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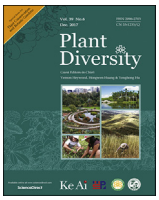

Editorial

# The future of plant conservation and the role of botanic gardens

## 1. Introduction

The papers included in this special issue are mostly based on presentations made at the IABG international conference held at Shanghai Chenshan Botanical Garden, China, November 2016, which addressed the roles that botanic gardens, both in China and elsewhere, can play in national biodiversity conservation strategies, such as maintaining and conserving plant material *ex situ* and in contributing to the recovery of threatened plant species, reintroductions and other translocations. It also looked beyond botanic gardens and addressed how to work and plan much more closely with other practitioners.

China is one of the world's richest countries in terms of plant diversity and also has a high level of endemism. However, plant diversity in China is increasingly threatened due to rapid industrialization, extensive urbanization, and explosive economic growth. Twenty percent of China's total higher plants are threatened with extinction (Huang, 2011; Huang et al., 2013). As a result, effective protection of plant diversity is a major problem and challenge that has to be faced and the paper by Charles Cannon (pp. 331–337) gives examples of the ways that China is addressing these issued. Part of this meeting focused on an assessment of China's existing plant conservation policy and the state of implementation. It discussed how to develop a plant conservation programme that takes into account the special characteristics of the Chinese situation and context, and ways of promoting cooperation between plant conservation research institutions and nature reserves, with a view to ensuring the conservation of Chinese plant resources through the adoption of efficient and effective procedures and protocols. These concerns are also faced by the rest of the world, and the speakers included leading plant conservation experts and researchers from abroad who shared their experience, and joined with key Chinese experts and with the leaders and plant protection specialists from the State Forestry Administration, provincial and municipal forestry bureaus in exploring these issues and proposing solutions.

## 2. The context

The impacts that humans are having on the earth's biological diversity and resources and on its climate, have led many to recognize that we are living in a new age, commonly known as the Anthropocene, although interpretations of its nature vary (Davies, 2016). One of its manifestations is that biodiversity continues to be lost at all levels, despite the worldwide mobilization of resources for its conservation on an unprecedented scale. The five principal pressures directly driving biodiversity loss (habitat loss and change, overexploitation, pollution, invasive alien species and climate change) are either constant or even increasing in intensity. In response, major advances conservation policy, planning and action have been made in recent decades and the role of established approaches such as protected areas, *ex situ* and *in situ* conservation have been the subject of major reassessments, while increasing emphasis is being given to ecological restoration and reintroductions, and massive reforestation programmes, in an attempt to address the consequences of habitat destruction and loss of species and seek the creation of a 'Garden Earth'. But still biodiversity continues to drain away.

Our collective failure to stem the tide of biodiversity loss, has led many to question the effectiveness of our current policies and approaches and many calls have been made for a radical rethink (e.g. Bridgewater, 2016; Kareiva et al., 2012) although there is no consensus as to how we should move forward. The reasons for this situation are complex, including scientific, technical, sociological, economic and political factors which are discussed in detail by Vernon Heywood (pp. 314–330) in his introductory paper. There is also a shift in focus away from biodiversity as such to the societal benefits of the goods and services that it produces, as witness the recent creation of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

One thing that is certain is the inability of governments, for whatever reasons, to implement effectively many of the commitments that they have undertaken under the various international treaties such as the Convention on Biological Diversity to which they are party. An inevitable consequence of this is that the various targets that have been set for biodiversity conservation cannot be met and the ability of other countries to make up any resulting deficits in achieving the global targets is limited. Although it is generally recognized that most biodiversity-rich countries lack sufficient infrastructure and resources to undertake the necessary conservation actions on a sufficient scale and are largely dependent on external aid for such work, the level of funding they receive remains inadequate (Waldron et al., 2013) and they continue to face high biodiversity loss rates, despite the recognition of their key importance.

If we focus on plant conservation, after long years of neglect it has made remarkable progress during the past 40–50 years (outlined by Vernon Heywood pp. 314–330) and its importance is now much more widely accepted. In fact, alone of the major groups of organisms it has its own dedicated strategy, the CBD's Global Strategy for Plant Conservation 2011–2020, which despite its shortcomings (Sharrock, 2012; Sharrock et al., 2014; Heywood, 2015) has served as a focus, framework and catalyst and brought together actors from different sectors in efforts to conserve the

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enormous diversity of plantlife and seek ways of using it sustainably. At the same, time there is still a curious failure on the part of the public and politicians to associate the need for the conservation and sustainable use of wild plants and their ecosystems with the calls for increasing investment in applied plant science in support of agricultural development.

