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## Feature

# Can botanic gardens save all plants?

Early botanic gardens served medicine, and then they became important for biological research as well as for the transfer of crop species around the globe. Today, they are important sites for outreach and education, but globally their most crucial role may be in conservation. Will they be able to save every plant known to science? **Michael Gross** reports.

Botanic gardens set up in Renaissance Italy, such as the one founded in Padua in 1645, are still thriving in their original location, displaying longevity and deep roots like their oldest trees. Swept along with the Renaissance, the movement spread across Europe, producing many similar institutions that are still open today, including Oxford University's Botanic Garden (1621), Chelsea Physic Garden in London (1673), and the Herrenhäuser Gärten in Hanover (1666).

They played important roles in supporting the emerging science of botany, providing the living material for botanists to study. In colonialism, they served to spread crop plants to places far away from their original habitat, including rubber to Malaysia and cotton to North America. This role also helped to spread the concept of a botanic garden, defined as a documented living plant collection used for scientific, education and conservation purposes, around the globe.

Nowadays, they serve the enlightenment and entertainment of 500 million visitors annually, in addition to supporting conservation and research. This work isn't always getting the appreciation it deserves. Press reports from Istanbul, Turkey, this July suggested that the authorities are planning to move the city's only botanic garden, the Alfred Heilbronn Botanik Bahçesi, in order to hand its location to religious institutions. Jewish, German botanist Heilbronn came to Istanbul as a refugee from Nazi Germany in 1933, when modern Turkey's Founding President, Kemal Atatürk, set up western-style universities complete with botanic gardens. A lifespan later, it now looks like science has to yield space to religion.

Some others have closed or been converted to ordinary parks due to lack of funding. On the other hand, new gardens are being born in China's rapidly growing cities, such as Hainan, Guangzhou and Xiamen. And yet, a recent scientific study found that more facilities are still needed if plants are to survive the mass extinction brought about by man-made land-use change and climate change.

### Global network

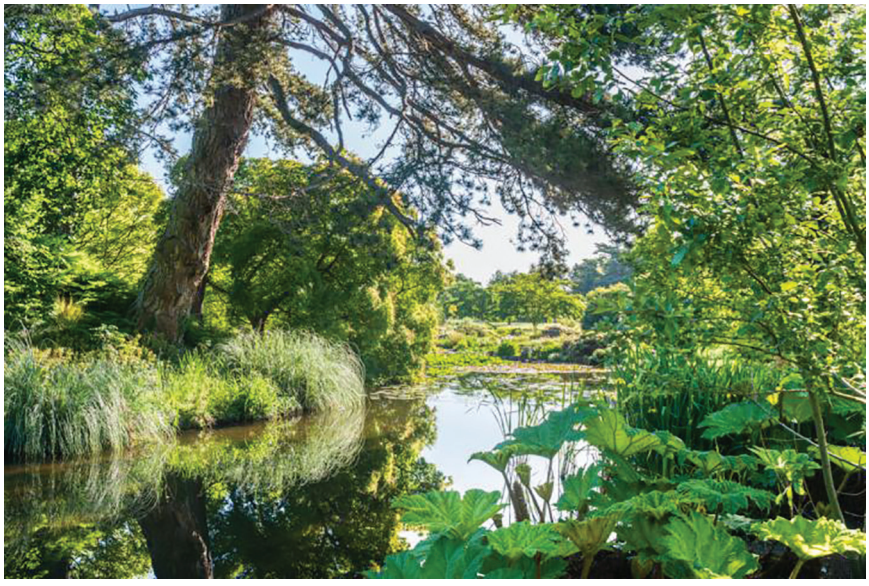
Today there are more than 3,200 botanic gardens around the world, which are listed in the GardenSearch database of the global network Botanic Gardens Conservation International (BGCI). For around one third of these institutions, details of their collections are available in BGCI's PlantSearch database, with a total of more than 1.3 million records and almost half a million taxon names.

In the first global assessment of the plant diversity represented in botanic gardens, Samuel Brockington and Ross Mounce from the University of Cambridge, UK, and Paul Smith from BGCI have analysed these datasets and their geographic distribution, in comparison with the known distribution of plant species in the wild. They also looked at the representation of endangered species and asked how botanic gardens can help conservation (Nat. Plants (2017) *3*, 795–802).

