. The reserve protects a small, about 1km^2, disjunct population of *C. maculata.*

Our mission was to collect seed from these trees. Our purpose was twofold: firstly to propagate the trees with a view to planting out at the RBGV’s Melbourne Gardens site and secondly, to provide seed for storage in the collections of both the Victorian Conservation Seed Bank, situated within the National Herbarium of Victoria, and the Millennium Seed Bank Project in the United Kingdom.

Peter Berbee observing flowering, 20 July 2015

Why Corymbia maculata*?*

In 2013 the RBGV lost its finest *C. maculata* specimen. This large tree fell as a consequence of the combined impact of the activity of decay fungi in its roots and butt and the tremendous load generated in the tree by windy spring weather. Thus a eucalypt planting opportunity presented itself, but a question arose – did *C. maculata* remain a suitable taxon for planting at Melbourne Gardens?

To answer this question a matrix-based tree selection process was undertaken in conjunction with study for the University of Melbourne's Graduate Certificate in Arboriculture. An initial shortlist of six eucalypt taxa was compiled. The candidate taxa were chosen via reference to literature and field observations with particular focus on suitability to Melbourne's warming, drying climate. The six shortlisted taxa were: *Angophora costata* subsp. *costata, Corymbia maculata, Eucalyptus benthamii, E. bosistoana, E. occidentalis and E. polyanthemos* subsp. *vestita.*

A total of 15 selection criteria were established which represented required aesthetic, biological and functional characteristics. Informed by literature review each taxon was scored according to its capacity to satisfy each criterion. Scores were then totalled to provide a species ranking.

Corymbia maculata ranked first and was therefore selected for planting. The tree met the gardens' aesthetic requirement for a tall, straight and single trunked specimen with attractive bark and a fairly dense shade-providing canopy. It satisfied the biological criteria of local climate suitability, drought tolerance and relatively low susceptibility to pests and diseases. Spotted Gum scored highly against necessary functional criteria for longevity, a balanced crown, strong branch attachments and low volumes of dead wood.

Spotted Gum trunks, Mottle Range Flora Reserve

Information about this taxon is relatively abundant in literature and the exhaustive study of Bone[1] is particularly informative. Bone's paper compared arboricultural traits of 11 Spotted Gum populations including that at the Mottle Range. This provenance compared reasonably favourably, and it was considered an especially appropriate selection from a state conservation perspective because of both the rarity and the small area of the natural occurrence of the taxon in Victoria. In addition, the isolated nature of the stand (the nearest population is 200km away in New South Wales) is mysterious and a source of intrigue – therefore offering thought-provoking interpretive opportunities.

Spotted Gum taxonomy

In their controversial 1995 taxonomic review of the eucalypts, botanists Ken Hill and Lawrie Johnson included the Spotted Gums within the new genus that they formally raised – *Corymbia*. The Spotted Gums which had been known collectively as *Eucalyptus maculata* were divided into three species – *Corymbia maculata, C. henryi and C. variegata.*

The debate continues and South Australian eucalypt researcher Dean Nicolle contends that *C. henryi* is actually the same as true *C. maculata* and that most of the established so-called *C. maculata* plantings in Melbourne are in fact *C. variegata*[2]. Nicolle writes in his soon-to-be-published book, 'Eucalypts for Planting', that *C. maculata* is better suited to urban planting because its relatively compact crown of shorter branches is structurally superior to the slender and spreading canopy of *C. variegata.*

The Mottle Range provenance of *C. maculata* has potential to be a useful addition to the plant palette of landscape designers for use in climate suitable areas of Melbourne and regional Victoria (and indeed elsewhere). It may produce a structurally superior tree in comparison to earlier Spotted Gum plantings in Melbourne.

Seed is now being propagated at RBGV's nursery at South Yarra. It will be interesting to see how plantings perform. If more local tree planters were to make selections informed by provenance data then, unlike the fabled leopard that cannot change its spots, the trees that comprise Melbourne's Spotted Gum population might do just that.

References – Full list on our website

James Shugg hand picking capsules & Peter Berbee, a man on the way up, Mottle Range Flora Reserve

The science section

Compiled by **Brett Summerell**, Director, Science and Conservation, Botanic Gardens & Centennial Parklands

Brett Summerell

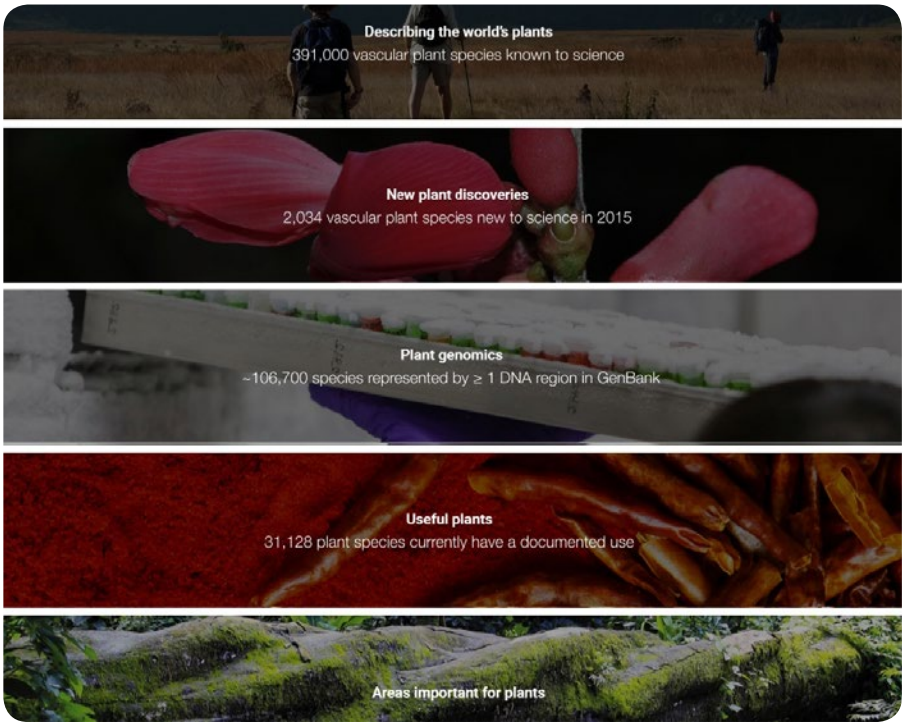
First word

In this section of the magazine we highlight some of the academic research happening both in Australia and internationally of relevance to botanic gardens. Those of us who work in botanical and conservation research hope to make our science more accessible to the community at large and hope what follows will help you communicate this core function in your work too. If you have science information for inclusion in future issues or see something that you think should be highlighted (or needs clarification) please drop me a line at brett.summerell@rbgsyd.nsw.gov.au

State of the world's plants

The Royal Botanic Gardens Kew has released a very comprehensive report on the state of play in documenting the world's plants, outlining the global threats to plants and providing a summary of the policy and international trade, particularly with respect to CITES and the Nagoya Protocol.

In the section on describing the world's plants, there are very useful summaries of the numbers of species described worldwide in 2015 and estimates of the total number of world's plants. There are estimates of the number of threatened species and coverage of the impact (or likely impact) of invasive plants, diseases, climate change and land cover.



Some of it is confronting reading outlining the many ways in which plants are under threat globally but it is essential reading for those of us involved in protecting plants and explaining their importance to the community.

More information: The whole report is freely available and can be downloaded at: State of the Worlds Plants plus there is a range of other information available on the website.

Surviving mass extinction by eating seeds

A paper by Derek Larson and others in the journal Current Biology has provided evidence that bird ancestors adapted to eating seeds of plants were better able to survive the mass extinction events that occurred in the latter half of the Cretaceous period.

The authors did this by combining data from analysis of fossils of teeth and teeth serration patterns (and the dietary behaviour implied by that) in bird-like dinosaurs with evolutionary tree-of-life information of modern birds.

> They postulate that the last common ancestor of all birds alive today was a beaked seed-consuming bird.

They postulate that the last common ancestor of all of the extant birds alive today was a beaked seed-consuming bird. They explain that these types of birds would have been better able to survive long periods of time with reduced sunlight (which caused the mass extinction in larger forms of dinosaurs). Because plant seeds played a critical role in the survival of these birds through this very difficult period, these creatures could then flourish and evolve when conditions were more favourable.

More information: Dental disparity and ecological stability in bird-like dinosaurs prior to the End-Cretaceous mass extinction. Derek W. Larson, Caleb M. Brown and David C. Evans. Current Biology 2016; DOI.

A 'new' tree of life

We all try to categorise things – whether it is books, music or films – or the myriad of life that surrounds us. Since Charles Darwin started to discuss the relationships between different groups of organisms till now, scientists have invested much time in defining and describing these relationships.

Until relatively recently this focussed on those organisms we could see, even if we had to use culturing techniques and a microscope, or tried to relate one to another via their physical features.

Molecular biology has been a paradigm changer with respect to this and now with genomics techniques it is to possible to both get vast quantities of data plus get data on all those 'hidden' organisms present in soil, the ocean or just ubiquitously around us.

Sampling the DNA of over 3,000 species Laura Hug and colleagues have published an expanded tree of life. Unsurprisingly much of the diversity is in those microorganisms that cover all the niches on the planet, particularly in those species difficult (if not impossible) to isolate, culture and grow.

Ourselves, other animals and the plants we love, form only a small part of the tree and clearly aren't the dominant life forms on the planet. It is likely that, as tools to analyse genomes improve and become cheaper, much more diversity will be discovered and the interesting question of how organisms like plants interact with the diversity of microorganisms in soil, in the atmosphere or even in or under the leaf surface, will begin to be elucidated. More information: *A new view of the tree of life.* Laura A. Hug et al. *Nature Microbiology* 2016 – 16048; doi:10.1038/nmicrobiol.2016.48

Ash dieback

The existence of Common Ash *Fraxinus excelsior*, a common and important tree species throughout Europe, is currently under extreme threat due to the presence of an introduced disease, ash dieback.

This disease is caused by a fungus *Hymenoscyphus fraxineus* that was introduced into Europe in the 1990s, most probably from East Asia. The fungus infects via leaves and then invades the stem, causing dieback and then killing the tree. Large numbers of trees across Europe have been infected. The pathogen easily spreads and there appears to be no effective control by the way of fungicides.

The Common Ash forms a significant component of ecosystems throughout many parts of Europe and thus its decline and potential disappearance from these ecosystems could have a devastating impact on biodiversity, particularly on those species that are dependent on the tree.

> The decline and potential disappearance of the Common Ash could have a devastating impact on biodiversity in Europe.

A recent paper by Landolt and others from the Institute of Integrative Biology at ETH Zurich provides a good overview of the disease and also outlines how evolutionary ecology research could aid in the fight against the disease.

There appears to be variability in the level of resistance of individual trees to the pathogen, with some individuals tolerant and some very susceptible. An understanding of the genetic basis of this would be desirable, as would be identification of a molecular marker to test individuals for their tolerance.

They also discuss the vexed question of whether it is better to remove or leave diseased individuals that might show some symptoms but do not die. That is, is it better to encourage evolution of resistance or to reduce the spread of the pathogen? There is no easy answer to this and it parallels issues common to a number of invasive diseases around the world – including myrtle rust invasion in Australia.

More information: J. Landolt, A. Gross, O. Holdenreider and M. Pautasso (2016) Ash dieback due to *Hymenoscyphus fraxineus*: what can be learnt from evolutionary ecology? Plant Pathology Doi: 10.1111/ppa.12539.

Citizen science time!

Citizen science programs are becoming more and more commonplace.