As Havens et al., (2014) have commented: '… no country is currently getting plant conservation right; plants are becoming increasingly rare around the world. Plants are often not fully protected by policy, their conservation is underfunded, and their importance is underappreciated'. It is becoming increasingly evident that our current strategies for plant conservation are not sufficiently effective to prevent the continuing decline in plant diversity and we need to review their effectiveness, identify the limiting factors and take whatever steps are necessary to make our conservation protocols more explicit, operational and efficient.

Compared with other groups of organisms, notably birds and mammals, the conservation of plants is poorly funded and the great bulk of the literature on conservation biology and practice refers to animal examples and is not necessarily applicable to plants. This situation has been exacerbated, especially in developed countries, by the decline of botany in universities as an academic discipline and the widespread closure of departments of botany or their loss of identity when they are included within schools of biology, ostensibly due to lack of student demand. Curiously, zoology has not suffered the same fate.

## 3. Plant conservation approaches

Each country has developed its own biodiversity strategy and action plan as required under the CBD and its own national policies legislation and mandate. The situation in Australia with a flora of 21,000 species, of which at least 84% are endemic, is explained in the paper by Linda Broadhurst and Davis Coates (pp. 348–356) where as they say, 'Plant taxa are protected, conserved and managed under a range of legislation at the State- and Territory-level, as well as Federally for matters of national significance'. Yet, despite considerable investment aimed at conserving and recovery of Australian biodiversity, threatened plants in particular appear to be continuing to decline. The reasons for this are explored, including the consequences of loss of habitat, impacts of biological invasions, and a lack of public awareness of the importance of the cultural and eco-economic value of wild plants and the need to conserve them.

Plant conservation is largely dependent in most countries on the creation of a system of protected areas. This is complemented by both *in situ* and *ex situ* actions at the species and population level, notably species recovery actions, reintroductions and conservation translocations and the creation of genebanks for storing germplasm such as seed, pollen, cell and tissue cultures. Also, much effort is now being placed on ecological restoration.

Protected areas now serve a variety of functions of which biodiversity conservation is but one and a series of best practice guidelines for their maintenance and management are available (https://www.iucn.org/theme/protected-areas/publications/best-practice-guidelines). Ideally, their role in biodiversity conservation is to provide some degree of protection to the ecosystems habitats and species within them. This requires that they be properly maintained and managed but these conditions do not apply in many such areas. There is often undue reliance on protected areas a means of conserving the species they house and a failure to distinguish between the presence of species in a protected area and their persistence over time (Heywood, 2015; Donaldson et al., 2017). Moreover, if target species within a protected area are threatened, their effective conservation will require that the threats be removed or contained. Unfortunately, many protected areas have not been fully inventoried and the threat status of the species they contain is not known. The effectiveness of protected areas in conserving biodiversity as compared with non-protected areas is still not well understood and the available evidence is somewhat equivocal for plants (for references see discussion in Heywood, 2015).

Most biodiversity is found outside protected areas and although various off-site conservation approaches have been developed, such as conservation easements, incentive-based schemes, local participatory management, public-private partnerships, etc (Gustanski and Squires, 2000; Hunter and Heywood, 2011), it is remarkable how little attention has been paid by the conservation community to this key issue. It is conventional belief that most targeted *in situ* conservation of species takes place in protected areas but that is only true of a number of developed countries (for example Australia, USA and Europe) but not in most tropical countries. For example, a recent review states that 'most *in situ* conservation of forest genetic resources happens outside protected areas on lands in a range of public, private and traditional ownerships, especially in multiple-use forests and those used primarily for wood production' (Potter et al., 2017).

An encouraging development is the increase in the participation of local communities in the co-creation and co-management of protected areas, especially in tropical countries. For example, in Bolivia, Peru, Brazil, Ecuador and Colombia, under the PANORAMA – Solutions for a healthy planet initiative, coordinated by the IUCN Global Protected Areas Programme, innovative strategies to empower indigenous groups, 'utilising joint administration and implementing integrated or mosaic management of adjacent 'zones' have all had wide-ranging positive socio- and environmental benefits' (http://panorama.solutions/en/about-panorama-%E2%80%93-solutions-healthy-planet).

