



Importance of botanical gardens in plant sciences: A review

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Abstract

Botanical gardens present a potential solution to the paucity of functional data for underrepresented plant taxa. The diverse living collections housed in botanic gardens represent roughly 30% of all plant species ^[1] and provide researchers with easy access to thousands of species from all over the world with diverse life and evolutionary histories. Botanic gardens also often have in-house laboratories and are associated with universities and other research institutions, thus allowing scientists to overcome many of the infrastructural difficulties associated with acquiring functional trait data for tropical forest species *in situ*. In this review, I show that despite their potential value, botanic gardens remain grossly underused for studying the functional ecology of plants. The review discusses the benefits and potential biases of botanic gardens for academicians and researchers.

Keywords: botanic gardens, researchers, laboratories, *in situ*

1. Introduction

Plant diversity is currently being lost at an unprecedented rate, resulting in an associated decrease in ecosystem services ^[2]. About a third of the world's vascular plant species face the threat of extinction due to a variety of devastating activities, including, over-harvesting and over exploitation, destructive agricultural and forestry practices, urbanization, environmental pollution, land-use changes, exotic invasive species, global climate change, and more ^[3]. We therefore need to increase our efforts to develop integrative conservation approaches for plant species conservation. Botanical gardens devote their resources to the study and conservation of plants, as well as making the world's plant species diversity known to the public. These gardens also play a central role in meeting human needs and providing well-being. In this review, a framework for the integrated missions of botanical gardens, including scientific research, *in/ex situ* conservation, plant resource utilization, and citizen science are catalogued.

The review discusses the future challenges and responsibilities of botanical gardens in a changing world, including: the negative effects of outbreeding and/or inbreeding depression; promoting awareness, study, and conservation of plant species diversity; accelerating global access to information about plant diversity; increasing capacity building and training activities.

Botanical gardens are collections of plants cultivated in a closed space to be utilized for scientific inquiry, recreation, conservation, botanical and horticultural education and also for public landscape aesthetics. Due to their richness in plant diversity and also their facilities, botanical gardens can have remarkable roles in agricultural studies and plant sciences. In addition, botanical gardens are very important regarding to their roles in creating green space in urban spaces, tourist attractions, economical objects and well-being aspects of peoples. Accordingly, in this study, the roles of botanical gardens were reviewed regarding to research and educations. These topics were also discussed

regarding to their usage in agriculture and plant science studies. Furthermore, some scientific potential of botanical gardens for future studies have been also taken into account.

2. History and Development

As the biosphere itself is a global garden, there is no doubt that the first garden was not made but discovered. A natural spot was made pleasant by a belt of trees, plants with flowers and fruits. No one tends this garden and it grows of its own accord. In the oldest accounts, such spots are the gardens of the Gods or of those favoured by the Gods, so that there is no need as special effort to keep the place in order ^[1, 4].

The origin of modern botanical gardens can be traced to European medieval medicinal gardens known as physic gardens, the first of these being founded during the Italian Renaissance in the 16th century. This early concern with medicinal plants changed in the 17th century to an interest in the new plant imports from explorations outside Europe as botany gradually established its independence from medicine. In the 18th century systems of nomenclature and classification were devised by botanists working in the herbaria and universities associated with the gardens, these systems often being displayed in the gardens as educational "order beds". With the rapid rise of European imperialism in the late 18th century botanic gardens were established in the tropics and economic botany became a focus with the hub at the Royal Botanic Gardens, Kew, near London ^[5].

Over the years botanical gardens, as cultural and scientific organisations, have responded to the interests of botany and horticulture. Nowadays most botanical gardens display a mix of the themes mentioned and more: having a strong connection with the general public there is the opportunity to provide visitors with information relating to the environmental issues being faced at the start of the 21st century, especially those relating to plant conservation and sustainability.

3. Network

Worldwide there are now about 1800 botanical gardens and arboreta in about 150 countries (mostly in temperate regions) of which about 400 are in Europe, 200 in North America, 150 in Russia and an increasing number in East Asia [6]. These gardens attract about 150 million visitors a year so it is hardly surprising that many people gained their first exciting introduction to the wonders of the plant world in a botanical garden.

Historically, botanical gardens exchanged plants through the publication of seed lists. This was a means of transferring both plants and information between botanical gardens. This system continues today although the possibility of genetic piracy and the transmission of invasive species have received greater attention in recent times.