FungiMap is a real progenitor in citizen science programs, not only in Australia, but also internationally. Information on the distribution of common Australian fungi is provided by enthusiasts to build up information of the ecology of these species. More information at Fungimap.

Hollows as Homes: This project works with the community and land managers to assess tree hollow availability, as hollows are an important but limited resource for wildlife in urban and agricultural areas. You can document the hollows in trees in your area, what animals are using them and other information relating to them. For more information go to: Hollows as Homes.

I also mentioned **ClimateWatch** in the last issue – it is a program of climate observations coordinated by Earthwatch – again, a great citizen science initiative.

Systems for Indigenous knowledge stewardship in Australian seed bank institutions

Mark Shepheard, Australian Centre for Agriculture and Law, University of New England

Introduction

Botanical institutions are strategically positioned as cultural institutions providing the physical space and information systems to enhance people-plant interactions and be a hub for social, cultural, economic and environmental knowledge about plants. This represents a shift of institutional paradigm from repository for objective scientific data alone to sites of interchange for botanical knowledge in partnership with communities.

The stewardship of traditional Indigenous knowledge by botanical institutions is a social wellbeing concern for Indigenous communities because it involves negotiation of cultural impacts within the community[1].The arrangements for the stewardship of traditional Indigenous knowledge by botanical institutions are part of a partnership that should allow for access to plants and knowledge. This should be with support of the relevant Indigenous community and demonstrated by the granting of formal access and/or social licence.

The partnership is also, through networks, likely to be impacted by a range of other stakeholders, including governments, land owners, donors/supporters, media, and conservation and/or Indigenous rights interest groups. My analysis emphasises that recognition of socio-cultural wellbeing in the strategic discourse and its implementation into botanical institution practice is the way to foster productive and effective partnerships including traditional Indigenous knowledge.

Partnerships about plants and knowledge

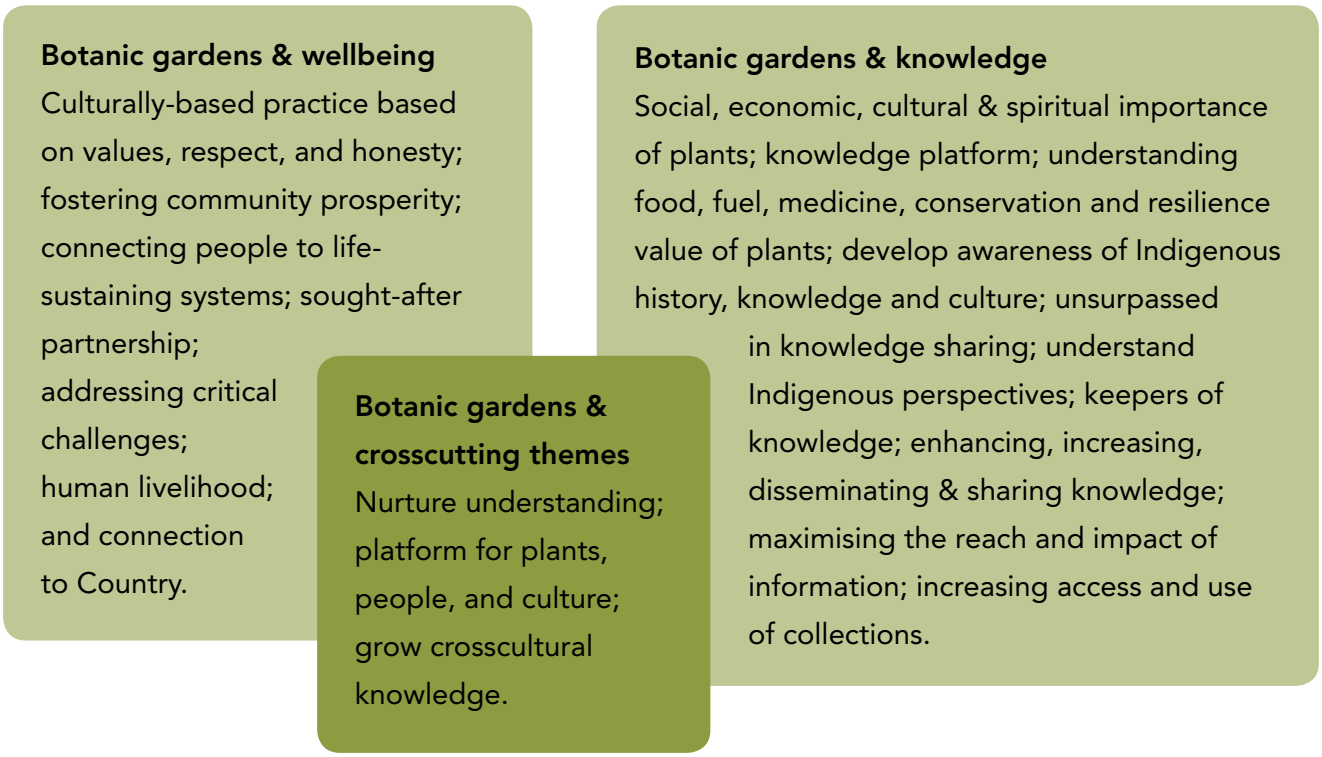
Partnership involves a relationship wherein the partners agree to work together for mutual benefit and are accountable to each other for performance. Ideally, the relationship will be collaborative in nature with a levelling out of the balance of power between the partners.

Following the Convention on Biological Diversity and its Nagoya Protocol, the relationship between botanical institutions and an Indigenous community can be said to involve access and benefit-sharing arrangements made on fair and equitable terms.

In a formal sense such expectations may be satisfied by seeking and obtaining prior informed consent with access and benefit-sharing arrangements in place and documented. However, social relations are rarely so neatly characterised.

Botanical institutions, socio-cultural performance and knowledge sharing

Botanic gardens, seed banks, plant banks, and/or herbaria define their approach to partnership largely through strategic plans and performance reports. These show how the institution sees itself, what its role and obligations are, and the performance level that has been achieved in line with expectations. Two broad yet overlapping stories are identified: the first centres on community wellbeing and a second about knowledge collection and exchange. The figure below illustrates the discourse associated with each of these stories.



The story arising out of this discourse places institutions at the hub of knowledge collection and dissemination as they discover and improve general understanding about people-plant relations and wellbeing. Botanical institutions in this story are:

- Culturally-based where decisions and actions are based on values, respect, and honesty;
- Nurturing understanding about importance of plants (in social, economic, cultural, and spiritual terms);
- Fostering community prosperity through connecting people with life sustaining systems;
- A platform for making connections between plants, people and culture;

- Sought after for strong partnerships;
- Understanding how plants help humanity to address critical challenges (species important for food, fuel, medicine, conservation, environmental change);
- Working with communities about the beneficial impacts of plant diversity for human livelihoods;
- Developing better awareness of Indigenous history, knowledge and culture;
- Connecting to country, understanding Indigenous perspectives, and growing cross-cultural knowledge;
- Keepers of collections and knowledge, and unsurpassed in knowledge sharing;
- Maximising reach and impact of information; and
- Increasing access and use of collections.

The botanical story with institutions at the hub of knowledge collection and dissemination may be compared to the strategic performance story projected by the museum sector. For example, in its Annual Report 2014-15, the National Museum of Australia identifies:

- Items and knowledge that are cared for in a culturally sensitive manner;
- Recognition and respect for Indigenous rights to access, maintain, and control use of their cultural heritage (inclusive of traditional knowledge);
- Acknowledgement of Indigenous cultural intellectual property; and
- Transparent processes regarding engagement with Indigenous people and their culture.

The museum story shows decolonisation of institutional practice[2]; moving away from the Western value systems encoded in institutional narratives to recognition of where knowledge comes from, how people and culture are represented, and whose voice speaks[3]. This story represents a shift in practice toward collaboration with Indigenous Australians on equal terms[4]. This involves responsibility to do more than continue to propagate a Western institutional world view[5]. Museums have recognised the strategic and operational imperative for cultural sensitivity; that ethical engagement with Indigenous cultural concerns cannot be ignored and will not go away[6]. Museums operate within an ethical context to engage and interact with Indigenous communities about traditional knowledge and cultural sensitivities.

Alternately, botanical institutions are translating objective scientific practice into a new function of being the source of expert knowledge about plant and people interactions for society at large. This interpretation comes with different ethical risks and accountabilities that are likely to impact on institutional operations. If botanical institutions are to develop cultural collaboration in their own context, there is a need to reconfigure strategy and operations. This will necessarily draw on experience of other disciplines[7], to place Indigenous knowledge and cultural sensitivity as an equal part of knowing about plants in botanical science. The following section reviews this accountability concern.

Linking strategy to practice for accountability

Botanical institutions are strategically developing collections that seek deeper engagement with Indigenous cultures and traditional knowledge (TK). Performance in these emerging areas of responsibility remains without a sector-wide culturally-sensitive approach to engage with Indigenous people and their knowledge about plants. There is an accountability gap between the strategic institutional discourse and operations. Strategic discourse recognises traditional Indigenous knowledge as an important part of complete plant collections and information sharing systems. In contrast operations appear not to follow through with this strategic intent. See the table below.

Operational perspectives about traditional Indigenous knowledge and its management in seed banks

QUESTION	RESPONSES
What processes are in place regarding the collection of traditional knowledge in the field?	No formal programs as part of seed collecting or research; no formal processes only informal transfer of traditional knowledge that is not documented.
Are distinctions made between functional ecological knowledge compared to culturally sensitive, sacred, or secret information?	Sensitive information is not collected; knowledge only collected in consultation with traditional owners; no institutional policy but the extent of permission is covered in the permit process; issues are captured in access agreements.
Are collection and storage processes informed by any conventions, treaties or other legal sources of rights over knowledge?	Collection requires land owner approval, either by government permit or private approval; collection follows access agreements; collection and storage is done on a scientific basis; research and collaboration agreements specify who the IP and TK belongs to; compliance with permits and access and benefit-sharing arrangements; ITPGRFA.
What protocols exist related to the storage of traditional knowledge once collected?	These are needed or else we will not be given the privilege of discovering and documenting it; TK is noted in the datasheet where it can be identified.
What access arrangements are in place related to use of traditional knowledge associated with further use of a seed for research or as an input to commercialisation?	Commercialisation arrangements to be negotiated on a case by case basis with traditional owners; verbal agreement sought about whether information can be used again (shared).
What formal agreements or licensing arrangements exist related to further use of stored material?	Individual protocols, agreements, or contracts with traditional owners; compliance with access and benefit sharing; material transfer agreement when transfer is a permitted use of Indigenous collected material.
Is there consultation with Indigenous peoples regarding access to traditional knowledge?	Only when collecting on Aboriginal land; through joint management agreements but not directly about particular seeds; discussion with traditional owners about access to information and records; most collection occurs in national parks or on government land and guidance is sought from those managing the site about cultural sensitivities; access permits under direction of an Indigenous guide; information likely to be documented with a specimen unless it is specifically excluded; consultation with elders prior to publication or sharing of TK.

The responses show that awareness of accountability for traditional Indigenous knowledge in the day-to-day operations of several botanical institutions is limited. The prevailing view is that responsibility for traditional Indigenous knowledge rests with Indigenous people. It is to be managed through access and benefit sharing arrangements, such as permits, prior informed consent, and material transfer agreements. These are negotiated on a case-by-case basis.

Undoubtedly, unique negotiations are appropriate for each case – this is not in question here. Instead, I challenge the operational reluctance to incorporate accountability for traditional Indigenous knowledge into the collections management practice of botanical institutions.