At the species level, targeted *in situ* conservation is undertaken by recovery programmes whereby species, or targeted populations of species, that have become endangered through loss of habitat, decrease in population size, loss of genetic variability, or other factors threatening their survival, are recovered in their present habitat to a state whereby they are able to maintain themselves without further human intervention (Heywood, 2015; BGCI and IABG, 2018). These programmes are mainly confined to countries such as Australia, Canada, China, New Zealand, and many European states but are rarely found in tropical countries. The reasons why many countries fail to undertake what is a key conservation approach, appear to lie in the widespread failure to recognize that *in situ* conservation of target species, especially those that are threatened, commonly requires action in addition to their presence in a protected area. A Manual of Species Recovery for plants, providing best practice guidelines and practical guidance, has been prepared by BGCI and IABG (2018). It stresses the need for proper ecogeographical surveys, a thorough assessment of the threats to target species and emphasizes the importance of understanding their genetic variation.

Species recovery programmes are complemented by plant reintroductions involving the deliberate movement of individuals of a species to parts of its natural range from which it has been lost, with the aim of establishing a new population. They are difficult and complex operations and reported success rates are low (Godefroid et al., 2011), due to range of factors such as poor planning and execution, overoptimistic expectations of what is possible and lack of suitable habitat. In their review of the Center for Plant Conservations's revised Best Practice Guidelines for the reintroduction of rare plants, Joyce Maschinski and Matthew Albrecht (pp. 390–395) recommend that before embarking on attempts at reintroduction, one should make the case for them and consider if alternative conservation strategies are available. As in the case

of species recovery attempts, it is important to understand the threats affecting the target species and ensure that they are not present in the recipient sites. Again, as in species recovery knowledge of the genetic composition of both the donor and recipient populations is critical for success.

In most countries, the management of national parks and protected areas is the responsibility of different ministries or agencies from those charged with *ex situ* and *in situ* conservation and species recovery. The need for close integration of area-based and species-based approaches in conservation planning is, however, essential. An excellent example of such coordination is in the 1125 ha Xishuangbanna Tropical Botanic Garden in Yunnan, China. It includes a 250-hectare patch of well-preserved primary tropical rainforest, two national field research stations, a centre for integrative conservation, laboratories for biogeochemistry, molecular biology & biotechnology, plant phylogenetics & conservation biology, physiological ecology, a germplasm bank for rare & endangered plants, all of which allows it to adopt a comprehensive approach to biodiversity conservation and sustainable use of plant resources.

Conservation of wild plants species *ex situ* is now increasingly being recognized as an important method of conservation, complementing *in situ* approaches, although for many years actively discouraged, largely on the grounds that it might encourage governments to rely on it as a more economical option than maintaining plants in the wild. In the case of plants of agricultural importance, *ex situ* conservation of material in genebanks, especially seed samples of land races and cultivars, has long been the main conservation approach and most of the technology and protocols for seed sampling, storage, germination and regeneration were developed for the agricultural sector, largely under the aegis of FAO and IBPGR (today Bioversity International). Today there are over 1300 seedbanks, housing over 6.5 million accessions. On the other hand, it was not until the endorsement by governments of the Global Plan of Action (GPA) for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture at the International Technical Conference on Plant Genetic Resources held in Leipzig, 17–23 June 1996 (FAO, 1996) that the importance of *in situ* conservation of wild plants and crop relatives in natural ecosystems was officially recognized as an important component of plant genetic resource conservation (Heywood, 1999a, 2009).

Of course, botanic gardens are characterized by their holdings of (*ex situ*) living plant collections although most of these were nor established with conservation in mind. Together the world's botanic gardens hold in cultivation about a quarter of the total number of known plant species but their value as conservation resources have been questioned (Heywood, 1999). The reasons for the poor conservation utility of botanic garden *ex situ* material is discussed in detail by Sergei Volis (pp. 365–372) who proposes a strategy for the management of threatened plants in living collections, which includes setting regional conservation priorities for the species, creation of genetically representative collections for high priority species, and the use of these collections in *in situ* actions such as recovery and reintroduction. The correct identification of botanic garden accessions can be a challenge but is essential if they are to be used for science, conservation or economic purposes. A major project that is aimed at providing an important resource for this purpose in China is described by Jingping Liao, Hongwen Huang and Zheng Zhang (pp. 357–364) – the *Ex situ* Flora of China. This aims to catalogue the enormous diversity of plants cultivated in China's 180 botanic gardens which grow an estimated 20,000 species and provide information on taxonomy, biology, introduction and collection data and color photos of stems, leaves, flowers, fruits and seed, as well as useful information of cultivation requirements and main uses of each species.

