From Idea to Realisation

BGCI's Manual on Planning, Developing and Managing Botanic Gardens

Botanic Gardens Conservation International

BGCI
Plants for the Planet

From Idea to Realisation

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1. Pyunggang Botanical Garden, South Korea
2. Oman Botanic Garden, Oman
3. Shashamene Botanic Garden, Ethiopia
4. Padua University Botanical Garden, Italy
5. Cincinnati Zoo & Botanical Garden, United States

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Preface

Plants are essential for human and other animal life on Earth in that they capture energy from the sun and convert it into food in the form of their seeds, leaves and roots. Human life is further sustained by the medicines, building materials and fuel that plants provide. Plants are central to many ecological processes such as climate regulation (including carbon dioxide absorption), soil fertility and the purification of both water and air. In spite of their importance, more than 80,000 seed-bearing plant species (20% of the total) are currently under threat. The threat of extinction is largely due to habitat degradation, invasive alien species and over-exploitation, and is likely to be exacerbated by climate change. This plant diversity will be essential to solving some of this century's major challenges in the areas of food security, energy availability, water scarcity, climate change and habitat degradation.

It is estimated that humans have modified more than 50% of the world's land surface, with approximately 40% given over to agriculture and livestock. For plants with natural distributions that fall within these transformed areas, *ex situ* conservation may be the only way they can survive. Even in national parks and wilderness areas not altered or actively managed by people, plant populations may be vulnerable – particularly to invasive species, pests, diseases and a changing climate. In this context, botanic gardens offer the opportunity to conserve and manage a wide range of plant diversity *ex situ*, and *in situ* in the broader landscape. The rationale that botanic gardens have a major role to play in preventing plant species extinctions is based on the following assumptions:

- There is no technical reason why any plant species should become extinct. Given the array of *ex situ* and *in situ* conservation techniques employed by the botanic garden community we should be able to avoid species extinctions.

- As a professional community, botanic gardens possess a unique set of skills that encompass finding, identifying, collecting, conserving and growing plant diversity across the entire taxonomic spectrum.

Botanic gardens are a diverse community, fulfilling multiple objectives including attracting visitors, education, scientific research, horticulture and conservation. They have the potential to maximise their societal impact by becoming better organised as a professional community, and effectively communicating their role and objectives in plant conservation and use to policy makers, funders and the general public.

Central to this mission is the garden itself and the documented collections that it holds. Every living collection in a botanic garden or seed bank has value, particularly if it is correctly named and documented, because it is part of a living laboratory from which we can learn how to conserve or manage plant species. A correctly named specimen is linked to a wealth of literature about its origins, value and uses, and the specimen itself is available for research into how to grow, conserve or use the species that it represents. As more and more plant species become extinct in the wild, the role of botanic gardens as the last refuges for declining species will grow, as will their importance as sources of material for human innovation, adaptation and resilience.

Botanic Gardens Conservation International (BGCI) published the *Darwin Technical Manual for Botanic Gardens* in 1998[1] at a time when very little development and management guidance was available to botanic garden managers. Today, in 2016, this is still the case as evidenced by the requests for technical support received by BGCI on a regular basis. The new *BGCI Manual on Planning, Developing and Managing Botanic Gardens* is a direct response to that demand – and to the growing importance, sophistication and complexity of the world's network of botanic gardens and arboreta over the past 20 years. This is reflected in this new Manual which goes into great depth and covers a wide range of subjects related to the establishment and management of today's botanic gardens. In order to prevent what has turned into a vast tome from becoming unwieldy, and to make it easily navigable by the reader, this Manual is published in a series of fascicles:

Part A: From Idea to Realisation – Bringing a Big Idea to Life is primarily aimed at people who wish to create a new botanic garden or substantially modify an existing garden. It covers the process involved in transforming the idea of a botanic garden into reality with all of the planning, building and development in between.

Part B: Organisational and Operational Essentials sets out the governance models, processes, human resources and financial mechanisms required to operate a botanic garden.

Part C: The Plant Collection – Linchpin of the Botanic Garden is the heart of the Manual, covering the plant collection that the botanic garden is built around. Topics covered in this fascicle include: the development of a collection policy; collection record management systems; horticultural management; and uses of the collection.

Part D: Botanic Gardens as Models of Environmental Sustainability sets out how botanic gardens around the world are addressing sustainability challenges such as energy, water and recycling.

Botanic Gardens Conservation International represents a network of botanical institutions in over 100 countries, including the largest and most influential botanic gardens and arboreta in the world. Our mission is *to mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet*. We do this through: promoting the role of botanic gardens to policymakers and funders; leading innovative and strategic projects; acting as a knowledge hub for best practice, training, resources and expertise; and by mobilising funding to deliver plant conservation impacts in the botanic garden sector and wider society.

We hope that this Manual will make a substantial contribution towards achieving our mission and we very much hope that you are able to make full use of it. This is a living document that, with your help, we will amend and enhance over time. Comments and suggestions are welcome!

Dr Paul Smith
Secretary General, Botanic Gardens Conservation International

[1] Leadlay, E. and Greene, J. (eds) (1998). The Darwin Technical Manual for Botanic Gardens. Botanic Gardens Conservation International, Richmond, UK.