In this reluctance, we see how softer social considerations can be marginalised in pursuit of objectivity within tight-knit institutional settings[8]. Although appearing peripheral to operations, the social and cultural issues surrounding traditional knowledge are far from trivial. They translate into material consequences if performance does not meet anticipated standards. For example:

- Funding allocation tied to culturally sensitive stewardship of traditional knowledge;
- Effectively tracing links between genetic resources, traditional knowledge and its use;
- Providing certainty about the terms of access to genetic resources and knowledge;
- Claims of misuse or mismanagement of traditional knowledge;
- Establishing trusted botanical collections (a type of accreditation status);
- Minimising confusion when dealing across jurisdictions; and
- Demonstrating institutional competence relative to relevant policy, administrative, industry, and/or community principles, standards or guides.

A basis for partnership and risk readiness in botanical institutions

The variation between museum and botanical institution discourse identified above and the gap between strategic and operational discourse within botanical institutions reflects a differing operating context.

Operational guides exist that can help (for example the NintiOne Aboriginal Knowledge and Intellectual Property Protocol; The Territory NRM Indigenous Ecological Knowledge Manual; and, the AIATSIS Guidelines for Ethical Research) but they need to be formally integrated in a way that links strategic discourse to practice.

Achieving this relies upon a shift in the underlying institutional accountability paradigm to view traditional Indigenous knowledge as an equal and valid part of plant collections. Scientific knowledge systems may then be transformed in the context of people, their traditions and ideas.

This flags the need for a more robust institutional accountability model to ensure the stories we see in strategic plans and annual reports are effectively linked to operations. I propose that this may be achieved through knowledge stewardship underpinning strategy and practice that helps establish a fair and equitable approach to the management of all knowledge about plants.

In this view, socio-cultural wellbeing sits alongside ecological wellbeing as context for institutional performance, with the following dimensions:

- Respect for cultural norms,
- Dialogue and alliance building,
- Legitimacy as a focus for strategy and practice, and
- Relationships based on trust.

Developing these enables botanical institutions to collaboratively define their traditional knowledge stewardship accountability in partnership with Indigenous communities. This is more likely to meet expectations of partnerships that seek honesty, trust, respect, legitimacy, awareness and commitment from relationships with botanical institutions.

References

Full list on our website

Can temperature sensitivity during germination help predict global warming vulnerability? A case study of Western Australian banksias

Anne Cochrane, Department of Parks and Wildlife, Western Australia

Background

The climate is undergoing substantial change in South West Western Australia. Since 1910 temperatures have increased by around 0.8°C and total annual rainfall has declined over the past 50 years, mostly in late autumn and early winter. In the future, and with 'business as usual', temperatures are expected to continue to increase by 3-4°C and rainfall to decline by 10-20%.

Under a high greenhouse gas emission scenario for 2070 (emissions scenarios describe future releases into the atmosphere of greenhouse gases, aerosols and other pollutants) it appears likely that species distributions will change and biodiversity will be negatively affected as the coolest and wettest climate zones of the South West contract. Plant species confined to the more southerly areas of the region may well be at great risk.

Seed germination is vital for the persistence of plant species, in particular those that rely on seeds for regeneration. This stage of a plant's life cycle is strongly influenced by temperature and moisture, and small changes in these environmental conditions during the critical transition from seed to seedling can affect plant distribution and survival.

Seed germination is strongly influenced by temperature and moisture, and small changes in these environmental conditions during the critical transition from seed to seedling can affect plant distribution and survival.

Favourable conditions are needed for successful recruitment; changes in germination behaviour, including germination failure, can lead to local population extinction. As temperature plays a critical role in regulating seed germination, species that rely solely on seed for regeneration (i.e. 'obligate seeders' or those species killed by fire with no lignotuber for resprouting) should make good 'indicator species' for identifying the impact of warming climates on germination.

Investigation

The objective of this study was to determine the sensitivity to germination temperature of seeds of all 38 Western Australia endemic obligate seeder *Banksia* (Proteaceae) species. Banksias are an iconic group of species; these woody shrubs and trees are a vital part of the food chain in native bushland and of economic importance to the horticultural and cut flower industries, and hence worthy of study. Two theories were explored in this study:

1. That warmer temperatures would alter the timing and final percentage of germination; and
2. That species with more restricted distributions (reflected in their listing as conservation-dependant species) would be disproportionately affected by higher temperatures.

Western Australian banksias are generally confined to the cooler south-western portion of the South West, where rainfall is greater than >250 mm per annum. Plants hold their fruits in the canopy in woody cones (this form of seed storage is called 'serotiny') with seed dispersal generally triggered by fire, with heat inducing the opening of cones.

Collage of *Banksia* species used in the investigation.

For most of the obligate seeder species, recruitment is limited to the post-fire period, and generally occurs in response to the cool, wet conditions of late autumn and winter, with some exceptions. The obligate seeder *Banksia* species are considered to be vulnerable to altered environmental conditions, including too frequent fire, due to their lack of resprouting ability and a long juvenile period before flowering and fruiting.

Methods and materials

Fruits were collected from wild populations and seed extracted from the woody cones by burning the cones until the follicles opened, then wetting and drying the cones until seed released. Once released, banksia seeds are highly viable and germinate freely when given sufficient moisture and appropriate temperature.

Burning banksia cones to stimulate seed release. Photo: Andrew Crawford

A bi-directional temperature gradient plate (TGP) with multiple temperature combinations between 5 and 40°C (constant and fluctuating) was used to build a profile of seed temperature requirements for each species, and thus identify upper and lower thresholds for germination. Seeds were sown in dishes on agar substrate and germination scored every two-three days for six weeks. Percentage germination was calculated as the percentage of filled seeds that germinated within the incubation period in each temperature cell of the TGP (49 temperature combinations per species) and the mean time to germination for seed in each cell was recorded.

Temperature gradient plate used to investigate temperature thresholds for seed germination, with inset of individual temperature cells.

Climate data for seed collection sites were obtained from WorldClim, a set of global climate layers with a spatial resolution of approximately 1 sq km. Climate variables for 'current' conditions came from averages for the period 1950-2000, and future projections for the same variables from the high greenhouse gas emission scenario (RCP 8.5) for 2070 from the Hadley Centre Global Environment Model version 2 (HADGEM2-ES).

The models were designed to incorporate variability in climate by considering mean monthly minimum and maximum temperatures (including average monthly rainfall) forecast for each specific seed source site to provide a more 'realistic' prediction of germination response to changing temperature conditions.

These data were then used to model the impact of increasing temperatures on future germination providing a germination response for each month of the year. The model that gave the most accurate predictions for germination performance under current and future temperature conditions incorporated both the mean and amplitude of temperature fluctuations experienced by seeds on the TGP.

Results and discussion

The data from the germination experiment show that species vary in the temperature requirements that produce the highest level of germination in the shortest possible time ('optimal' germination). Many of the species displayed broad tolerance for germination under a range of temperature conditions, greater than expected based on climatic conditions in their current distributions alone.

Most species reached 100% germination in at least one cell of the plate over the six week period, with the exception of *B. coccinea* and *B. seminuda* (60%) and *B. quercifolia* and *B. brownii* (90%). Germination was generally optimal around the temperatures currently experienced in May. In South Western Australia, this is traditionally the timing of the break in weather, when autumn rainfall commences and the soils are still relatively warm. These conditions generally trigger germination of seed released from woody cones.

Mean temperatures producing highest germination in the shortest possible time ranged from 10.4°C (*B. dryandroides*) to 25°C (*B. seminuda*), with an overall average of 16.2°C; temperature amplitudes ranged from less than 1°C (temperatures virtually constant) to 22.6°C (large temperature fluctuations). The average temperatures for germination were related to latitude from where seeds were sourced. The average time to complete germination at the optimal temperature regime ranged from 8 (*B. leptophylla*) to 26.7 days (*B. coccinea*) with an average of 15.5 days for all collections combined.

The most common prediction for germination response in the future was for levels of germination to increase slightly during the cooler winter months (Jun-Aug) compared to that predicted under current winter conditions. Northern species such as *B. burdettii, B. hookeriana, B. lanata, B. lindleyana* and *B. sceptrum* and southern species such as *B. aculeata, B. baueri, B. blechnifolia, B. caleyi* and *B. coccinea* responded in this manner to the forecast warmer temperatures.

A further suite of species responded to warmer temperatures by narrowing the temperature window for maximum germination over the winter months suggesting these species favoured cooler temperatures for germination. In the north, examples of this kind of response included species like *B. ashbyi, B. laricina, B. telmatiae* and *B. victoriae*; in the south, *B. baxteri, B. praemorsa, B. pulchella* and *B. speciosa* exhibited these responses.

A third response was provided by species that showed relatively little decline in germination under the forecast warmer temperatures. This response was seen in two critically endangered species with restricted southern distributions (*B. brownii* and *B. verticillata*) as well as in a range of other commonly occurring species with larger geographic distributions (e.g. *B. media* and *B. occidentalis*).

Overall, the models predicted that rising temperatures associated with climate warming are unlikely to adversely affect levels of seed germination in wild populations of many Western Australian obligate seeder *Banksia* species per se. In fact, for some species, there may even be a benefit from new environmental conditions as it may lead to more frequent conditions for recruitment (i.e. increased germination during the cooler months of the year relative to current expectations).

Actual declines in germination are expected in only one species (*B. dryandroides*) as the region warms up. This species is a relatively short range endemic with a predominantly coastal, east-west geographic distribution of less than 170 km, but not yet considered of conservation concern, despite populations being generally small and fragmented. A closer look at the conservation status of this species may be required in the future in the light of these current results.

The models predicted that the timing of maximum germination for many species would advance from late autumn into early winter, as the start of germination is delayed by temperatures above the current temperatures generating maximum germination. In seasonally dry ecosystems, germination timing is critical when moisture is a limiting factor.

Delayed germination may put seedlings closer to the summer dry and more likely to dry out and die. It may also mean greater competition from quicker growing species more able to cope with new conditions. Southern- and northern-distributed species varied little in their temperature sensitivity for germination and contrary to expectations, conservation-listed species with more restricted distributions were not considered more sensitive or disproportionately affected by forecast temperature change.

For two rare species (*B. brownii* and *B. verticillata*), the models predicted that germination will alter little under the forecast warmer conditions, and neither the timing, nor the percentage, of germination is predicted to change.

Temperature should not be viewed in isolation

Although these results are encouraging, there are many other environmental factors that influence seed germination that were not assessed in this study. For instance, moisture is a key limiting factor for germination, and in the typically winter-wet, summer-dry climate of the region germination for many plant species coincides with the cooler moist conditions of autumn-winter. However, rainfall in the region is forecast to decline by 14-29% by 2070.

The expected delays in germination, in conjunction with these forecast rainfall declines, will place seedlings of most species closer to a drier summer dry and in greater danger of desiccation. Furthermore, changes in fire regime associated with climate change include more frequent and more intense fires and these changes have the potential to lead to loss of serotinous species such as Banksia.

Species may persist under sub-optimal climatic conditions, or a narrowing of the germination window, but high mortality of seedlings post-fire due to reduced rainfall may gradually erode population size. The added stress of diseases such as Phytophthora dieback disease is a further worry for plant persistence.

Finally, inferring threat on the basis of results from only one population needs to be viewed with caution as germination patterns can vary along environmental gradients and from population to population within a single species. Failure to consider individual population responses can potentially over- or under-estimate a species capacity to cope with new conditions.