The role of botanic gardens in seed banking was slow to develop in comparison with that of the agricultural sector but in recent years there has been a steady growth in the creation of seedbanks and other *ex situ* storage facilities in botanic gardens, as the value of such material for species recovery and reintroductions has been better appreciated. According to Katherine O'Donnell and Suzanne Sharrock (pp. 373–378) in their paper on the contribution of botanic gardens to *ex situ* conservation through seed banking, information from BGCI's databases indicates that there are at least 350 seed banking botanic gardens in 74 countries and together they have banked 56,987 taxa including more than 9000 taxa that are threatened with extinction. They note however, that the majority of collections which have been the subject of threat assessments are from species that are not threatened with extinction.

The living collections and seed banked material in botanic gardens are also used for various purposes other than conservation such as horticultural research, phenological observations, maintenance of the displays, provision of material for seed exchange and for habitat restoration.

In addition to the above-mentioned conservation methods, a series of innovative or intermediate techniques are increasingly being deployed. These are discussed by Sergei Volis (pp. 379–382) who presents two approaches that in some ways bridge the gap between *in situ* and *ex situ*. In the first of these, *quasi in situ* material collected in natural populations is planted and maintained outside its original location for long-term storage of the genetic diversity of species and in the in production of seeds needed for restoration, while in the second of these, the *inter situs* approach the aim is reintroduction. He also explains the concept of 'conservation-oriented restoration' which he recently introduced (Volis, 2016a, b) in which *inter-situ* and *quasi in situ* are necessary components.

Considerable attention is now being paid to the problems of conserving species that are exist only as small populations. In China, a programme for the conservation of plant species with extremely small populations (PSESP) – defined as those having a narrow geographical distribution as a result negative external factors over a long period and whose numbers are below the minimum required to prevent extinction (State Forestry Administration of China, 2012) – first promulgated in Yunnan Province (Yang et al., 2017), is now becoming more widely adopted and several national and regional-level conservation strategies and actions for conserving them are being implemented over the coming years. A related conservation approach which originated in Valencia, Spain but has now spread to several other countries, is the Plant Micro-Reserves (PMRs) that is described by Simón Fos, Emilio Laguna and collaborators (pp. 383–389). The PMR model aims to model to protect small sites for endemic and endangered plants and complements conventional protected areas. As the authors say, it presents a unique opportunity to assess the role of small protected areas in improving our knowledge of biodiversity. They review the effectiveness of this approach and then consider if this model could help solve some of the problems found in the protection of Chinese endangered plants, notably those with very small populations.

## 4. The changing role of botanic gardens

Over the centuries, botanic gardens have occupied many roles and are constantly adapting to new circumstances. Today an increasing number of gardens have associated themselves closely with the biodiversity conservation movement although with the exception of new gardens designed specifically for conservation activities, the majority were not created for this purpose and sometimes have difficulties in adapting to this demanding new role.

Although the botanic gardens conservation movement developed during the 1970s and 1980s, with a series of conferences and seminars at Moscow, Kew, Kuala Lumpur and Longwood, and the creation of bodies such as the Botanic Gardens Conservation Co-ordinating Body at the IUCN Threatened Plants Unit at Kew in 1978, the Botanic Gardens Secretariat in 1987 (later BGCI) by IUCN and the Center for Plant Conservation in the USA, the notion that botanic gardens should occupy themselves with the conservation of rare and endangered species was first promulgated explicitly at the International Congress for Nature Protection held in Paris in 1923 with special reference to mountain gardens and at the second Congress also held there in 1931 which passed a resolution that rare or endemic plant species threatened with extinction should be cultivated and placed in reserve in botanic gardens. The first comprehensive attempt to involve the world's botanic gardens in the protection of species threatened with rapid extinction was made at an international colloquium of the sub-commission of Botanic Gardens of IUBS on 'The scientific organization of botanic gardens' in 1953 (also in Paris). Amongst the themes covered was the protection of nature and living collections and it was envisaged that some botanic gardens should be transformed into 'sanctuary gardens' and that they accept responsibility in their respective regions for the inventory and monitoring of the localities of rare plants and eventually their preservation. This foreshadowed at an international level the creation of IABG as a scientific member of IUBS and at a national level the creation of the network of Conservatoires Botaniques Nationaux in France charged with precisely the responsibilities just outlined.

The major event in the botanic garden conservation movement was the creation in 1987 by IUCN of the Botanic Gardens Conservation Secretariat (BGCS) as one of the key components of the joint IUCN/WWF Plant Conservation Programme. The publication of the 'Botanic Gardens Conservation Strategy' in 1989 indicated the main ways in which this new role for botanic gardens could be implemented in those gardens that wished to participate. At that time it was estimated that there were c. 1500 botanic gardens in the world, but today the number of recorded botanic gardens has increased to around 2500. It is not known how many of these are functional botanic gardens that meet the basic defining criteria, namely 'a centre holding documented collections of living plants for a range of purposes such as scientific research, horticultural development, conservation, plant introduction, display, sustainability, education and outreach'.