Introduction

Joachim Gratzfeld
Botanic Gardens Conservation International

I. SETTING THE SCENE

What started several millennia ago with the desire to domesticate and cultivate wild plant species for sustained provision of food, may have paved the way for the notions of garden and gardening, and the many forms and uses known today associated with these terms. While gardens were established to serve various functions throughout history, whether for contemplation and aesthetics, study and supply of herbal medicine, or cultivation trials of introduced, exotic plant species, this diversity is still well-reflected in the work of a botanic garden today. Rapid, worldwide change, environmental degradation and loss of biodiversity in the 20th and 21st centuries, have further amplified the roles of botanic gardens as major centres for the conservation of plant diversity in *ex situ* collections and environmental education. The multi-functionality of botanic gardens continues to grow in the face of escalating global challenges, in areas such as monitoring climate change, ecological restoration, food security and social inclusion. Likewise, botanic gardens are increasingly aspiring to act as model organisations for sustainability, promoting the use of environmentally friendly construction materials and low carbon, daily operations.

These multiple roles of botanic gardens in society and the environment are well-illustrated by the definition *'A botanic garden is an institution holding documented collections of living plants for the purposes of scientific research, conservation, display and education'* (Wyse Jackson, 1999). While this characterisation does not require an institution to address all these thematic areas, it places living plant collections and their documentation at the centre of a botanic garden. In turn, the types of living plant collections and the nature of the information recorded and managed, will vary according to their functions, be it for research, conservation, education, public outreach, inspiration or recreation.

Defining an institution as a botanic garden based on minimum standards of documentation for collections that serve different purposes however, is subject to ongoing debate and work-in-progress within the botanical community. For instance, this concerns historical institutions with collections whose documentation may have been lost, but whose plants represent unique specimens of a threatened species with universal heritage value. It also relates to institutions with an educational or recreational intention as the primary goal, but with limited details regarding the origin of the plant collection. However, documentation of collections – irrespective of their main purpose – is essential in the context of laws and policy covenants that govern the international exchange of plant material. Comprehensive information on plants held at botanic gardens is a necessity to demonstrate legal compliance with adopted provisions.

II. PURPOSE OF THIS MANUAL

Very few resources exist to this day that offer guidance on botanic garden planning, development and management in a single, comprehensive compendium. Building on BGCI's earlier handbook, The Darwin Technical Manual for Botanic Gardens (Leadlay and Greene, 1998), the present edition aims to maintain its major role in this niche by providing direction and up-to-date information. Since 1998, there have been major changes in biodiversity policy that influence and inform botanic gardens. These are reflected in the 2nd edition of the International Agenda for Botanic Gardens in Conservation published by BGCI in 2012 which serves as a companion volume to this Manual. Of major significance is the Global Strategy for Plant Conservation (GSPC) of the Convention on Biological Diversity (CBD) which acts as the focal, international framework to conserve and maintain plant diversity. The work of botanic gardens worldwide is paramount to achieving the objectives and targets of the GSPC as well as of the Strategic Plan for Biodiversity 2011-2020, including its Aichi Biodiversity Targets – the overarching framework on biodiversity, not only for the biodiversity-related conventions, but for the entire United Nations system and all other partners engaged in biodiversity management and policy development (Box I).

III. TARGET AUDIENCE

This Manual is intended for botanic gardens as ever-evolving institutions that respond to environmental and societal needs, changes and challenges. As a comprehensive resource, the guidance provided aims at an equally inclusive range of stakeholders, including:

- Newly developing or recently established botanic gardens with limited expertise that may use the manual as a source of ideas and guidance for their development;
- Established botanic gardens that may seek the latest information on particular aspects of botanic garden management as part of an ongoing re-development or organisational review;
- Botanic garden staff who may wish to broaden their outlook or see how their role relates to the overall work of botanic gardens; and
- Other environmental and conservation organisations, government agencies, businesses and individuals with an interest in supporting botanic gardens and/or integrated *ex* and *in situ* conservation initiatives.

This Manual is not meant to be prescriptive but to offer guidance and ideas with case studies from around the world. It is hoped that components will be useful in training, reviewing the ongoing work of botanic gardens and helping to raise standards. The internet-based version aims to facilitate a better understanding and visualization of interconnected themes and processes, and allows for regular updates, whilst users also have the option to download a print copy. Interactive, hyperlinked information is provided with extensive references for further information. Key messages are highlighted and illustrations are designed to reinforce important points. Overall, this Manual is intended to offer a globally representative illustration of botanic garden development and management issues, beyond a national or particular thematic focus. Feedback will be invaluable to ensure that the guidance and information provided meets its purpose and evolves over time to better serve the botanic garden community.

Box I The 2020 Objectives and Targets of the Global Strategy for Plant Conservation (with relevant strategic goals and targets under the Strategic Plan for Biodiversity 2011-2020, referred to as 'Aichi Biodiversity Targets')

Objective I: Plant diversity is well understood, documented and recognized.

Target 1: An online flora of all known plants.

Target 2: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action.

Target 3: Information, research and associated outputs, and methods necessary to implement the strategy developed and shared.