Conclusions

How seed are going to regenerate under warmer temperatures is an important global issue, pertinent to agriculture, horticulture and biodiversity conservation alike. Gaining knowledge of seed performance under a range of new environmental conditions will assist with understanding how climate change may affect plant regeneration into the future. If biological data (such as seed germination) is linked with historical and forecast seasonal temperature data from climate modelling it can help set priorities for the development of more effective management strategies that may reduce the chances of climate-driven extinction.

Reference

To read the full article please refer to Cochrane A. (2015) Can sensitivity to temperature during germination help predict global warming vulnerability? *Seed Science Research* **26**, 14-29.

PlantBank seed production area driving ecological restoration at Mount Annan

Peter Cuneo, Manager Seedbank and Restoration Research **Jordan Scott**, Supervisor, Natural Areas and Open Space, and **Katharine Catelotti**, Technical Officer, PlantBank Australian Botanic Garden Mount Annan

Seed technology is the key to achieving effective on-ground ecological restoration outcomes. As the conservation role of botanic gardens continues to evolve, we have seen its increasing involvement in species-based threatened plant conservation and the management and restoration of natural areas. In Australia, one of the major limitations to ecological restoration is a lack of suitable native seed. The wealth of seed and botanical expertise held within botanic gardens makes us well situated to play a key role in supporting and developing technology that enables landscape scale restoration.

At the Australian Botanic Garden, Mount Annan (ABG) we are faced with the daunting task of restoring native woodlands following control of a 'horticultural escapee' – the highly invasive African Olive tree *Olea europaea* subsp. *cuspidata*. The rapid spread of African Olive in the Cumberland Plain region of western Sydney in recent decades is now a significant conservation concern, with the critically endangered Cumberland Plain Woodland (CPW) which occurs at ABG particularly vulnerable to olive invasion.

The wealth of seed and botanical expertise held within botanic gardens makes us well situated to play a key role in landscape scale restoration.

African Olive is able to form dense forests shading out native species, with the original dense olive infestations at ABG covering 80 hectares. Over 40 hectares have now been controlled at ABG using mechanical mulching ('forest mowing') techniques. However the subsequent challenge was accessing sufficient local native seed to kick start the restoration of these 'ground zero' sites where very little native plant diversity remained.

Faced with this shortage of native grass seed, a successful NSW Environmental Trust application provided the funding support to develop a 1500 sq metre native grass seed production area as

part of the Australian PlantBank landscape. The key objective was to grow high quality weed free native grass seed (of known germinability) to direct sow on degraded African olive sites.

Recent research (Cuneo & Leishman 2015) has indicated that a 'bottom up' approach restoration using native grasses as an early successional stage has potential to restore these transitional landscapes and achieve a trajectory towards CPW.

The seed production area was established by tube stock planting of four key local grasses: Plume Grass *Dichelachne micrantha*, Weeping Meadow Grass *Microlaena stipoides*, Windmill Grass *Chloris truncata* and Tussock Grass *Poa labillardieri*. Seed was wild source collected from CPW and grasslands within ABG, which provides a reference vegetation type and condition to guide restoration.

> The total output over the 2014/15 summer was an impressive 118 kg of seed material harvested.

The seed production area which was irrigated and fenced to exclude rabbits was highly productive, even during the first summer season. Both hand and mechanical harvesting were used, and the total output over the 2014/15 summer was an impressive 118 kg of seed material harvested. All seed batches were germination tested at PlantBank which indicated a total output of over 13 million viable seeds from the first harvest season!

Windmill Grass and Plume Grass (distant) produced a heavy seed crop for onsite restoration.

Taking the seed into the landscape

Direct seeding can be a highly effective way to reintroduce native plant diversity, but requires large volumes of seed. A decision was made at ABG to focus the direct seeding into a series of cultivated two metre wide strips in an effort to create an 'in situ' seed production area rather than

Mechanical harvesting *Microlaena* seed using 'Grass Grabber'.

apply seed more broadly across 40 hectares. These seeded strips could then be managed in a similar way to surrounding cleared areas with broadleaf selective herbicide and slashing.

Seeded grass strips were prepared using a small track machine with surface tilling attachment to provide good soil/seed contact. Seed material (seed/stalks) were combined with compost and sand and then hand broadcasted. In an effort to create an 'in situ' seed production area and robust native grass populations, harvested grass seed was then used to high density (up to 3300 seeds/m^2) direct sow a total of 5km x 2m wide strips throughout five hectares of cleared African olive sites at ABG in March 2015.

Favourable conditions during autumn 2015 resulted in excellent field germination, with established seedling densities of up to 608 seedlings/m^2 observed after 10 months. The combination of surface tilling and dense sowing rates has resulted in a dense and competitive grass layer, however some further broadleaf weed control along the strips will improve long term grass density and establishment.

In-field germination of direct sown native grass seed at cleared African olive site ABG.

These native grass strips will provide a 'nucleus' grass seed source for these degraded areas, maintaining soil stability, improving ecological resilience and accelerate the regeneration of these degraded areas.

Seed production areas will continue to play a significant role in providing a sustainable source of native seed for restoration projects. This project is a good example where botanic garden horticultural and seed technology skills, have delivered positive on-ground ecological restoration results.

This NSW Environmental Trust project has also relied significantly on working with industry partners, Greening Australia, Cumberland Plain Seeds and Australian Land & Fire Management who bought additional technical expertise as well as on-ground implementation.

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For more information see EMR Project Summaries.

Direct seeding Australian trees and shrubs: lessons learnt over 25 sowing seasons

Graham Fifield, Senior Project Manager, Greening Australia
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Introduction

Direct seeding is a vital component of our mission to revegetate the Australian landscape with trees and shrubs. Direct seeding is a technique for sowing seeds directly into the soil bypassing the need for pots, potting mix, nursery irrigation and planting. In a single day an experienced direct seeding operator can sow the equivalent of 10,000-20,000 plants at a fraction of the cost of planting.

This article briefly summarises, from humble beginnings, the experience of the Greening Australia Canberra hub and the lessons learnt from 25 years of direct seeding in the temperate grassy woodland belt of south-east NSW. Of particular note is the ability to capture, store and interrogate data on direct seeding, due to the long lag times between sowing and the mature stands of vegetation which result.

> Direct seeding is a technique for sowing seeds directly into the soil bypassing potting and planting out.

While the specific challenges of direct seeding vary across land use, vegetation type and climatic zone, the lessons described should be broadly applicable across much of Australia. The article concludes by reflecting on where direct seeding could be improved in the future.

A brief history of direct seeding

To my knowledge the first direct seeding machines were designed and built in South Australia in the late 1980s. They were the Rodden tree seeders. In 1991 our Canberra office purchased the fifth of these machines and our first trials began in the following spring. Since this time it is estimated that 12,500kms of tree lines have been sown in south-east NSW distributing 3.2 tonnes of seed back into the local landscape. This article draws on our experience primarily with the Rodden III tree seeders, which were renamed Burford tree seeders approximately 15 years ago. We have owned five iterations of these machines.

Precise seed placement

The basic design of the Burford seeder is to create a weed free, reduced fertility and mineral soil seed bed. The top 50-150mm of soil is turned over and to one side creating a furrow approximately 200mm wide. Larger seeds (typically Fabaceae) are placed at a depth of 20-40mm, while fine seeds (typically Myrtaceae) are then dropped into a fine tilth of soil 0-10mm deep before a press wheel ensures good seed-to-soil contact. The ability to place native seeds of different sizes (these vary by several orders of magnitude) at different depths within the soil profile is vital.

There are still many machines residing in Landcare and regional natural resource management sheds which do not have this capability, often with highly variable and inconsistent results.

Here the large seeds are dropped into a slot (left of image) before being covered over by soil disturbed by two cultivating bars. The fine seeds are then dropped into the fine tilth created on the surface. A press wheel (not shown) ensures adequate seed to soil contact.

The evolution of seeding rates

The initial seeding rates were 400 grams per kilometre and the result was often an undesirable thicket of dense vegetation. From the mid 1990s the seeding rate was reduced to 260 grams per kilometre, comprised of 200 grams of fine seed, and 60 grams of large seeded species. The median stem density that resulted from this was 0.4 plants/metre, or expressed another way, one plant every 2.5 metres[1]. In 2012 this rate was further reduced to 200 grams per kilometre, comprising 150 grams of fine and 50 grams of large seed.

It is worth considering that this represents approximately 30 fine seeds and three large seeds sown per metre, which is a useful way of visually assessing establishment rates. The question of 'how many eucalypts are enough?' is a fascinating social and ecological question, particularly in the context of the Whole of Paddock Rehabilitation project[2,3] and the fact that eucalypt seed represents approximately half of the cost of direct seeding. This is currently being researched by an honours student at the Australian National University.

Machinery advances

Direct seeding machinery for trees and shrubs remains a boutique industry in Australia, with perhaps only 100 machines ever constructed across the country. As a result most machines borrow heavily from agricultural equipment, often with unsatisfactory results. For example in the original Rodden III seed box, fine seed would literally leak out from between the yellow fluted cogs.

Direct seeding machinery for trees and shrubs remains a boutique industry in Australia, with perhaps only 100 machines ever constructed across the country.

The rate of large seeds dispensed was also very difficult to calibrate. The introduction of the Aitchison seed metering system together with Zero-Max variable gear boxes, greatly improved the control of seeding rates, seed retention and seed placement.

Using GPS technology to capture meaningful data for monitoring

In 2010 a GPS unit borrowed from the fitness industry, a Garmin Forerunner 305, was introduced into our direct seeding operations. It was a simple, easy to use GPS which can display the distance travelled, average speed and current speed (vehicle speed is a useful proxy for a range of site conditions such as soil type, slope and vegetation cover). This allows us to accurately determine the distance we have seeded, a huge advance over the vehicle trip meter, with important consequences for later monitoring.

GPS units have also allowed us to create a procedure to track seed usage across multiple vehicles, machines and operators – another important step to ensure consistency and reliability of seeding rates. The system devised uses a combination of a GPS alarm (every 2kms), pre-weighed batches of seed (in multiples of 2kms) and a simple method for placing a required volume of seed into the seed box (kitchen measuring cups). Inspections and modifications can be made to the machine each time the seed box is filled, seeding rates can be adjusted on the fly, and seed wastage or 'leftovers' have been virtually eliminated.

Inspired by field sheets developed by the Murray Catchment Management Authority (now Local Land Services), we also capture many of the site variables that may affect the success or density of direct seeding for later monitoring. In brief these include: the volume of seed sown, distance travelled, dominant groundcovers, presence of herbivores, condition of fencing, weather conditions, soil type, slope, number of herbicide applications and the effectiveness of the herbicide.

Eucalypt seed size is much less important than the number of seeds

In 2010 a study of direct seeded sites by Ian Rayner highlighted the dominance of certain eucalypt species and the consistent absence or low numbers of others. When we compare these results with the number of seeds per gram for each species it is clear that that the number of seeds hitting the ground, rather than the size of those seeds, had the greatest effect on the chance of establishment.

For example, when equal weights of two species are sown at a site, a tree such as Blakely's Red Gum *Eucalyptus blakelyi*, with 687 seeds per gram has perhaps six to nine times more chance of producing an adult tree than Red Stringybark *E. macrorhyncha*, which has only 73-120 seeds per gram[4]. This is despite the fact that Red Stringybark has significantly larger seeds and cotyledons than Blakely's Red Gum.

The solution therefore, assuming the aim is to have an even distribution of each species, is to manipulate the weight of seed from each species to create a statistically even chance for germination and establishment.

The right species in the right place

One of the criticisms of direct seeding was the tendency to use an enthusiastically eclectic mix of species. There was liberal use (including by our office) of wattle species outside of their home range (examples include *Acacia baileyana*, *A. cardiophylla* and *A. boormanii)*.