BGCS and its successor BGCI have transformed attitudes to conservation by botanic gardens and today BGCI now includes over 500 member institutions in 96 countries. A great deal of networking, strategic thinking and technical planning has been carried out, strategies and guidelines produced and an increasing number of botanic gardens have committed themselves to conservation. What is now needed is more effective and consistent implementation of these policies, a problem that affects plant conservation as a whole.

In view of the enormous disparity of botanic gardens, it is not altogether surprising that despite all these efforts, they still constitute a much under-used resource in the conservation of native plant species, despite the fact that they have unrivalled skills and knowledge of growing plants built up from many years of practical experience. Initially there was great skepticism as to the capacity of BGs to play a significant role in plant conservation and even today some conservation agencies are often unaware of this vast resource that is available to them. Conservation is difficult both scientifically and technically, it is expensive and requires properly trained staff, space and facilities, and it requires long-term commitment. And this is beyond the capacity of many botanic gardens and great challenges lie ahead if they are to mobilize their efforts effectively. It is to the enormous credit of the botanic garden community that it has assumed the mandate of *ex situ* conservation and participation in other conservation procedures such as species recovery and translocation, often without official national recognition, let alone the necessary finance. The imbalance in the distribution of botanic gardens around the world needs to be addressed although it may not be possible to resolve this fully, and another challenge is matching the demand for conservation action by botanic gardens with the capacity available. We will have to give serious consideration to developing new models of botanic gardens that are more suited to their current scientific, horticultural, educational, outreach and social roles.

Looking to the future, botanic gardens will become more specialized and more intimately related to and interactive with other urban green spaces (including public parks and gardens, urban forests and nature reserves). They will need to become much more responsive to the demands of the local community and intensify their attempts to put across the conservation and sustainability messages to the public through their displays, collections, electronic media and so on. This will be one of their most valuable roles because ultimately it is the force of public pressure that will force governments into action.

Global change will affect botanic gardens in many different ways. Human population displacement and large scale movements as a result of demographic growth, changes in agricultural and land use policies and the impacts of war may place some gardens at risk. Already many of the older botanic gardens in Europe and the Mediterranean region that were founded in cities are now surrounded by massive building development and remain as tiny islands in a sea of urbanization and pollution. The effects of climate change on botanic gardens will be various. For one thing, in some parts of the world, global warming and increasing aridity may make the growing conditions unsuitable and imperil the continued existence of some botanic gardens and the living collections that they maintain. The accessions policy of gardens may have to change to take into account the new conditions – some species will no longer be able to be grown while the successful introduction of others that were previously unsuitable for cultivation will become possible. Changes in flowering times may affect the availability of pollinators and increase or decrease hybridization between species, with serious implications for conservation collections. Invasive species will become more common and cause problems for botanic garden maintenance.

Timothy Entwisle, Chris Cole, Peter Symes (pp. 338–347) describe how Royal Botanic Gardens Victoria plans to adapt to projected climate change. It has published a 'Landscape Succession Strategy' for its Melbourne Gardens, that recognizes the need adapt its planting and planning, so as to take into account anticipated changes to rainfall and temperature. Specifically, the Strategy sets out the steps needed over the next twenty years for the botanic garden to make the transition to one resilient to the climate modelled for 2090.

Christopher Dunn (pp. 396–401) draws attention to the fact that it is not just plant diversity that will be affected by environmental change, but also cultural and linguistic diversity. As he points out, of the c. 7000 extant languages in the world, fully 50% are considered to be at risk of extinction. So he makes the case that if we are to maintain the integrity of plant life, botanic gardens need to do more than consider the effects of environmental change on plants within the context of major conservation strategies but 'should actively engage in understanding and communicating the broader impacts of environmental change to biological and cultural diversity'.

In the coming decades, we will see a substantial redistribution of botanic gardens: more will be established in the tropics and subtropics/Mediterranean areas, while in temperate areas of the world an increasing number of the older gardens which are unable to

adapt to the changing world will lose their status and cease to operate as botanic gardens, become redundant, unviable or even close. Thus the biogeographical map of botanic gardens will be redrawn.

The future will be one of renewal for the older foundations which are able to adapt to the changing condiitions while new models of botanic gardens will be established and new kinds of activities will develop in the more recently founded gardens. There will be many conflicts and challenges and much of the old order may well disappear but botanic gardens will continue to play a major part in our scientific, socio-economic and cultural life.

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