(All targets relevant to Aichi Target T19)

Objective II: Plant diversity is urgently and effectively conserved.

Target 4: At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration. (Relevant to Aichi Targets T5, T11, T19)

Target 5: At least 75% per cent of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity. (Relevant to Aichi Target T11)

Target 6: At least 75 per cent of production lands in each sector managed sustainably, consistent with the conservation of plant diversity. (Relevant to Aichi Target T7)

Target 7: At least 75 per cent of the world's threatened species conserved *in situ*. (Relevant to Aichi Target T12)

Target 8: At least 75 per cent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes. (Relevant to Aichi Target T12)

Target 9: 70 per cent of the genetic diversity of crops, including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge. (Relevant to Aichi Target T13)

Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded. (Relevant to Aichi Target T9)

Objective III: Plant diversity is used in a sustainable and equitable manner.

Target 11: No species of wild flora endangered by international trade. (Relevant to Aichi Targets T4 and T6)

Target 12: All wild-harvested plant-based products sourced sustainably. (Relevant to Aichi Targets T4 and T6)

Target 13: Indigenous and local knowledge, innovations and practices associated with plant resources, maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care. (Relevant to Aichi Target T18)

Objective IV: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted.

Target 14: The importance of plant diversity and the need for its conservation incorporated into communication, educational and public awareness programmes. (Relevant to Aichi Target T1)

Objective V: The capacities and public engagement necessary to implement the Strategy have been developed.

Target 15: The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy. (Relevant to Aichi Target T20)

Target 16: Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy. (Relevant to Aichi Target T17)

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A From Idea to Realisation – Bringing a Big Idea to Life

Part A: From Idea to Realisation – Bringing a Big Idea to Life

Contents

CHAPTER 1: PLANNING AND IMPLEMENTING BOTANIC GARDEN DESIGN PROJECTS

Chapter 1:
Planning and Implementing Botanic Garden Design Projects

Annette Patzelt and Andrew Anderson, Oman Botanic Garden

1.0 DEFINITIONS

Business case: A compelling justification of the added value of the proposed action and resources needed for the investment, intended to convince decision makers to approve a proposed action.

Business plan: A document outlining how an institution will be governed, marketed and funded to successfully achieve its goals and objectives. Depending on the context, the business plan may either be short-term or long-term.

Design brief: A document containing very detailed information about the project to guide the design process. It is a more exhaustive expansion of the scope of work.

Detailed design: Development phase that comprises the production of detailed information and construction specifications.

Feasibility study: Evaluation and analysis of the potential of a proposed project which is based on extensive investigation and research to support the process of decision making.

Master plan: An essential document of any botanic garden development that identifies activities, opportunities and facilities that need to be considered to deliver the vision and mission of the organisation. It can be used to translate the requirements defined in the scope of work and design brief into a concept design solution. It may comprise to-scale plan drawings, illustrations and sketches, as well as cost estimates of the construction work.

Mission: Concise statement articulating an institution's fundamental purpose.

Pre-operations: A vital component during the planning and design phases of the botanic garden which establishes the preliminary governance and organisational structure, the plant collection and initial programmatic activities including research, outreach and education.

Assessing project site suitability in Madagascar. (Image: Paul Smith)

Request for proposals (RFP): A comprehensive document that outlines the aims of the project and allows bidders to produce a proposal.

Scope of work: Most critical component of the Request for Proposal (RFP). It provides comprehensive information about the project and defines the expertise and experience required.

Strategic plan: Description of the overarching direction or directions during a specified period, often over three to five years. Strategic plans set the tone and targets for the entire organisation and identify the highest programme priorities.

Tender documents: Provide the highest level of detail for all technical construction specifications.

Vision: The long-term aspiration(s) of an institution.

1.1 INTRODUCTION

KEY MESSAGE

Time and resources are often underestimated – botanic gardens do not happen overnight but are long-term endeavours with considerable ongoing operational requirements.

The conceptualisation, design, renovation, transformation or expansion of a botanic garden or any of its parts is a unique and rewarding experience, with ecological, cultural, educational and economic benefits that may last for generations. Comparatively few resources exist to date to guide the development process of a botanic garden. This chapter is intended to provide an outline of the steps and strategic thinking recommended for the planning, design and construction of a botanic garden project of any scale or complexity.

Time and resources are often underestimated – the development of a botanic garden is a long-term endeavour with considerable ongoing maintenance requirements. Appropriate allocation of time and resources during the preliminary planning will maximise the chances of the project meeting its budgetary and scheduling needs in the ensuing phases. This will also help attract further support and funding at a later stage, as illustrated in Case study 1.1.

CASE STUDY 1.1

How to establish a botanic garden? The example of the Australian Arid Lands Botanic Garden, Port Augusta

John Zwar, Port Augusta, Australia

How do you establish a botanic garden? The short answer is: with difficulty and extreme persistence in the case of The Australian Arid Lands Botanic Garden at Port Augusta in South Australia.