The International Association of Botanic Gardens was formed in 1954 as a worldwide organisation affiliated to the International Union of Biological Sciences. More recently coordination has also been provided by Botanic Gardens Conservation International (BGCI) which has the mission "To mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet". BGCI has over 700 members- mostly botanic gardens- in 118 countries and strongly supports the Global strategy for plant conservation by producing a range resources and publications, and by organizing international conferences and conservation programs [7].

Communication also happens regionally. In the United States there is the American Public Gardens Association and in Australasia there is the Botanic Gardens of Australia and New Zealand (BGANZ) [7].

4. Role and Function of Botanical Gardens

Botanic gardens have had a changing role throughout history, beginning often as medicinal gardens for the study and cultivation of plants with healing properties and going through many phases including of course as pleasure gardens. But the fact that their collections are more or less scientific means they are continually adapting and serving the needs of their societies in evolving ways as new challenges face those societies [8].

In current times, they are becoming key players in both the conservation of plants and in the education of the people who come to see them. They are also starting to play a role in the mitigation of the effects of climate change, and could be absolutely vital to the survival of the planet as they are perfectly placed to help move species around and help ecosystems to adapt to new climates in different regions. The various roles played by botanical Gardens are as follows.

4.1 Scientific research

Botanical gardens are good locations for many branches of scientific research. Botanical gardens not only serve as taxonomic and systematic research centres [8], but they also play an important role as valuable sources of plant ecology data collection such as phenological indication of climate change, plant physiology and plant growth tactics, and plant-animal interactions [3, 4, 5, 9]. For plant functional characteristics, botanical gardens can provide a large set of species to study functional trade-offs between species traits and plant performance [10]. The study of bamboos at Xishuangbanna Tropical Botanical Garden in Yunnan, China by [10, 11] revealed that the maximum height

of grasses is determined by their roots. Another example is the monitoring of plant phenology varieties, which has a long tradition in some gardens and is regarded as one of the most sensitive indicators of climate impacts on vegetation in mid-latitude areas [12]. In fact, botanical gardens have contributed greatly to our understanding of the responses of plant species to global climate change [13].

4.2 Plant Conservation

Plants are universally recognized as a vital part of the world's biological diversity and an essential resource for the planet. In addition to the small number of crop plants used for basic food and fibres, many thousands of wild plants have great economic and cultural importance and potential, providing food, medicine, fuel, clothing and shelter for vast numbers of people throughout the world. Plants also play a key role in maintaining the planet's basic environmental balance and ecosystem stability, and provide an important component to the habitats for the world's animal life.

Living plant collections are the main contribution of botanical gardens and Botanical Gardens Conservation International (BGCI) estimates that there are 6.13 million accessions in botanical gardens, comprising more than 80,000 species [14, 17]. The conservation of living plants in botanical gardens, especially of species that are threatened in the wild, has a long tradition and has greatly contributed to our understanding of threatened species [18]. The Convention on Biological Diversity defines *ex situ* conservation as the conservation of components of biological diversity outside their natural habitats. *Ex situ* conservation, which plays an important role in saving threatened plant species, is generally associated with botanical gardens. One of the major objectives of botanical gardens is to create and support collections of native taxa, and to build and maintain stocks of plants for *ex situ* conservation and sustainable utilization of plant resources in the world [18, 19, 20].

Strategies for conserving living plants vary among and within garden collections [20]. The direct evaluation of the conservation value of an *ex situ* collection is difficult [21]. Understanding effective sampling structure to allow the capture of significant variation for living plant conservation collections is very important for *ex situ* botanical populations of endangered species. Botanical gardens cultivate many species introduced from different areas, but most cultivated taxa are held in only a small number of collections, and mostly only in small populations without sufficient genetic representation. Lack of genetic exchange and stochastic processes in small populations make them susceptible to detrimental genetic effects [22]. Therefore, both *in situ* ecosystem management and *in situ* conservation play important roles for the conservation of certain plant species in their native habitats. For example, Xishuangbanna Tropical Botanical Garden plays a leading conservation role because of more native species distributed in that area [2, 23]. The botanical garden conserves more than 10,000 plant species with living collections. Of course, the classic functions of a botanical garden, i.e., plant resource development and utilization, should not be neglected in modern botanical gardens.

4.3 Citizen science and popularization of flora

In addition to scientific activities such as conservation and research, public education and garden displays are also

important aims of botanical gardens in different countries [24, 25]. Citizen science, the process whereby citizens engage in science as researchers [26], has long been associated with botanical gardens. Nowadays, the focus of modern citizen science is not “scientists using citizens as data collectors,” but rather, “citizens as scientists” [27]. In fact, decision-makers and NGOs are enhancing their use of volunteers to increase their ability to monitor and control natural resources, assess at-risk species, and protect natural conservation areas [28]. For instance, over the past 36 years, volunteers were able to provide evidence for dramatic declines in the numbers of monarch butterflies in western North America over the past 36 years [29]. Using a citizen science program to investigate the spread of invasive plant species by local resident may promote both knowledge and behavioural changes in local communities [7, 30]. In fact, developing and implementing public data-collection projects often yields both scientific and educational outcomes such as biological research, biodiversity monitoring, and science education [31,32].