Also common was the inclusion of 'bird-attracting' flowering shrubs such as Coastal Bottle Brush *Callistemon citrinus*. On reflection the wattles pose a potentially serious weed threat due to their long-lived seeds and the bottle brush has been implicated for the spread and dominance of hyper-aggressive birds such as noisy miners and rainbow lorikeets.

The planting and seeding of these showy myrtaceous species outside of their home range, in part inspired by the nursery industry and public perception, is a serious concern and one which requires much further press.

Before we criticise these early direct seeding operators however, it is useful to reflect on the history of direct seeding and the social context into which it was born. During the decade of Landcare (around1990-2000) the revegetation debate was one of pines versus natives.

'Natives' which could be demonstrated to grow successfully and provide the production and social goals required by landholders were widely canvassed and adopted. These early direct seeding successes were therefore vital for the industry and adoption as a whole. Nevertheless locally endemic species are now used almost exclusively.

Diverse seed mixes don't always result in diverse revegetation

Repeat surveys of our direct seeding sites in 1998 by Susie Wilson and in 2008 by Bart Schneemann highlighted that the most successful sites (i.e. those with a high number of stems and with rapid growth rates) were dominated by fast growing and tall species, to the detriment of both species and structural diversity[5]. This follows a broader trend whereby shrubs with a final growth height less than 1.5 metres, are consistently absent from our sites after five or 10 years.

The success and uptake of direct seeding in south east NSW is largely thanks to Brian Cumberland, shown here in his beloved Landcruiser towing an early model Rodden III direct seeder.

> Perhaps 'less is more' when it comes to direct seeding trees and shrubs, particularly in modified landscapes.

A combination of the inability to reach an 'escape height' from herbivores and the competition from either adjacent revegetation or introduced grasses on fertilised soils are the likely cause. In various scenarios we have thus reduced the number of tall growing species, the amount of seed of these tall growing species, or excluded the small shrubs to conserve seed. It is worth considering that the greatest plant diversity in grassy woodlands lies in the grasses and wildflowers and that perhaps 'less is more' when it comes to direct seeding trees and shrubs, particularly in modified landscapes.

Seed preparation

In 2008 we purchased a Kimseed seed scarifier to treat the hard-coated seeds prior to direct seeding. The savings in time, water and drying space compared with the former boiling water treatment were substantial. Germination trials done in partnership with the Australian Tree Seed Centre at CSIRO suggest that those acacia species from high rainfall areas (800-1000mm/year) may require greater scarification of their seeds for germination, possibly as a proxy for hotter fires, than the species from a lower rainfall zone (600mm/year).

Seed from species from the semi-arid zone (250-500mm/year) however are often destroyed by scarification. It is hypothesised that flood, rather than fire, might be the germination trigger in the drier parts of our landscape.

The future

Over the last 25 years there have been advances in every aspect of direct seeding. One of the challenges moving forward however is to improve the reliability, efficiency and diversity of direct seeding across different soil types, land uses and rainfall zones. Improvements may be found in:

Whole of Paddock Rehabilitation approach.

> Over the last 25 years there have been advances in every aspect of direct seeding.

- Increasing the diversity of species available for direct seeding. For example, germination dormancy in plants with berries and drupe largely prohibits their use in direct seeding.
- A systemic review of herbicides for direct seeding. This process has been started by Taylor and others[6] but requires more detailed work across a number of genera, species and soil types.
- Developing regional revegetation handbooks based on soil type, soil fertility and rainfall zone to ensure our experiences are captured and the industry continues to progress. For example, we have recently increased the seeding rate of large seeds (100g/km), but instead hand plant eucalypts on sandy soils derived from granite or red soils which have been previously cropped.
- A modular seeding machine which combines the best aspects from each of the existing designs and can perform tasks such as top soil removal or deep cultivation as and when required by soil type and soil fertility. For example it may combine the precise seed placement of the CommVeg machine[7] with the ability of the KB seeder[6] to aerate hard setting soils while maintaining the flat and stable seed bed created by the Burford seeder for the germination of fine seeds.

References

Full list on our website

Science, seeds and scats: engaging the community at the Australian PlantBank

Cathy Offord, Principal Scientist and Manager of Germplasm Conservation and Horticultural Research, Australian Botanic Garden Mount Annan

Balancing the needs of good science with opportunities for public observation and engagement was a challenge that we set ourselves in the building of new science facilities at the Australian Botanic Garden (ABG) at Mount Annan. For several decades there has been a need to establish a purpose-conservation science facility for the Royal Botanic Gardens Sydney, with a major seed and tissue bank at its heart. The space and access at the ABG site, gave us the ideal opportunity to bring our science 'out into the open'.

We studied several successful models such as Kew's Millennium SeedBank at Wakehurst Place in the UK which has its laboratories and seed bank placed around, or beneath, the public viewing and interpretation area. From our observations it was clear that an essential design element is to firmly link the interpretation of science directly to what the visitors can see the scientists doing, however mundane! Another element is to provide opportunities for passive and active engagements, across all ages and backgrounds. Our particular challenges were to do this with a limited budget and ensure a high level of sustainability.

From the outset of concept, our scientists were involved in the design of the building, particularly how it functions. We mapped the 'journey(s) of the seeds' from plant collection in the wild though seed cleaning, germination, banking and use. The architects and designers used these pathways to design the building as well as the development of interpretive elements. Science and conservation interpretation was 'built into' the building and the surrounding landscape, in subtle and often powerful ways.

From the outset of concept, our scientists were involved in the design of the building, particularly how it functions.

Visitors gain a sense of arrival by passing through a tunnel of mirrors. Seeing themselves first they are then presented with a series of interpretive panels on the external walls of the building that challenge them to think about our individual and collective roles in looking after the environment. Large letters on the building spell out the words 'PLANET PLANT'.

The landscape plantings are sourced from the adjacent endangered Cumberland Plain Ecological Community and were chosen to tell stories about how humans 'choose, use, abuse' our natural resources (focussing on the role of plants) and how we can help conservation efforts. Particular focus is placed on plants and their role in feeding and sustaining us and the role that science plays in this.

Visitors engage with the work of the building as soon as they enter the surrounding landscape.

Playful elements link the landscape with the interior activities inside the building. Blank granite lines run across the pathways, up walls and inside across floors, linking the garden plantings with the laboratories where they are studied and grown. The fern beds link to the tissue culture laboratory; a field of grasses links to seed processing and banking; a bed of crop wild relatives, such as native raspberries, links to the physiology lab where we study how plants grow. Stories about plants are told throughout that are used for schools and other active activities.

Visitors can experience working science laboratories.

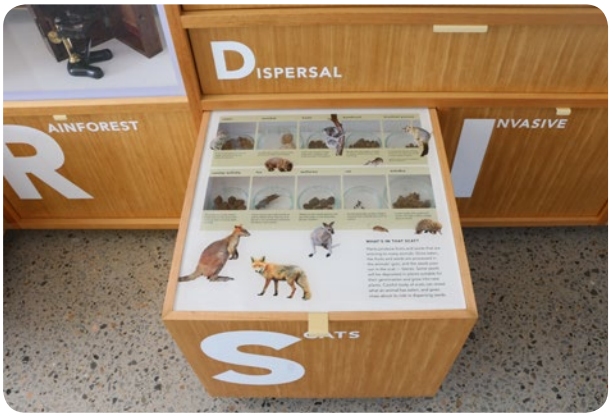
Once inside the building, visitors immediately engage with the laboratories. Only a glass wall separates them from the work within. Experience in other similar buildings indicated that this might be distracting for people working inside, but so far, this has not proved to be the case, not doubt due to the design. Not only can the visitors see into the laboratories, but they can see back into the inner workings – the germination cabinets, microscopes and seed packaging areas can be easily seen.

The seed bank is inside that seed vault that also includes the drying room. This is the coolest place in the garden.

Of particular note is the seed drying and storage vault that has a rather atmospheric blue light that gives the (right) impression that this a cool area. Signage and cartoons on the glass walls tells the stories of the seeds and the techniques of tissue and cryogenic storage on the adjacent labs.

The hub of the PlantBank is the central gallery – a light-filled space for gathering and contemplation. Its centrepiece is the Diversity Wall, a 2.5 metre high by 12 metre long collection of 44 different topics on the interrelatedness of plants and, basically, the rest of the planet! Soil, insects, timber, plant discovery and botanical history are covered. Open a drawer and you might find a large book on Aboriginal medicine, or how Aboriginal people tell the seasons by what plants are flowering or animals are visiting. In another, a cornucopia of seed and fruit types from around the world.

We used many different sources to develop the interpretation topics including the kindergarten to year 12 science curriculum. One backlit drawer shows the diversity of adaptive foliage shapes in the genus Acacia. There are serious as well as playful displays. The bottom row of drawers is for children. A particular favourite is the drawer of scats from native and introduced animals, and what's in the scats, from seeds to hairs. It bookends a drawer higher up showing the various types of seed dispersal – the gliders, helicopters, floaters, drifters and hitchhikers.



Kids get their kicks from seeing what seeds are in animal poo.

Displaying the incredible diversity of fruit types.

Off the gallery is a small lecture theatre and meeting rooms and a learning laboratory for the extensive community education program that is delivered out of PlantBank. In March this year we hosted the first Seed Science Forum for seed researchers and restoration practitioners (with the Australian Seed Bank Partnership and Australian Network for Plant Conservation). At this forum the PlantBank spaces were used to capacity and this was a great test event for us. Through events such as these and the capacity for national and international collaborations, we aim to be major contributors to conservation science, plant conservation and community education in Australia.

The big question is – how are people responding to the Australian PlantBank? Feedback has been overwhelmingly positive and visitation numbers are increasing. I was amazed to recently witness a couple of children dragging their parents into the building and excitedly pulling open drawers and explaining the Diversity Wall. They had been on a school excursion the week before and were keen to share their knowledge with their elders. That's exactly as it should be!

Why do we care about plant conservation?

There are around 300,000 plant species in the world. Eight to ten per cent of these occur in Australia. Scientists estimate that there are 25,000 to 30,000 species in Australia. The current number of recorded species in NSW is 5,810. Globally, around 10 per cent of all plant species, and an astounding 30 per cent of gymnosperms are threatened with extinction. In NSW we have 611 species considered rare or endangered.

Seed collection and storage has been a function of the Royal Botanic Gardens since its establishment in 1816. The NSW Seedbank was established in 1986 as an integral part of the ABG, the Australian plant garden of the Royal Botanic Gardens & Domain Trust.

The Seedbank supports a wide variety of activities from horticultural development, to molecular research. In recent times, plant conservation has been a particular focus.

As a response to the need to address the conservation of NSW species in a more holistic fashion, the Australian PlantBank concept was developed over a very long period and finally opened in 2013. Primarily funded by the NSW government, over four million dollars was raised from the private and corporate sectors.

Community engagement

- The Australian PlantBank is more than a building. It is a science and education facility where visitors can immerse themselves in the workings of our scientists by seeing into the laboratories aided by interpretation which starts from the minute visitors approach from the carpark.
- The experience is enhanced by the PlantBank app.
- Social media is an integral part of the delivery of our science messages and our staff and students are increasingly engaging with this form of science communication.
- Open days and tours challenge us to communicate our science one-on-one.
- Digital and on-line resources such as websites/ databases are the key to better delivery of seed science messages.

For more information visit Australian PlantBank.

Open days in Science Week have a variety of activities to engage young and old.