My horticultural training was undertaken at the Botanic Gardens of Adelaide. Following an overseas study tour looking at amenity horticulture in arid regions, I proposed to the Port Augusta City Council in 1981 that a botanic garden featuring arid zone plants, both for its scientific and educational value and as a tourist attraction, should be established. Although not enthusiastic, the Council gave approval to investigate the proposal. There was no budget and the help of some keen local supporters of the idea was enlisted. The concept was publicised using local and state media, letters to politicians, by talking to interested groups and mounting public displays over many years. There was considerable interest and support in the wider community.

A site of more than 250 ha of Crown land at Port Augusta West was identified. It included the best remaining natural vegetation close to the city with a range of soil types and access from a national highway. In 1984, a 'Friends' support group was formed. This group became incorporated and, with an active committee, vigorously promoted the project and commenced fundraising. Regular meetings were held and a newsletter produced. Petitions were prepared and more than 30000 signatures of people supporting the development of the botanic garden were presented to both state and federal parliaments. Assisted by volunteers, a site clean-up and fencing were initiated, funded by the Friends group, City Council and government unemployment relief schemes.

After further investigation by a state government committee, support for the concept came from the state, but without financial commitment. There were occasional meetings held by the City Council to discuss the proposal with interested parties but progress was slow and little happened for long periods. Eventually the state government commissioned a plan for the botanic garden which proposed displaying collections of arid zone plants from around the world but, with no funding, this lapsed.

In 1988, the Port Augusta City Council established a Management Advisory Committee to seek funding and oversee development. At this time corporate sponsor Western Mining Corporation (WMC) became interested and funded initial botanical surveys of the site and commissioned a detailed master plan by landscape architect Grant Henderson, which was adopted as the basis for future development. WMC successfully put pressure on both state and federal governments to provide some funding for the project whilst they made a substantial contribution as well. The City Council also contributed and, after more than 12 years, AUD 1.2 million was available to develop the botanic garden. Its first permanent worker commenced work in 1994 which greatly advanced site progress, aided considerably by Friends volunteers.

In February 1996, a Board of Management reporting to the Council met for the first time replacing the Advisory Committee. Stage 1 of The Australian Arid Lands Botanic Garden opened in September 1996. The City Council operates and funds the botanic garden which continues to develop on a low budget with a small number of paid staff. Up until 2004, WMC resources provided a total of almost AUD 1 million. State and federal governments have had little further input. Friends' volunteers with appropriate skills assist substantially with the development and maintenance, plant propagation, tour guiding and working with visiting students. The Friends have provided close to AUD 1 million for the botanic garden since its inception.

The development of The Australian Arid Lands Botanic Garden has been difficult, slow and drawn out and would not have happened without the dogged persistence of the Friends group, wider community support and substantial input from a corporate sponsor (WMC). The botanic garden now has an impressive plant collection, visitor interpretive centre, meeting room and nursery facility, as well as a research area looked after by a small number of paid staff and a group of dedicated volunteers. It plays an increasingly important role in the scientific and cultural life of the region and the state.

The central courtyard in The Australian Arid Lands Botanic Garden features plants from the Great Victoria Desert. Swainsona formosa, Sturt's Desert Pea (Fabaceae), South Australia's floral emblem, is the impressive ground cover in the foreground. (Image: John Zwar)

1.2 THE FOUNDATION: THE BIG IDEA

1.2.1 Envisioning the Botanic Garden

"We have a big idea!" Botanic garden development projects of any scale begin with someone having a vision for a new botanic garden or the redevelopment of part of an existing one. A comprehensive, well-thought-out process will ensure that the initial creativity and passion nurture the big idea and continue to inspire the project through to its completion and launch. While the structure and organisation of a new development, as well as of the stakeholders involved, vary significantly between different projects and locations, answering the following key questions will get the process going:

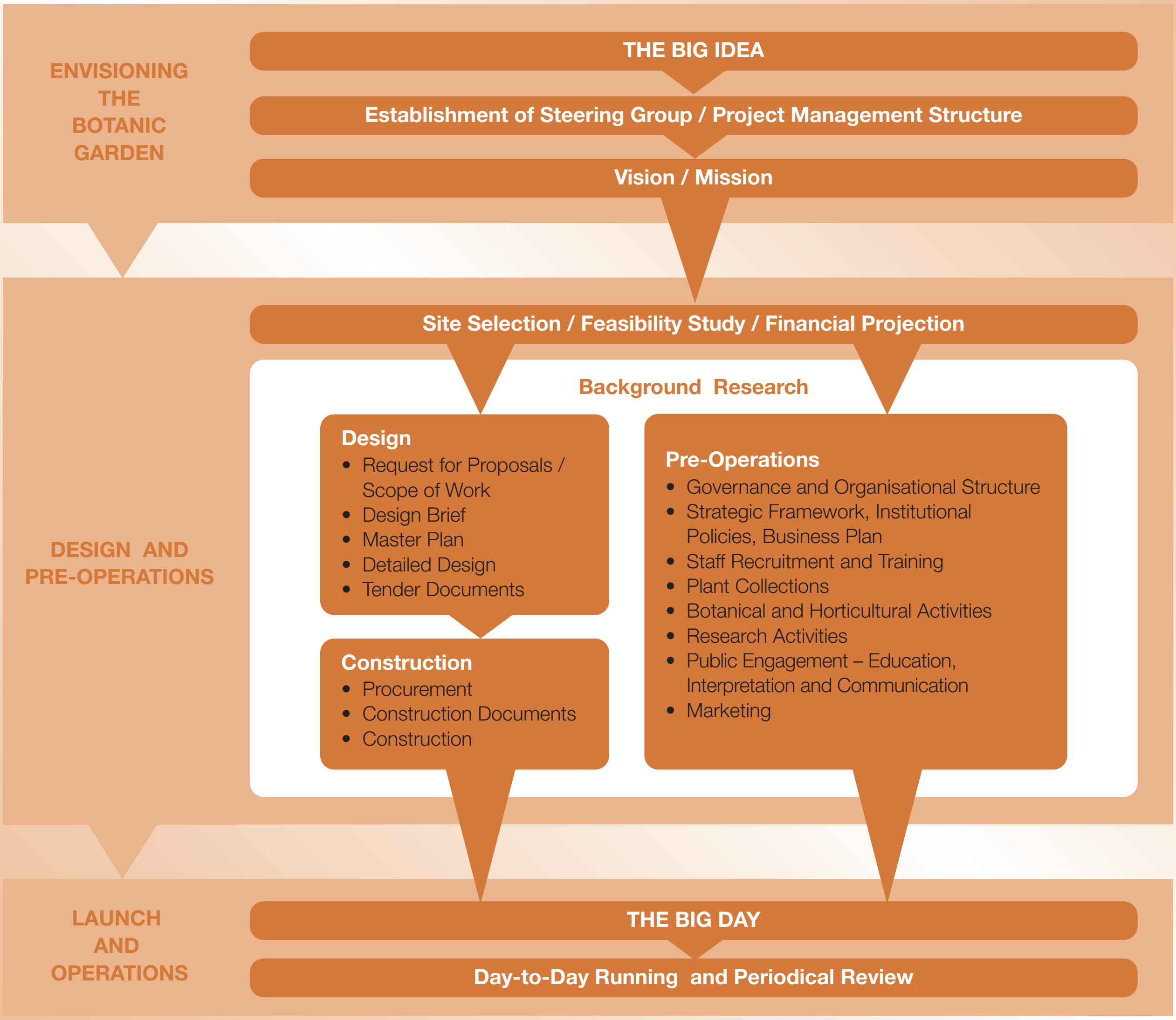
- What are we trying to achieve?
- Is it possible?
- How can we make it happen?

Having generated the big idea, the project owner – be it an enthusiastic individual, a community group, an organisation or the general public – will actively engage in the entire development process, including:

- Fine-tuning the big idea;
- Developing support;
- Assuming responsibility for the viability, planning and eventual success of the project;
- Establishing a steering group;
- Approving the project budgets;
- Entering into contracts with funding bodies, consultants and/or contractors;
- Approving design decisions and authorizing the project manager and design team to proceed at key milestones;
- Reporting to regulating agencies.

Depending on the type and magnitude of the project, whether it is a new botanic garden venture or the redevelopment of an existing institution, not all steps outlined in this chapter will be relevant to each undertaking. Further, implementation is not a linear process throughout: pre-operational management occurs in tandem with design and construction, progressing and complementing each other in parallel (Figure 1.1).

Figure 1.1 Parallel development flows



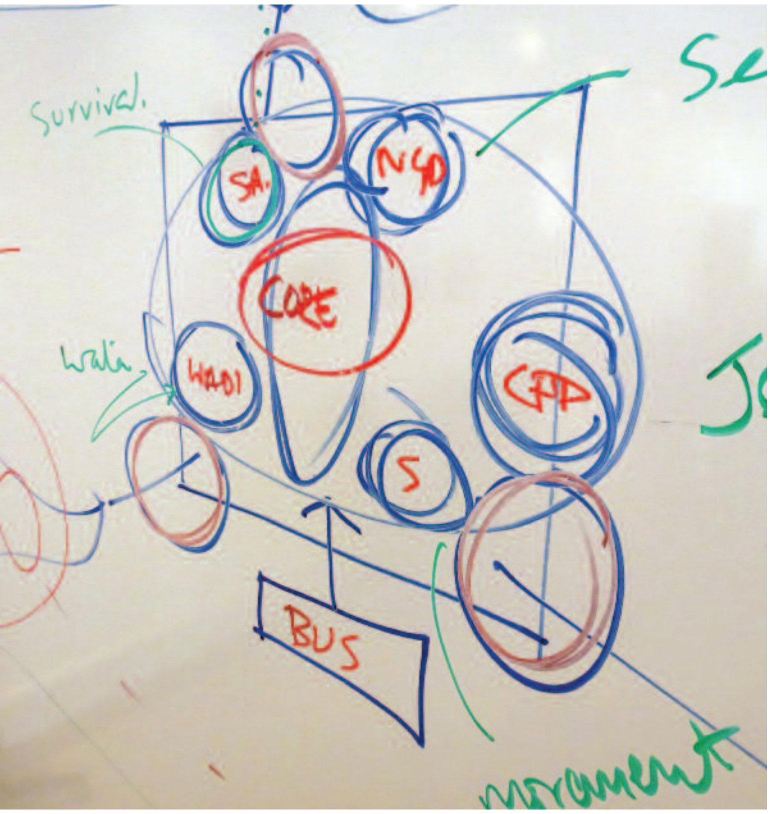
1.2.2 Directing the Project – The Steering Group

The steering group represents the core group of stakeholders of the botanic garden development venture and capitalises on a wide range of areas of expertise. As a highly multi-disciplinary group it may include:

- The project owner;
- The project manager/botanic garden director;
- Senior botanic garden staff;
- External, independent stakeholders, e.g. specialist consultants, sponsors, representatives from other botanic gardens or members of the public;
- Volunteers.