Cooperation between scientific researchers and volunteers from local communities has the potential to deepen the scope of research and increase the ability to collect scientific data [33, 34, 35]. Local resident may contribute valuable information because they have more local knowledge from their communities [36]. Collection-based botanical gardens exhibit plant species and thus have a special connection with nature [4, 37]. Citizen science projects at botanical gardens include studies on demographics [38], reproduction [39,40], and ecological and genetic responses to habitat fragmentation [41]. According to a recent study on the interactions between climate change and the functions of botanical gardens, environmental education or citizen science can affect the knowledge, attitudes, and beliefs of the people involved [42]. For instance, by conducting pollination in botanical gardens, citizen scientists were able to help children make the transition from seeing the natural world to scientifically observing nature [43].

5. References

- Mounce R, Smith P, Brockington S. Ex situ conservation of plant diversity in the world's botanic gardens. *Nat. Plants*, 2017; 3:795-802.
- Agurauja R, Zobel M, Zobel K. Conservation of the endemic fern lineage *Diellia* (Aspleniaceae) on the Hawaiian Islands: can population structure indicate regional dynamics and endangering factors? *Folia Geobot*, 2008; 43:3-18.
- Andersen BA, Nicolaisen M, Nielsen SL. Alternative hosts for potato mop-top virus, genus pomovirus and its vectors *Spongopora subterranea* f. Sp. *Subterranea*. *Potato Res*, 2002; 45:37-43.
- Bakalin VA. New taxa of solenostoma and plectocolea and other taxonomic novelties based on study of collections in the New York botanical garden herbarium. *Pol Bot J*, 2013; 58:127-142.
- Galbraith DA, Rapley WA. Research at Canadian zoos and botanical gardens. *Mus Manage Curatorship*, 2005; 20:313-331.
- Gratani L, Crescente MF, Varone L, Fabrini G, Digiulio E. Growth pattern and photosynthetic activity of different bamboo species growing in the Botanical Garden of Rome. *Flora-Morphol, Distrib, Funct Ecol Plants*, 2008; 203:77-84.
- Heywood V. Botanic gardens and the conservation of medicinal plants. *Conservation of medicinal plants*. Cambridge University Press, Cambridge, 1991a, pp 213-228.
- Stevens AD. Botanical gardens and their role in *ex situ* conservation and research. *Phyton*, 2007; 46:211-214.
- Dosmann MS. Research in the garden: averting the collections crisis. *Bot. Rev*, 2006; 72:207-234.
- Coates DJ, Dixon KW. Current perspectives in plant conservation biology. *Aust. J Bot*, 2007; 55:187-193.
- Gratani L, Crescente MF, Varone L. Growth pattern and photosynthetic activity of different bamboo species growing in the Botanical Garden of Rome. *Flora*, 2008; 203:77-84.
- Dawson W, Burslem DFRP, Hulme PE. Herbivory is related to taxonomic isolation, but not to invasiveness of tropical alien plants. *Divers. Distrib*, 2009; 15:141-147.
- Primack RB, Miller-Rushing AJ. The role of botanical gardens in climate change research. *New Phytol*, 2009; 182:303-313.
- Wang B, Phillips JS, Tomlinson KW. Tradeoff between physical and chemical defense in plant seeds is mediated by seed mass. *Oikos*, 2018; 127:440-447.
- Herben T, Nováková Z, Klimešová J. Species traits and plant performance: functional trade-offs in a large set of species in a botanical garden. *J Ecol*, 2012; 100:1522-1533.
- Cao K, Yang S, Zhang Y. The maximum height of grasses is determined by roots. *Ecol. Lett*, 2012; 15:666-672.
- Primack RB, Miller-Rushing AJ. The role of botanical gardens in climate change research. *New Phytol*, 2009; 182:303-313.
- Menzel A, Sparkset TH, Estrella N. European phenological response to climate change matches the warming pattern. *Global Change Biol*, 2006; 12:1969-1976.
- Jackson PSW. An international review of the *ex situ* plant collections of the botanic gardens of the world. *Bot. Gard. Conserv. News*, 2001; 3:22-33.
- Cibrian-Jaramillo A, Hird A, Oleas N. What is the conservation value of a plant in a botanic garden? Using indicators to improve management of *ex situ* collections. *Bot. Rev*, 2013; 79:559-577.
- Farnsworth EJ, Klionsky S, Brumback WE. A set of simple decision matrices for prioritizing collection of rare plant species for *ex situ* conservation. *Biol. Conserv*, 2006; 128:1-12.
- Schal B, Leverich WJ. Population genetic issues in *ex situ* plant conservation. In: Guerrant E.O., Havens K., Maunder M., editors. *Ex Situ Plant Conservation: Supporting Species Survival in the Wild*. Island Press; Washington, 2004, pp. 267-285.
- Brütting C, Hensen I, Wesche K. *Ex situ* cultivation affects genetic structure and diversity in arable plants. *Plant Biol*, 2013; 15:505-513.
- Chen G, Wang ZW, Wen P. Hydrocarbons mediate seed dispersal: a new mechanism of vespicochory. *New Phytol*, 2018.
- Donaldson JS. Botanic gardens science for conservation and global change. *Trends Plant Sci*, 2009; 14:608-613.