As the authors could only access the collection details of a third of the existing botanic gardens, their data represent a lower limit of the plant species represented. They found that, of the 350,000 plant species recognised in The Plant List in 2013, at least 30% are represented in botanic gardens. Coverage for genera is 59%, for land plant families 75%, and for vascular plant families 93%.

Botanic gardens tend to occur in large cities and are more likely to be found in more affluent countries. Thus, they are scattered around the globe in a pattern that is markedly different from that of the natural richness of plant biodiversity. Given this discrepancy, how well can the gardens represent global plant life? With their analyses, Brockington and colleagues confirm that the latitudinal distribution of the number of species represented in digital collection data peaks at 50 degrees north. The natural biodiversity of plants, by contrast, is highest in the tropics.

Although some tropical plants are represented in greenhouses in cooler climates, the authors argue that the cost of such accommodations makes it impossible to apply this approach



**Horticultural heritage:** Historic botanic gardens across Europe, such as this one at Cambridge University that was laid down by Darwin's mentor John Stevens Henslow, often look back on centuries of scientific tradition. (Photo: Cambridge University Botanic Garden.)

**Truly tropical:** Although plant biodiversity is highest in the tropics, there are fewer botanic gardens at these low latitudes. The Gardens by the Bay in central Singapore, covering 101 hectares of reclaimed land, is a notable exception. (Photo: Botanic Gardens Conservation International.)

on a scale that has a major impact on conservation. Therefore, they call for the global network of botanic gardens to be significantly expanded in tropical countries, such that tropical biodiversity can also be represented and, if necessary, saved from extinction, in such institutions that are close to its original habitat.

The analyses also quantify other kinds of biases that are plausible and predictable, but not in the interest of conservation. Humans tend to have a strong enthusiasm for flowering plants, somewhat less interest in ferns, and very little appreciation for mosses and their relatives. Accordingly, Brockington and colleagues find that 96.6% of gymnosperm genera are represented in the database, but only 54% of fern genera, and fewer than 5% of non-vascular plants, such as bryophytes (liverworts, hornworts and mosses).

While this bias favouring vascular plants doesn't surprise anybody, the authors state that "the magnitude of the deficit calls for action". They note that many botanic gardens already have an unplanned presence of bryophytes, which could simply be documented and declared part of the collection.

"Non-vascular species are the living representatives of the first plants to colonise the land," said Brockington. "Within these plants are captured key moments in the early evolutionary history of life on Earth, and they are essential for understanding the evolution of plants."

The plants not yet represented in botanic gardens are often more interesting than those that are, the researchers note, and they may pose new challenges. *Hydrostachys polymorpha*, for example, is an African, aquatic plant that only grows in fast flowing streams and waterfalls. Parasitic plants are also challenging. One very small example, *Pilostyles thurberi*, is only a few millimetres long and lives entirely within the stem tissue of desert shrubs.

## Conservation contribution

Analysing how well the botanic gardens in their analysis contribute to conservation of plant species, Brockington and colleagues specifically used Target 8 from the Global Strategy of Plant Conservation, last updated in 2010, as a yardstick. This target calls for at least 75% of threatened plant species to be included in *ex situ* collections, preferably in the country of origin. Their analysis finds that the institutions represented in the database have already progressed more than halfway towards that target, with 41% of threatened species represented.

While praising this achievement, the researchers note that only 10% of the capacity of the global network is currently used for threatened species, such that an expansion of conservation efforts could be easily accommodated within the existing facilities. As with the total global statistics, the analyses again show a bias favouring vascular plants, as well as neglecting tropical plants.

Interestingly, if a temperate plant species is threatened, it has a higher probability of being included in collections compared with species without a Red List status. By contrast, this kind of rescue response does not appear to apply to tropical plants. If they are threatened, they are somewhat less likely to be represented in botanic gardens. In either case, the level of protection offered is relatively thin, as many of the endangered species are only represented in one institution, and half of them in no more than three.

Thus, even the existing botanic gardens could do more to help plant conservation. As the researchers note, there is no good reason to let any plant become extinct. In contrast to the situation in animal conservation, where extinctions are bound to happen, a well-managed, global network of botanic gardens could keep all plant species for as long as there are people around to look after them. This is the vision that BGCI's Paul Smith has laid out in a recent essay (Sibbaldia (2016) *14*, 5–13).

## Paradise planned

One thing is immediately clear even from looking at the graphics presented by Brockington and colleagues, namely that more institutions are needed in the places where plant biodiversity is to be found, and where it is also increasingly threatened, i.e. mainly in the tropics. Fresh thinking and innovative approaches may also help.