2015 A big year in the Kimberley

Luke Sweedman, Curator, WA Seed Technology Centre & Kings Park and Botanic Garden Seed Collector

In 2015 as part of the Global Tree Project initiative and working in concert with the Australian Seed Bank Partnership, Kings Park and Botanic Garden embarked on a comprehensive collection program throughout the Kimberley region in search of tree species that were not secured in long-term conservation facilities. The trips took place at different times of the year to secure species that fruit over a range of timings. This captured a number of species previously uncollected and new to cultivation with the additional emphasis on storing the species at both the Seed Technology Centre at Kings Park as well as the Millennium Seedbank in the UK.

Some of the remarkable species found in seed included *Corymbia cadophora* subsp. *pliantha*, a stunningly beautiful tree that may well find its way into domestic gardens in future by way of the Kings Park plant breeding program, and *Corymbia ptychocarpa* from Mt Elizabeth station.

Corymbia cadophora subsp. *pliantha* in full flower is a striking sight.

> Some of the remarkable species may well find their way into domestic gardens in future by way of the Kings Park plant breeding program.

The Halls Creek White Gum, *Eucalyptus cupularis* is a striking small tree with white trunks and weeping form that has outstanding potential for domestic gardens especially as this form and colour gains fashionable prominence.

Eucalyptus ordiana, another superb small white trunked tree with lovely glaucous foliage, was collected south of Kununurra and offers a great form as well as feature foliage. Many others that may be lesser known but nevertheless are new in cultivation are *Eucalyptus tephrodes* from Halls Creek; *Eucalyptus obconica* and *Eucalyptus limitaris*, both from Mornington Sanctuary.

The strategy of visiting the Kimberley in the dry season in June and July and again at the beginning of the wet season in December provided us with a good range of species.

This strategy enabled us to find species and observe their behaviour across a longer time frame to help time collections that we had missed previously. In many cases we were able to get species in flower as well as in fruit. In past visits to the Kimberley, collecting has often been more opportunistic and less strategic, resulting in fewer species collected and duplication of the same species.

The collecting program in 2015 was a far more comprehensive approach that has yielded a fantastic range of new collections for long term conservation. Twenty one tree species in total that were previously uncollected by Kings Park were collected and the majority of these were not found in seed banks internationally – until now.

Halls Creek White Gum *Eucalyptus cupularis* growing in the hills around Halls Creek.

Twenty one tree species in total were collected and the majority of these were not found in seed banks internationally – until now.

Eucalyptus ordiana growing in the hills south of Kununurra.

Seed banking in New Zealand: success through partnership

Craig McGill and **Jessica Schnell**, Institute of Agriculture and Environment Massey University, **Kate Nolan**, Institute of Education Massey University, **Rebecca Stanley**, Auckland Botanic Gardens, and **Rewi Elliot**, Wellington Botanic Gardens

New Zealand's unique plant biodiversity is being safeguarded through a national partnership to collect, study and conserve seed of New Zealand's flora. The long term vision is for the project to facilitate the development of networked collaborations that result in sustainable conservation and preservation activities for New Zealand, locally, regionally and nationally. The seed bank will coordinate ex situ and in situ conservation activities at the individual, community, regional, national and international levels to help ensure the continued existence of indigenous plant life and the biodiversity it contains. Key national partners for the seed bank are New Zealand's botanic gardens.

To ensure sustainable conservation there is a need to grow public understanding of why conservation and preservation of New Zealand's indigenous species is important. It is also important to enable New Zealand citizens to become part of the conservation solution through participation and a sense of ownership. Key drivers are to grow capability through education outreach, citizen science, community-led conservation efforts/living laboratories, research partnerships and iwi (local tribal groups) relationships.

The New Zealand seed bank was initially established with funding from MWH New Zealand Limited, an employee-owned engineering company, with further funding from the Massey University Strategic Innovation Fund and the New Zealand Lottery Grants Board. The seed bank was created as a partnership to bring together organisations with the expertise and/or facilities to achieve the collection, study and banking of seed of the New Zealand flora.

The project is being led from Massey University in Palmerston North in collaboration with the Department of Conservation, two Crown Research Institutes *viz*. AgResearch and Landcare Research, the New Zealand Plant Conservation Network and the Royal Botanic Gardens, Kew.

Massey University is providing research expertise and governance oversight to the project as well as holding the herbarium voucher specimens for the seed collected.

The Department of Conservation is providing access to public conservation land, threatened species advice and connections with iwi. The New Zealand Plant Conservation Network is giving access to its flora database, Landcare Research is providing taxonomic advice and duplicate herbarium storage and AgResearch is hosting the seed bank within its forage seed bank.

Four target species groups have been identified. These are the Myrtaceae, the alpine flora, the Fabaceae and the Podocarps / other trees of the forest. The groups have been targeted for a number of different reasons:

1. Myrtaceae; there are 28 Myrtaceae species in New Zealand including Pohutakawa *Metrosideros excelsa*, the Northern Rata *Metrosideros robusta*, the Southern Rata *Metrosideros umbellata*, Manuka *Leptospermum scoparium* and Kanuka *Kunzea ericoides* amongst other *Kunzea* species. Two species, Rata Moehau *Metrosideros bartlettii* and *Kunzea toelkenii* are threatened. Myrtaceae are found in every New Zealand forest and Manuka is a species of economic importance. The unknown impact of Myrtle Rust should it arrive in New Zealand has made the Myrtaceae a high collecting priority.

Native Bee on New Zealand Myrtaceae. Photo: Ngā Manu Nature Images

2. The alpine flora; one-third of New Zealand's flora is found in the alpine zone. This includes around 500 species that are exclusive to the alpine zone. Around 83% of the species in the alpine zone are endemic and about one-third are either at risk or threatened. Alpine systems are fragile and are especially vulnerable to climate change so there is some urgency to conserve these species. Seed banking of this group will safeguard the diversity of these species.
3. The Fabaceae include some of the best known flowering plants in the New Zealand flora, such as kowhai *Sophora* species, the native brooms *Carmichaelia* species and two kakabeak species *Clianthus puniceus* and *Clianthus maximus*. Many of these are limited in their distribution. Seventeen species in this group are at risk or threatened, from browsing pests and / or habitat loss. Seed banking of this group will safeguard these species until the threats in their habitats can be overcome.
4. The broadleaf and coniferous trees and shrubs are the backbone of the New Zealand's forests. Some 250 tree and shrub species are at risk or threatened. A number of species in this group are thought to be desiccation sensitive and therefore cannot be banked under standard conditions. New protocols will need to be developed for these species.

The project is part of the international Millennium Seed Bank Partnership but, unlike arrangements with other partner countries, duplicate safety storage of New Zealand seed will occur within this country rather than at the Millennium Seed Bank. Auckland, Wellington, Christchurch and Dunedin botanic gardens will provide the duplicate safety storage.

Juvenile Green Gecko on Manuka seed capsules. Photo: Ngā Manu Nature Images

The New Zealand model will create a decentralised seed bank. At the centre will be coordinated research activity, seed storage, information / data sharing and project management. This hub will serve a range of connected groups (scientists, educators, community leaders, conservationists) to support and resource local and regional conservation activities.

The 'hub and spoke' model will facilitate community engagement in the project through education outreach and citizen science. This is currently being achieved by training collectors at regional workshops. To date over 100 collectors throughout New Zealand have been trained and are now collecting and sending seed to the central seed bank. Once the seed reaches Palmerston North volunteers extract, clean and dry the seed in preparation for banking.

A core role of botanic gardens is educating and engaging the community in the importance of plants in their lives and livelihoods. The botanic gardens in New Zealand, have a combined visitor count of over four million visits annually. At Auckland Botanic Gardens alone, 150 school children visit each day. The botanic gardens are a teaching space for the delivery of education programs linked to the New Zealand school curriculum in partnership with local schools. In addition the botanic gardens provide an important advocacy and awareness-raising role for the both the New Zealand seed bank and conservation of New the Zealand flora through citizen science and educational outreach.

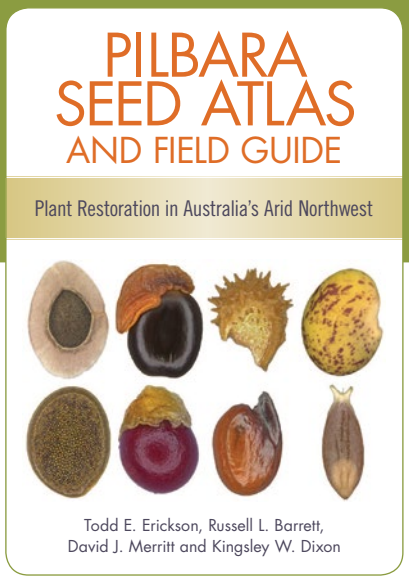
Botanic gardens in New Zealand already contribute to the collecting program by hosting training workshops for seed collectors and initiating seed collecting expeditions. Botanic gardens also hold many of New Zealand's threatened species in living collections, for example kakabeak *Clianthus puniceus* and, where populations are large enough, seed collected from these plants is being sent to the seed bank.

There is a need to understand New Zealand's indigenous plant ecologies in specific locations and regions across New Zealand to enable effective seed collecting. Collecting essential phenological data provides an opportunity for citizen science projects locally, regionally and nationally with the potential to grow scientific capability to ensure that we know how to collect and store indigenous seed, and can effectively grow them into plants.

BOOK REVIEW

Pilbara Seed Atlas and Field Guide by Todd Erickson *et al.*

Daniel Duval, Technical Officer, Seed Collections & Research, Botanic Gardens of Adelaide, Department of Environment, Water and Natural Resources



At first glance this is quite a comprehensive book but is still compact enough (25cm X 17cm) to be used as a field guide which will probably fit into a vehicle glove box. The pages seem to be glossy & durable and the book appears to be bound well and seems robust enough to be used in the field. The first urge is to flick through the atlas of plants and seeds which most of the book is devoted to (Chapter 5 pages 45-251). It is the first field guide for plants I have read that includes images and detailed information of seeds for each species. But more of that later, for now let's wander back to the preceding four chapters.

The brief first chapter provides some background about the climate and plant communities in the Pilbara region. It highlights the harsh climate in this region with peak rainfall coinciding with peak summer temperatures which consistently exceed 40-45°C! It is a very rugged and harsh landscape and as a reader I was immediately thinking about the adaptation of the flora to the highly variable climate & extremes in this region. (*It also has me thinking about the adaptation of my feet to the harsh red spinifex plains in the Pilbara region where I grew up. My first day at school at Roebourne Primary School having to wear shoes for the first time was a painful one.)*

In this hot arid climate it is quickly appreciated that many plants spend most of their life history as seeds sequestered in the soil seed bank or contained in woody fruits awaiting a favourable season. This poses consequences for seed collecting, germination & dormancy for the Pilbara flora as well as challenges for restoration in the region as the authors allude to in the early chapters. It becomes readily apparent early in the book why a field book containing information about seed biology and seed photographs for the Pilbara region is so pertinent.

The second chapter discusses seed collection, cleaning and storage and illustrates some species examples from the Pilbara region. There are some very useful illustrated examples of dissected and x-rayed seeds that explain 'filled' seeds that many readers will find interesting.

These illustrations and excellent figures in the subsequent chapter (e.g. Fig 3.5) provide a microscopic view inside seeds to see the types of embryonic plants within the seeds of different plant families.

The third chapter explains the types of seed dormancy, embryo types and some of the seed pre-treatments for overcoming dormancy in arid zone species. This includes physical dormancy which occurs in many hard-coated species with water impermeable seed coats through to morphological dormancy which is imposed by the tiny underdeveloped embryo within the seeds of some families. There is a lot of valuable & concise information on seed biology in this chapter which makes the atlas a handy quick reference for this topic in itself. The authors have provided some interesting case examples from the Pilbara from their own germination research which is well illustrated with comparative germination graphs.