26. Maunder M, Higgins S, Culham A. The effectiveness of botanic garden collections in supporting plant conservation: a European case study. *Biodivers. Conserv*, 2001; 10:383-401.
27. Kruger LE, Shannon MA. Getting to know ourselves and our places through participation in civic social assessment. *Soc. Nat. Resour*, 2000; 13:461-478.
28. Conrad CC, Hilchey KG. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environ. Monit. Assess*, 2011; 176:273-291.
29. Silvertown J. A new dawn for citizen science. *Trends Ecol. Evol*, 2009; 24:467-471.
30. Schultz CB, Brown LM, Pelton E. Citizen science monitoring demonstrates dramatic declines of monarch butterflies in western North America. *Biol. Conserv*, 2017; 214:343-346.
31. Jordan RC, Ehrenfeld JG. Knowledge gain and behavioral change in citizen-science programs. *Conserv. Biol*, 2011; 25:1148-1154.
32. Raimondo DC, Ebrahim I, Donaldson JS. Involving communities in the conservation of threatened plants in the Cape Floral Region, South Africa. *S. Afr. J Bot*, 2006; 72:330-331.
33. Bonney R, Cooper CB, Dickinson J. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *Bioscience*, 2009; 59:977-984.
34. Close DC, Messina G, Krauss SL. Conservation biology of the rare species *Conospermum undulatum* and *Macarthuria keigheryi* in an urban bushland remnant. *Aust. J Bot*, 2006; 54:583-593.
35. Fu Y, Guo H, Chen A. Household differentiation and on farm conservation of biodiversity by indigenous households in Xishuangbanna, China. *Springer Netherlands*, 2006; 15:2687-2703.
36. Agurauja R, Zobel M, Zobel K. Conservation of the endemic fern lineage *Diellia* (Aspleniaceae) on the Hawaiian Islands: can population structure indicate regional dynamics and endangering factors? *Folia Geobot*, 2008; 43:3-18.
37. Cohn JP. Citizen science: can volunteers do real research? *Bioscience*, 2008; 58:192-197.
38. Miller B, Conway W, Reading RP. Evaluating the conservation mission of zoos, aquariums, botanical gardens, and natural history museums. *Conserv. Biol*, 2004; 18:86-93.
39. Wagnuis S, Lonsdorf E, Neuhauser C. Patch aging and the S-Allee effect: breeding system effects on the demographic response of plants to habitat fragmentation. *Am. Nat*, 2007; 169:383-397.
40. Donaldson JS, Nänni I, Zachariades C. Effects of habitat fragmentation on pollinator diversity and plant reproductive success in renosterveld shrublands in South Africa. *Conserv. Biol*, 2002; 16:1269-1276.
41. Wagnuis S. Scale dependence of reproductive failure in fragmented Echinacea populations. *Ecology*, 2006; 87:931-941.
42. Neale JMR, Ranker TA, Collinge SK. Conservation of rare species with island-like distributions: a case study of *Lasthenia conjugens* (Asteraceae) using population genetic structure and the distribution of rare markers. *Plant Species Biol*, 2008; 23:97-110.
43. Sellmann D. Environmental education on climate change in a botanical garden: adolescents' knowledge, attitudes and conceptions. *Environ. Educ. Res*, 2014; 20:286-287.
44. Eberbach C, Crowley K. From seeing to observing: how parents and children learn to see science in a botanical garden. *J Learn. Sci*, 2017; 26:608-642.