The steering group has executive oversight of the development process, and formulates clear objectives and terms of reference for the project. Specific roles and responsibilities of the steering group may include:

- Develop, confirm or refine vision, mission (Section 1.2.4) and other objectives;
- Approve design decisions and deliverables;
- Oversee the project, and contract management;
- Provide overall guidance and direction to the design team, project management team or any consultants;
- Prepare, revise and manage business plans and other policy frameworks.



A typical work-in-progress design diagram, produced during a collaborative, multi-disciplinary design workshop at Oman Botanic Garden. (Image: Andrew Anderson)

1.2.3 Managing the Development – The Project Manager

Thorough project management expertise is required throughout the entire development process from inception through to the opening day of the botanic garden. This may be provided by the botanic garden director, the design team (Section 1.5.1) or by an external, professional project management consultant. Frequent consultation with the steering group is essential to ensure that the project is delivered on time and budget.

Key roles of the project manager include:

- Establishing and monitoring the budget;
- Establishing and monitoring project schedules and timelines;
- Procurement of the appropriate consultants and/or contractors
- Monitoring risks and quality;
- Overseeing and managing the project scope, keeping a close watch on 'scope creep';
- Ensuring effort and expenditure are appropriate to expectations;
- Resolving differences and disagreements during the project development process.

1.2.4 Defining the Purpose – Vision and Mission Statements

The vision and mission are short statements that capture the main aspirations of any organisation or project. When a botanic garden is being developed it is vital that the intention of the institution is clearly articulated from the outset. The vision and mission inform the identification of specific goals and objectives of the project and provide a tangible direction for the design, development and realization of the project. The vision and mission statements relate to the institution's target audience and specify which aims are to be achieved, which experiences a botanic garden would like its audience to have, and how a botanic garden sees its position within the education, science and conservation communities. While the vision generally expresses the botanic garden's aspirations over a number of years or even decades, the mission (also called a corporate mission or corporate purpose) distils the vision into a more specific statement that explains the aims of the project (Box 1.1).

The development, confirmation or fine-tuning of a concise vision and mission should inform all stages of design, construction and pre-operations (Sections 1.5, 1.6 and 1.7). If such statements have already been formulated for existing botanic gardens, confirmation or modification as part of a review should be undertaken at key project milestones, i.e. submission of the master plan or detailed design documents (Sections 1.5.4 and 1.5.5) to ensure that the vision and Mission and any new developments are in line with each other. For instance, a review of The Australian Botanic Garden Mount Annan of the Royal Botanic Gardens and Domain Trust initiated in 2005, recommended a renewed emphasis on engaging with the local community. The earlier vision statement from 2000 was therefore deemed to be amended to: *'By 2016, Mount Annan Botanic Garden will be a highly valued botanic garden and sustainable parkland embraced by the community and recognised both locally and internationally for its botanic, cultural and natural landscapes'*, with the organisation's bicentenary celebrations in 2016 providing an opportune occasion to take stock of progress made.

Box 1.1 Examples of vision and mission statements

Oman Botanic Garden, Muscat, Oman – a new botanic garden in development
Vision: To inspire people to conserve and cherish the biodiversity and botanical heritage of Oman for a sustainable future.
Mission: Discover, cultivate, showcase and protect Oman's unique plant diversity and ethnobotany through innovative research, exciting displays and engaging communication.

Shanghai Chenshan Botanical Garden, Shanghai, China – a large botanic garden opened to the public in 2011
Mission: To conserve plants of Eastern China, discover sustainable ways of using them, and share our knowledge and enthusiasm with the public.

Tooro Botanical Garden, Fort Portal, Uganda – a dynamic young botanic garden established with limited resources
Vision: We look forward to a society with a well conserved green environment.
Mission: To promote community-centred conservation of botanical resources in the Albertine region.

Tooro Botanical Garden, Fort Portal, Uganda. (Image: Sara Oldfield)

Jerusalem Botanical Gardens, Jerusalem, Israel – a forward-looking botanic garden run by a non-profit organisation
Vision: The Jerusalem Botanical Gardens, where Plants Grow People.
Mission: Protecting biodiversity and welcoming human diversity.

South African National Biodiversity Institute, South Africa – a well-established government organisation including a network of national botanic gardens
Vision: Biodiversity richness for all South Africans.
Mission: To champion the exploration, conservation, sustainable use, appreciation and enjoyment of South Africa's exceptionally rich biodiversity for all South Africans.

Jardín Botánico Carlos Thays, Argentina – a historical institution of the municipality of Buenos Aires
Mission: To contribute to the conservation of plant diversity, especially the flora of Argentina, and advance the knowledge and appreciation of the world's plant kingdom.