The fourth chapter briefly discusses the use of seeds in restoration projects including some of the seed enhancement technologies that might be interesting to practitioners.

The atlas in the fifth chapter contains two pages of photographs and descriptions for each of the 103 species. The first page contains descriptions of the species habit, flowering period, habitat etc. and up to five photographs showing plant habit, foliage, flowers and importantly key distinguishing features. There is also a useful legend describing the landscape niche for each species.

The second page contains high quality photographs of seeds and fruits with information about seed biology. Each species has undergone extensive laboratory testing to derive information about the seed embryo and dormancy types, seed viability and purity, seed germination requirements etc. It is a credit to the authors for the sheer amount of work required to derive this information for each species. Importantly this information on seed biology is often very applicable to many other species in the same genus.

The field atlas is most applicable to readers visiting or working in the north-west region of Western Australia, probably an absolute requirement for anyone working with the flora in the region. But it will also be a very useful reference to anyone with an interest in flora of the arid zones of Australia.

I sporadically work in the rangelands of South Australia and at a quick glance recognised that at least 43 of the 103 species covered in the field guide occur in South Australia, as well as all of the genera apart from five. I would expect this to be higher for the arid zones of Northern Territory and Queensland.

So overall the field guide is an important reference for readers interested in the rangeland flora of central and northern Australia, but also a particularly useful reference for seeds, seed collecting, seed germination methods and other aspects of seed biology for rangeland flora. It'd be fantastic to have a comprehensive book like this for every region.

FEATURE GARDEN

The Australian Botanic Garden Mount Annan

John Siemon, Curator Manager, Australian Botanic Garden Mount Annan

Once a paddock with a bunch of white agricultural tin sheds, the Australian Botanic Garden at Mount Annan (ABG) is slowly developing into a world class botanic garden. The rolling hills of golden grassland that were once home to dairy cows in the 1940s and a riding school in the 1970s are still a defining feature.

However the 'park' has matured in recent years through a concerted effort to re-establish and regenerate hectares of critically endangered plant communities and the ongoing development of scientific collections and horticultural plantings across a vast landscape of 416ha – Australia's largest botanic garden.

The ABG, previously known as Mount Annan Botanic Garden, has been keen to shake off the park-like activities that most of our visitors would experience on a typical visit to the garden. With just two permanent buildings on site, the most recent addition of the Australian PlantBank, in October 2013, marked a significant leap in the technical capabilities and breadth of the garden's conservation initiatives.

The addition of the Australian PlantBank, in October 2013, marked a significant leap in the technical capabilities and breadth of the garden's conservation initiatives.

PlantBank. Photo: John Gollings

The opening of this stunning building also created an opportunity to shift the perceptions of our visitors and engage them passively and actively in the science programs once confined to behind the barb wire fence.

The Australian PlantBank

PlantBank was more than a decade in the making. It wasn't just an idea conceived overnight – rather it was a project refined from the passion of staff and the lessons learnt from other like-minded institutions both at home and abroad. To be a success the facility needed to achieve three things.

Firstly, and probably most importantly, it needed to enable the scientists to do their science. Secondly, it needed to link to core infrastructure, particularly the garden's nursery and propagation facilities. The final priority was to extract the facilities from the obscurity of several agricultural sheds and relocate them to a public interface where our scientists and their stories could be a primary focus.

To achieve these outcomes the Foundation and Friends of the Botanic Gardens funded an overseas scholarship to allow the PlantBank Project Manager (myself) to scope similar institutions in North America and Europe, to learn from their mistakes and embrace their successes.

It was evident that cultural institutions are more than just static collections and contemporary institutions were finding innovative ways to engage with visitors, to create VIP experiences and breaking the mould with the traditional interpretation one usually finds at galleries, museums and botanic gardens.

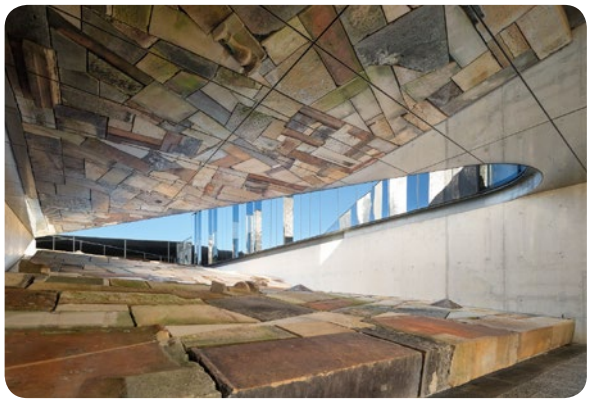
Key influences for the buildings layout and design came from: the Millennium Seed Bank (RBG Kew), Daniel F. and Ada L. Rice Plant Conservation Science Center (Chicago Botanic Garden) and the Californian Academy of Sciences.

These lessons were fused with a long wish list of staff ideas and handed to a leading architecture firm, BVN Architecture, to craft into a world-class science facility. The result is more than just an ordinary building with a bunch of sterile science labs. PlantBank is now firmly front-and-centre of the Botanic Gardens & Centennial Parkland's plant conservation programs. The multi-award winning building is a talking point for the science programs within as well for its remarkable stainless steel, concrete and glass structure.

Connecting with communities

The interpretation and the digital app, available on both Android and Apple platforms, have secured awards in their own right and connect the science and conservation messages of PlantBank to students and the visiting public. In an effort to strategically deploy technology, the Connected Classroom infrastructure, a digital classroom, allows geographically challenged students to participate in an incursion through a specially designed interactive learning experience. This has enabled classes from Lord Howe Island, Mount Hotham and even China to participate in plant-based learning programs.

The Living Laboratory garden forms the central landscape element as a deconstruction of the floral biodiversity where visitors can see and learn about the greater than 140 herb species that make up the Cumberland Plain Woodland (CPW) community. A key highlight of this landscape is the Lichen Garden that blends science, art and history into a living sculptural element.



The Lichen Garden at PlantBank.
Photo: John Gollings

The Lichen Garden is comprised of damaged building stones from 200 years of Sydney's building heritage. The surface of these stones is slowly being colonised with cryptogams, organisms that reproduce by spores, including lichen, moss & algae. The Lichen Garden has become a talking point of the landscape and has featured on several television programs.

A surprise to many, the building's architecture has become a backdrop for car manufacturers keen to show off the latest in engineering masterpieces. This has been primarily driven by the unique reflective stainless steel ceiling that enthrals visitors on arrival to the building and makes small children squeal with delight. PlantBank has also become a location shoot for fashion publications and those seeking a unique wedding venue. These uses may seem at odds with the purposes of PlantBank but they present an opportunity for a much broader audience to engage with the role of PlantBank.

[The unique reflective stainless steel ceiling that enthrals visitors on arrival to the building and makes small children squeal with delight.]

What's inside the Seed Vault?

The Australian PlantBank is now one of the most biodiverse locations in the nation with a seed repository of hundreds of millions of seeds from over one fifth of Australia's native flora.

One seed packet alone, of *Juncus bufonius*, a small toad rush that grows in moist and muddy places, holds over 2.3 million seeds and several of our orchid collections, including *Cymbidium suave*, an epiphytic snake orchid, may hold as many as 10 million seeds. Conversely some plants are so rare that we only have a few seeds of these species.

The PlantBank collection includes 5,260 species of plants and, in recent months, the PlantBank facility has celebrated a milestone having now collected and banked more than 50% of New South Wales 620 species of vulnerable, endangered and critically endangered flora. More than just an insurance policy for species loss, the collection is an active repository enabling different streams of science from seed biology to bio-pharmaceutical research.

What's the real cost of the Australian PlantBank?

An increasing dilemma for scientists and scientific institutions is funding and where the next dollar will come from. Such was the case when PlantBank's fundraising commenced in one of the worst economic global downturns in recent memories.

PlantBank's capital cost of $19.8M is certainly significant but in reality it equates to 200m of freeway construction. Funded through a carefully planned campaign the NSW state government contributed $15.5 million and $4.25million was raised through generous sponsorship or donations from organisations including the Foundation and Friends of the Botanic Gardens, the Ian Potter Foundation, HSBC Bank Australia, BHP Billiton Illawarra Coal, TransGrid, and many other donors.

Technology was used to engage with our donors throughout the construction phase with a blog (www.plantbank.tumblr.com) allowing key stakeholders and donors to follow the construction progress from bare earth to the project completion.

While there is so much more to PlantBank than just seeds, it is amazing to think that all of Australia's flora could one day be represented in PlantBank's Seed Vault with the ability to regrow seeds if and when required, of any given species or potentially whole plant communities.

There is a compelling story with PlantBank that resonates with donors and the story, or the potential story, of each species we have or are yet to collect. In less than three years PlantBank has obtained significant media coverage and leveraged over $2.7M in much needed funding with key research programs on rainforest conservation and Persoonia conservation currently underway.

Save a Species Walk

An idea conceived by staff at the Royal Botanic Garden Sydney, the Save a Species Walk, is now in its third year. Three teams from the Botanic Gardens & Centennial Parklands have each walked over 100km of spectacular but challenging terrain. This clever initiative raised over $70,000 to collect, process, research and store more plant species in the Australian PlantBank. The escapades and injuries of the walkers have made good fodder for social media feeds and a broad range of media outlets have supported this worthy cause.

Save A Species walk 2016.

Science and cultural hub

The Australian PlantBank provides an opportunity for like-minded scientists to share the exceptional resources available. PlantBank recently hosted its first major conference, the National Seed Science Forum, bringing together the scientists and restoration and conservation experts from the botanical and agriculture fields. This was a rare opportunity to promote the work of the Australian Seed Bank Partnership and the outcomes of the forum will be published in a special issue of the Australian Journal of Botany (AJB) in early 2017.

The building has also facilitated a diverse range of visiting scientists and artists who work beyond the pure science. Professor Dornith Doherty visited Australia on a prestigious Guggenheim Fellowship in 2012 to explore the role of seedbanks through photography and spent many hours taking images of uniquely Australian flora at PlantBank's x-ray machine.

See more of Sophie Munns' creations at http://sophiemunns.blogspot.com.au/

Artist-in-residence, Sophie Munns, has been establishing firm connections between our science team and avid followers through her passion for the critical work of seed conservation and the future of seeds. Sophie has a remarkable ability to create engaging stories, from the work of PlantBank's scientists, telling them through a progression of social media posts and the generation of copious amounts of artistic works including photography, sketches, paintings and digital art.

As part of her residency Sophie joined in on collecting trips mapping the journey of our scientists and their escapades. In doing so Sophie reaches an entirely new audience which shares a passion for art blended with horticulture and conservation focussed messaging.

Evolution of the garden

Following abolition of entry fees and the opening of a new prominent entrance in 2011, off Narellan Road, ABG has witnessed a dramatic rise in visitors. Over the last four years visitation has nearly quadrupled and now we must focus on how best to engage with our rapidly growing audience rather than just simply working out how to get people 'in' through the front gate.

This increased visitation is an opportunity, but seriously challenges the concepts and delivery intended for the ABG's Master Plan. In reality a new strategy is required that considers the rapidly evolving 'landscape' surrounded by a region under development with one of Australia's fastest growing populations.

To remain contemporary, relevant and engaging the Botanic Gardens and Centennial Parklands actively uses media and social media streams. The quirkier the angle the more interest it seems can be generated. Take the not-so-humble Bunya Pine *Araucaria bidwillii* 'nut' or cone.