The Eden Project opened in a disused china clay quarry in Cornwall, UK, in 2001. With its multiple biomes housed in iconic spherical domes, it introduced a new approach to helping people experience plants and their environment. Its subsidiary Eden Project International is now planning to develop new sites on all continents apart from Antarctica.

Currently, three sites are planned in China, including one in Qingdao focusing on the importance of water for life, an issue particularly pressing in

China (Curr. Biol. (2018) *28*, R135–R138), one in Yan'an dedicated to the role of land and soil, and one at Sheng Lu Vineyard in Beijing, putting education and connecting with nature at the forefront. Further developments are planned in Hobart, Tasmania, Australia, in Christchurch, New Zealand, and in Derry, Northern Ireland, UK, as well as in a sequoia forest in California, USA.

A major, Eden-inspired botanic garden is also being developed at Sharjah in the United Arab Emirates, close to the border of Dubai, and built by the architects that also created the Eden Project as well as other new botanic gardens, including the one currently being built in Oman.

"We want to develop experiences for visitors that make plants exciting and allow people to explore the green magic in a fun and educational way, while using the same documented plant material to drive research," said Dave Aplin, a senior executive of the project. "We are expecting the institute to be globally recognised in the years to come for the work it will do, so to that extent the garden will form the green heart of an institution, achieved as sustainably as possible — a huge opportunity for all concerned."

Apart from the living collections, plant tissues collected in herbaria over centuries can also make valuable contributions to research and conservation efforts (Curr. Biol. (2011) *21*, R6–R7), especially due to the long time spans covered by their collections and the vast amounts of materials that have accumulated. In a recent paper using this approach, Emily Meineke from Harvard University and colleagues have analysed insect damage in plants collected in the early 20th century compared with the early 21st century (J. Ecol. (2018) https://doi.org/10.1111/1365-2745.13057). After accounting for possible collection biases, the authors conclude that insect damage in four plant species investigated has increased by 23% in just over a century, an effect that may be related to climate warming.

## Saving plant biodiversity

As the Global Strategy for Plant Conservation (GSPC) agreed in 2010 approaches the end of its ten-year lifetime, conservationists are considering the future direction of their efforts. For this purpose, the Global Partnership for Plant Conservation (GPPC), in association with the Secretariat of the Convention on Biological Diversity (SCBD) and BGCI, and with the South African National Biodiversity Institute (SANBI) as the local host, organised a conference on the GSPC held at Kirstenbosch National Botanical Garden in Cape Town, South Africa, at the end of August. At the meeting, the GSPC was recognised as a useful and successful policy framework that has helped to drive integrated conservation action by the botanic garden community, according to a statement released by the BGCI's international advisory council.

**Blooming Florida:** Although technically just outside the tropics, Miami, Florida, still has a tropical climate favouring the establishment of a tropical botanic garden. Established in 1938 and comprising 83 acres, Fairchild Tropical Botanic Garden hosts palms, cycads, and orchids, as well as tropical fruit trees. (Photo: Botanic Gardens Conservation International.)

The conference has also been developing and discussing scenarios and priorities for the GSPC in the period beyond 2020 and the ways in which it will contribute to the 2050 Vision for Biodiversity and the 2030 Agenda on Sustainable Development. To inform this beginning discussion, the CBD also conducted an online survey, which was launched in July. The new strategy document for the next decade is due to be finalised and published in 2020.

At the end of August, the BGCI also published its second technical review on the economic, social and environmental impacts of botanic gardens. The review highlights case studies where impact evaluation studies have been carried out by objective third parties, such as auditors, consultants or academics. It calls on member institutions to monitor and measure not just their activities but also their interactions and impacts on the surrounding communities.

So, with all that strategic thinking, planning and monitoring under way, can we save all threatened plants from extinction? Botanic gardens can certainly make their contribution towards that goal, but experts caution that '*ex situ*' conservation is no replacement for maintaining the original habitat and the activities of the gardens should be part of a wider effort to protect nature.

"When we talk about plant conservation, and particularly *ex-situ* plant conservation it is critical to recognise the botanic gardens as part of a more holistic range of activities," says Brockington. "These activities include seed banking to store a whole range of diversity in bulk and cheaply, taxonomy to describe and define the units of biodiversity for conservation, and the integration of *ex-situ* and *in-situ* conservation to ensure survival of species in their natural habitats."