The steering group (Section 1.2.2) should be involved in all stages of the formulation or refinement of the botanic garden vision and mission. Often developed through collaborative workshops, the preliminary statements should be reviewed by peers or relevant organisations as part of a final refinement process.

The vision and mission statements constitute an important part of a botanic garden's strategic framework documents (Section 1.7.3). Generally drawn up by the steering group in consultation with other botanic garden staff, these documents set out the broad framework within which a botanic garden will operate and define key roles and responsibilities of the stakeholders involved. While these documents do not usually confer any legal power or responsibilities, they form a key part of accountability and governance and should be reviewed and updated as necessary to reflect change.

1.3 ESTABLISHMENT OF A DESIGN PROGRAMME

KEY MESSAGE

During the continued refinement of the design programme it is important that all stakeholders are involved, and agree on the programme elements and time frame before initiating the next design stages of the project.

It is helpful to establish a comprehensive list of programme elements that form the foundation of the physical design of the botanic garden development project. These components will correspond directly with the vision and mission (Section 1.2.4) of the botanic garden, and provide an overview of physical and operational elements to achieve the project goals. While individual components of the design programme vary considerably based on individual project requirements, potential elements include:

- Specific buildings and functions (e.g. interpretation centre, research facilities, storage areas);
- Key project components (e.g. plant displays, recreation and special events areas);
- Operational or 'back-of-house' programme elements (e.g. nursery and maintenance facilities);
- Vehicular and pedestrian circulation infrastructure for visitors, employees and operational activities (e.g. path- and roadways, parking areas).

A design schedule should be defined early in the process to establish an overall target for the completion of key milestones of the botanic garden project. The schedule will inform the preparation of a feasibility study (Section 1.4.2) and will be further refined in the following development stages. The schedule is essentially a linked series of work activities that help establish a forecast against which the project implementation can be tracked. The forecast should be realistic, taking into account a broad range of factors based on project complexity, from availability of resources to construction seasonality. A pragmatic project timeline and schedule will also help to identify factors and activities that pose a threat to timely delivery, and will allow adjustment to unanticipated changes. Obtaining feedback and consensus from all stakeholders when the schedule and sequence of project tasks are established is essential to developing realistic forecasts.

The design programme is initially a planning tool for the project owner and the steering group. When moving to the design and construction stages (Sections 1.5 and 1.6), the design team (Section 1.5.1) and the contractors are responsible for translating the overall project timeline into increasingly detailed schedules to meet the project requirements.

1.4 SITE SELECTION AND FEASIBILITY STUDY

1.4.1 Selecting the Botanic Garden Project Site

The idea of a new botanic garden development is often linked with a site already in mind, or with several potential sites from which the most appropriate location is selected. A list of possible sites for consideration may be developed as appropriate, based on criteria to achieve the project's vision and mission. These potential sites should be evaluated for suitability. Criteria for the assessment and selection of the site may include:

- Present ownership and availability;
- Existing bylaws, zoning or legal restrictions on site uses;
- Access and suitability for visitor and operational access;
- Existing buildings and infrastructures;
- Biophysical site conditions (climate, topography, solar aspect, soils, geology, hydrology, vegetation, wildlife habitat);
- Key views into and out of the site into the surrounding landscape;
- Special or distinctive attributes of a particular site;
- Sensory experiences (views, sounds, seasonality);
- Size (and scope for expansion in the future).

These criteria, along with any other project-specific considerations, should be evaluated and scored by the steering group or a team designated to select the site. A comprehensive feasibility study (Section 1.4.2) should then be carried out for the preferred location.

Drain construction, Pha Tad Ke Botanic Garden. (Image: Rik Gadella)

1.4.2 Conducting a Feasibility Study

KEY MESSAGE

The outcome of any feasibility study should be the answer to one key question: is the project realistic and achievable?

Any new botanic garden development should ideally be preceded by a comprehensive feasibility study. This comprises an evaluation and analysis of the potential of a proposed project, and is based on extensive investigation and research to support the process of decision making. External expertise may be required to prepare a feasibility study, depending on the scale and complexity of the botanic garden project. For smaller projects, a small group of informed stakeholders may be sufficient to ascertain if the project is feasible.

A feasibility study typically includes a preliminary analysis of the project, potential sites and ideas for its development. A feasibility study should be conducted in an objective, unbiased way to provide information upon which decisions can be based. A well-designed feasibility study will provide a historical background, a description of the project, a detailed site analysis, financial projections, information on operations and management, estimated timeline, and marketing research.

A key part of the feasibility study is a multi-disciplinary site assessment that cumulatively assesses and analyses existing site conditions. Generally, the same criteria as for those used for the site selection (Section 1.4.1) will be applied to establish the detailed site analysis, but these will be studied in much greater detail. Additionally, operational aspects, the cultural context, education and interpretation provisions and how they influence each other, should be considered. Further, potential risks should be identified, such as relating to the physical environment, visitor numbers, financial needs, marketing, etc. Likewise, ways of maximising local, regional and national benefits of the botanic garden should be evaluated and compared (Case studies 1.2 and 1.3).