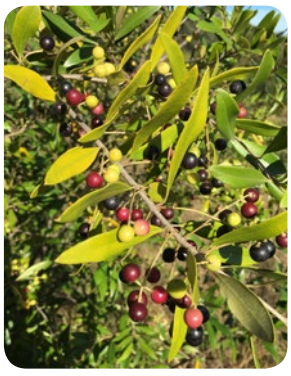
What started as a simple tweet of a 6.2kg cone at the ABG, cascaded into a media frenzy with publication or syndicated publications in hundreds of media publications across the globe. A catchy headliner or clickbait, a digital link designed to draw attention, started the process with a tongue-in-cheek message by @gregbourke3.

A media release then drafted by the Botanic Gardens & Centennial Parklands lead to a series of publications including the Huffington Post's *In Australia even the trees can kill you*. Ultimately these forums enable our key science, horticulture and conservation messages to be told. (Huffington Post or Sydney Morning Herald).

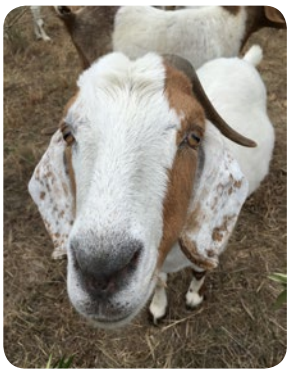
Weed management

The ABG landscape has been modified through successive agricultural land management practices and staff are slowly regenerating hectares of critically endangered plant communities once endemic to the garden including Cumberland Plain Woodland (CPW), Western Sydney Dry Rainforest and Moist Shale Woodland. An example of this restoration can be seen in the Australian PlantBank landscape where approximately 1.6ha has been constructed around the CPW community creating an engaging discussion point for visitors.

With such a vast landscape, staff have also inherited significant weed issues including Chilean Needles Grass *Nassella neesiana*, a weed of national significance, and African Olive *Olea europaea* subsp. *cuspidata*. The African Olive is an aggressive woody weed that establishes well on clay soils. A mature tree can produce in excess of 25,000 seed per annum and is easily spread by numerous bird species.



African Olive.



Boer goat.

Its dense and smothering canopy has resulted in its listing as a key threatening process to biodiversity and is a significant regional problem, particularly in the Macarthur region south-west of Sydney. In just 20 years post the removal of grazing, the weed spread uncontrolled to more than 80ha of the garden

Before and after goat deployment.

landscape and a concerted effort has been underway for some time to manage the scale of the infestation. Staff implement a combination of techniques including manual removal, herbicide application, fire, and mechanical removal to reduce the biomass and limit the spread.

Misfortune or opportunity?

In recent months ABG has employed a herd of Boer goats to eat through the invasive African Olive in a novel, environmentally friendly weed reduction trial. The 22 de-sexed goats have drawn significant media attention. Current statistics suggest the TV and print media stories reached a staggering 28 million people generating significant conversation around the threat of weeds and their impact on our lives. While the fruit were rapidly consumed the olive plants themselves appear less palatable and in a mixed grazing situation the goats preferred the surrounding pasture.

In recent months ABG has employed a herd of Boer goats to eat through the invasive African Olive in a novel, environmentally friendly weed reduction trial.

Communication success isn't always predictable but it does present an opportunity to embed key messages. It's hard to imagine that a Facebook post, captured by one of our scientists, Dr Cathy Offord, of a duel between a white cockatoo and a lace monitor lizard was viewed over 134,000 times. Even misfortune provides an opportunity with recent inundation of the garden, due to torrential rain of 278mm sustained over 48hrs. A quick video edit, on a smartphone, of the dramatic cascading waterfalls of floodwater resulted in a reach of over 70,000 people in just 48 hours.

The future

With a rapid climb in visitation the ABG must carefully consider the future development of its gardens and how best to meet the needs of the community. Equally, that growth in visitation brings the opportunity for engaging a new generation of visitors and introducing them to the amazing world of Australian plants. As rapid adopters of technology our Science & Education teams are connecting with our visitors in innovative ways through smart and sophisticated interpretation experiences like our soon to be released digital dinosaurs, behind-the-scenes tours, nocturnal garden tours and progressive dinner experiences. One day soon our visitors will hold the ABG's entire living collections database in the palm of their hand but hopefully leaving their phone in their pocket or handbag and just wandering around the garden will be okay too!

Botanic Gardens Reports

Botanic Gardens Australia and New Zealand Open Day 2016

Eamonn Flanagan, Executive Officer BGANZ

A grand total of 76 botanic gardens and arboreta took part in the inaugural Botanic Gardens Australia and New Zealand Open Day held on Sunday, 29 May, 2016. The theme of the 2016 Open Day was *Botanic Gardens Conserving Plants – Our lives depend on it.*

BGANZ and our botanic gardens received a significant amount of media coverage in digital and social media print and television across Australia and New Zealand. Open Day Garden reports have been very positive, despite heavy rain in Auckland, and timing clashes with local events in one or two places.

There were a wide range of events held across our two nations. Christchurch Botanic Gardens had a photographic exhibition highlighting key messages, George Brown Darwin Botanic Gardens held Indigenous walking tours, Albany Botanic Garden and Botanic Gardens South Australia involved children in planting and conservation activities. Take a look at the range of events on the BGANZ website to see what others did. It might give you additional inspiration for 2017!

Many gardens and their BGANZ members contributed to the national success of the day, and BGANZ Council would like to thank each one. Special thanks go to Craig Easdown, *Manager Communications & Public Affairs* Royal Botanic Garden Sydney; Alison Morgan, Marketing & Paul Tracey, Curator Wollongong Botanic Garden; Greg Bourke, Curator, Blue Mountains Botanic Garden, Mount Tomah; David Sole & Raydeen Cuffe, Wellington Botanic Garden and Bede Nottingham, Christchurch Botanic Gardens.

Costa Georgiadis, ABC TV Gardening Host and BGANZ Open Day Australia Ambassador contributed hugely to the success of the day. He used Periscope (*@periscopetv*) on his visits to RGB Sydney and Wollongong Botanic Gardens. Periscope is a social media tv station that you use on your own to tweet from any venue. This is a relative new technique that I can see many gardens adopting in time – an idea for your local garden in the future perhaps. Jack Hobbes, New Zealand Ambassador, headed a promotions video in New Zealand.

Members are encouraged to send feedback to secretariat@bganz.org.au as soon as possible.

BGANZ Council will review the first Open Day, highlighting successes and improvement possibilities, before confirming themes and dates for #BGANZOpenDay 2017.

A report on the American Public Gardens Assoc. Conference Miami, USA, 6–10 June 2016

Sharon Willoughby, Manager of Public Programs, Royal Botanic Gardens Victoria (Cranbourne) and **Eamonn Flanagan**, Executive Officer BGANZ

The American Public Gardens Association (APGA) is the peak organisation for botanic and public gardens in the USA (formerly the ABGA). In 2016 APGA and BGANZ established a formal partnership.

Apart from the many benefits of connecting like-minded organisations and networks, this new relationship will provide a conference registration scholarship, which will allow one member from each organisation to attend the reciprocal organisations annual conference without paying the conference registration fee.

To cement this new partnership APGA invited Sharon Willoughby, at the Royal Botanic Gardens Victoria, Cranbourne Gardens to attend and speak about the role of socially inclusive practice in a modern botanic garden.

Sharon's attendance was supported by BGANZ Council, BGANZ (Vic), RBGV and self-funding. Eamonn Flanagan also attended the Conference, self funded.

Conferences can be great networking opportunities and this conference was no exception with a big emphasis on meeting everyone and the open sharing of practice and ideas.

This in itself was a huge undertaking with 750 people attending from 575 gardens.

As well as a printed guide book there was a conference app to help delegates work out which parallel session to attend from the seven themes that ran across the week: Plant Collections Management, Planting for the Future, The Living Landscape, Education and Science, Making Friends and Making Money, Climate Change and Sustainability, Collecting and Conserving.

In addition to Eamonn and Sharon, the Australian contingent was augmented by Fran Jackson, who has recently graduated from the Longwood Fellowship Program and Stephen Halliday, a horticulturalist, from Living Museums Sydney.

Conference impressions

Eamonn: I went to listen and learn – with a focus on revenue-raising opportunities for botanic gardens/BGANZ and individual professional development opportunities for BGANZ members.

I went to listen and learn – with a focus on revenue-raising opportunities for botanic gardens/BGANZ and individual professional development opportunities for BGANZ members.

I aimed to cement the APGA/BGANZ reciprocal conference attendance agreement and encourage APGA members to attend BGANZ conferences. I'm pleased to say there was no shortage of AGPA member interest in the prospect of attending BGANZ conferences in Australia or New Zealand.

American gardens have some key revenue advantages over our gardens. Almost all gardens charge an admission fee and this gives many opportunities to promote memberships and member benefits. Garden Membership and Development Officers spoke of having to service over 28,000 members paying $100 each per year as well as donors contributing $4-5 million dollars each!

The conference held sessions with slightly different session formats which, if adopted, may enhance BGANZ national congresses. The First Time Attendees meeting, held after breakfast on the first day, was useful. The energy of the Professional Groups matched BGANZ speed-dating night at the Wollongong Conference. The Professional Group Sessions, two for each group, were held across the conference as part of the main program.

Sharon: On the first day of the Conference I visited Fairchild Tropical Botanic Gardens – the gardens responsible for the remarkable Fairchild Challenge Education model, which was a moment to tick off the bucket list. That evening I spoke to the International Section Dinner (one of the APGA Professional Groups), which really gave me a head start on getting to know people.

I was really impressed by the Climate Change and Sustainability thread that ran so strongly through the conference. Florida gardens, such as Montgomery Botanical Gardens, are already experiencing salt-water inundation due to climate change. Issues of global change both in terms of mitigating garden impacts and community education are firmly on the agenda.

Sessions on Education, Garden Tourism and Revenue Generation were strongly attended and the ideas that flowed from those sessions were fabulous and make up most of my notes from the conference. The best thing about conferences like this is the feeling that you return home with your batteries fully charged and refreshed with new ideas and perspectives.

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Please remember that BGANZ has a free APGA conference registration each year when planning your professional development. APGA 2017 will take place at Hamilton Botanic Gardens in Canada, which is situated between Toronto and Niagara Falls (a scenic six hour drive from New York). Next year it could be you!

Calendar of conferences and events

BGANZ Queensland Conference 18–20 August 2016

Themed *Cultivating Botanical Richness* and held in Toowoomba, it will include presentations, a trade expo and technical/learning tours to several key gardens in the area.

For further information or if you have any questions, please contact Councils Parks and Recreation Services Administration team on 131 872 or recadmin@tr.qld.gov.au

BGANZ NSW Regional Conference and AGM 3–5 Nov 2016

This will be held at RGB Sydney with the AGM on 4 November.

BGANZ Victoria and Parks Leisure Australia horticultural seminar 20 July 2016

Themed *Which Plant Where – Improving plant selection in urban landscapes* this will be held between 9.00am – 3.00pm at University of Melbourne, Burnley Campus, 500 Yarra Boulevard, Richmond. More details.

BGANZ Vic Plants Forum 8–9 September 2016

Themed *Bringing Plant Collections to Life* this will be held at Grampians Retreat, Wrights Road Dunkeld, Victoria.

BGCI's 6th Global Botanic Gardens Congress 26–30 June, 2017

To be held in Geneva Switzerland. Information as it comes to hand on this and other international events as well as proceedings of past conferences can be found here.

www.bganz.org.au