Natasha de Vere from the National Botanic Garden of Wales raises the

**Endangered beauty:** Many threatened tropical plants are grown in botanic gardens, but statistical analyses revealed that their threatened status doesn't increase their likelihood of being represented there. The image shows leaves of *Wollemia nobilis*, a critically endangered coniferous tree. (Photo: Cambridge University Botanic Garden.)

question: "What does 'saved from extinction' really look like? It is definitely true that for many plants we are able to preserve them as seed that could be grown in the future, but if the habitat and ecosystem of that species is lost, can we really say that the species is saved?"

Still, saving all plants is an eye-catching proposal that may well help to bring attention to species that may have otherwise fallen by the wayside, like the project to sequence the genomes of all eukaryotic species (Curr. Biol. (2018) *28*, R719–R721). A forthcoming meeting in China, the 4th Xishuangbanna International Symposium to be held at Xishuangbanna Tropical Botanical Garden from 3rd to 4th January 2019, will focus on this challenge: 'Saving all the plants in a changing world'. The declared aims of the meeting are "to provide some of the solutions for saving plant diversity and to assess how botanical gardens can play a key role in plant conservation."

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## Book review

# Science careers — improve your effectiveness but keep your passion

Robert Insall

*The Effective Scientist: A Handy Guide to a Successful Academic Career*
Corey J.A. Bradshaw
(Cambridge University Press, Cambridge; 2018)
ISBN: 978-1-107-17147-3

Planning a science career was always a rocky road, and it seems particularly tough at the moment. The scientific press constantly features stories detailing bias and unfairness. Social media is replete with short stories concerning the unhappiness of young researchers. Clearly, all is not well.

Two main themes underpin the feeling of dissatisfaction with the current state of careers: first, there are simply not enough jobs for the number of excellent scientists who need them, and, second, nobody is quite sure what separates the fortunate ones, who get through to the next stage and keep their careers alive, from the unfortunate. Is it high-impact papers, mentorship, connections, or presentation? Or simply luck?

Corey Bradshaw's *The Effective Scientist* addresses the second question. While the book doesn't define the secret of success, it does make suggestions on every aspect of how to improve. As the title implies, the unspoken logic is that, if you are effective enough, you will be the one who succeeds and is rewarded with a career. The connection between efficiency and success is justified by the author's (substantial) success in grants won and conferences chaired. It's hard to fault either the logic or the justification, though as a complete prescription it's a little limited.

The book itself is a curious assembly. The secret is in the title: it's all about 'effectiveness'. If you are writing a paper, what should and shouldn't you write? How can you ensure that you get enough recreation? What is the best way to respond when *Current Biology* asks you to review another researcher's work? Bradshaw serves up a treasure trove of suggestions, nuggets of disapproval, and lists of priorities. They're mostly excellent. Progressing scientists benefit from a wide range of sources of advice, but few channels have as much detail or prescriptions as precise. Sections include how to publish, how to manage a lab, how to keep track of data, and how to get the most out of trips and conferences — and above all how to make people listen to you. All of these sections are full of the same density of advice and caveats — and, to be sure, if you can keep track of them all, you will be a more effective scientist.

One thing that the book doesn't offer much is narrative structure. Within a few pages of opening the book, for instance, the reader is confronted with detailed examples of bad writing (such as using 'less' when you should say 'fewer'; I'm pleased to report I knew that one). This would not be a writing style that I suggest: my personal advice to trainees (and anyone else who'll listen) is that narrative is everything, and you must never talk about specifics until you've cascaded through the generalities and set the scene. That's not this book's style. It's no unstructured pile, but one gets the opinion that this author values precision in small things ahead of global statements and generalities. Indeed, with its penchant for facts and lists, the text conveys a strong sense of the author's personality; I imagine an avuncular but detail-obsessed professor with an almost military desire to improve his charges with a thousand small tweaks (I hope to meet him at a conference one day and see if the human matches the text; Dr Bradshaw, I'll buy the first round…).

The 'how to be a scientist' genre contains some heavy-hitting precedents. Perhaps the most notable are *Advice to a Young Scientist* by Nobel Laureate and immunologist Peter Medawar and *Letters to a Young Scientist* by the naturalist E.O. Wilson. There are also some reprehensible examples. During my PhD in the 1980s, I was appalled by a book that used to be left around the library,