The feasibility study should ideally be performed by the design team (Section 1.5.1), with extensive input from the steering group (Section 1.2.2), and will contribute to a thorough understanding of the site before exploring detailed design (Section 1.5.5) options. It will conclude with a case either for or against the project. If its establishment proves feasible, an outline of its facilities, location, organisation, role and design can be presented, drawing together the major conclusions of the study and identifying risks and opportunities.

CASE STUDY 1.2

Feasibility studies in the Pha Tad Ke Botanic Garden, Laos

Rik Gadella, Luang Prabang, Laos

As the first botanic garden in Laos, the emerging Pha Tad Ke Botanic Garden aims to establish a prime *ex situ* living collection of the national flora. It will serve practical conservation of threatened native plants, education and eco-tourism development.

As part of the due diligence required by the sponsor of the project, three feasibility surveys had to be conducted: a financial and legal study, a marketing study as well as an environmental and a social impact study. Although these analyses did not come cheap, the botanic garden staff learned considerably from the process as well as from the results, including how to issue a public tender, how to judge the proposals and how to accompany the consultants in undertaking the feasibility studies.

Especially the establishment of a financial model can be laborious and tedious, but it also provides a good opportunity to confirm figures and budgetary assumptions. If one does not have a head for numbers, support by a professional should be sought to explain and translate the 'accounting language'. A robust financial model and financial statement will be needed by most grant providers and donors, and perhaps even to open a bank account.

It quickly became apparent for all staff of Pha Tad Ke Botanic Garden that thorough and clear terms of reference for carrying out the feasibility studies were essential, and it cannot be overstated that one should spend sufficient time to establish these conditions. Consultants may at times come up with unexpected and new ideas. Experts from other relevant fields – such as PR and marketing specialists and lawyers, may have their own particular views of the project. Even if these are not taken on board ultimately, one should keep an open mind and listen carefully; there may always be something to learn from on how to develop a new venture successfully.

View to the Mekong river from Pha Tad Ke Botanic Garden. (Image: Alexandre Espenel)

CASE STUDY 1.3

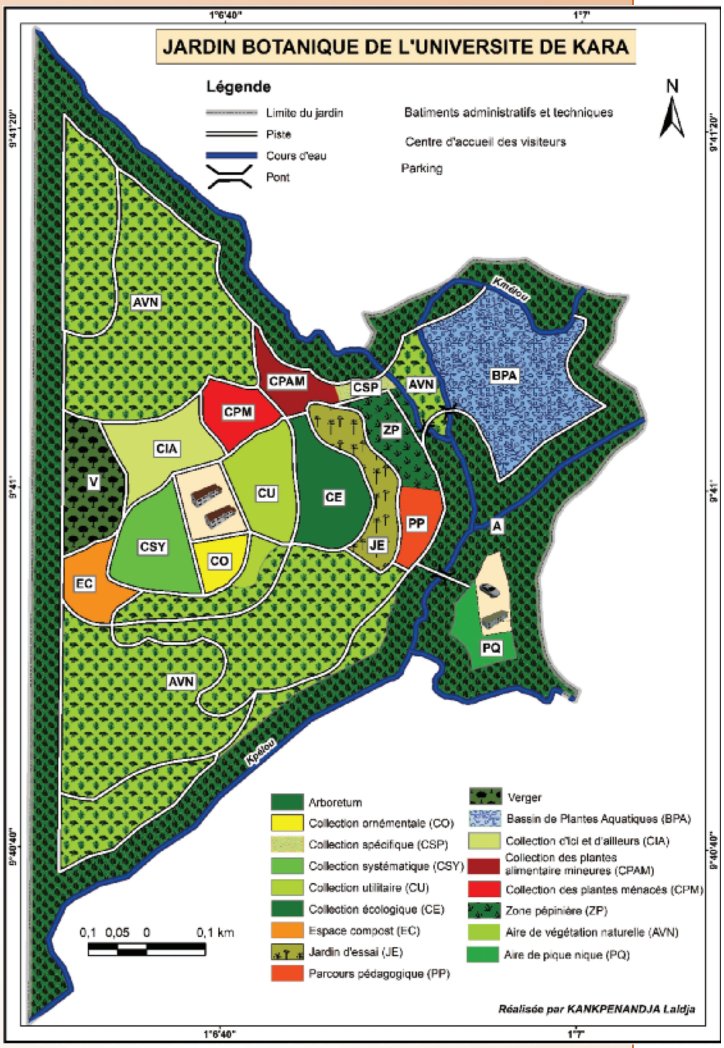
Site selection and feasibility assessment for the development of the Kara University Botanic Garden, Togo

Atato Abalo, Kara, Togo

With the opening of the University of Kara in northern Togo in 2004, initial ideas for a university botanic garden were drawn up to support and enhance the country's plant sciences development. Over the years, a number of studies have been carried out to identify the most appropriate site of the botanic garden.

The main, natural vegetation on the 1050 ha large grounds of the university is represented by savannah (woody on well-drained soils and more grassland-type in humid areas) as well as riparian forests along the two main rivers. Studies of the geomorphology of the area have yielded data on risk factors and have in turn informed the development of countermeasures to manage potential threats. These include high-intensity precipitation during the rainy season, triggering possible landslides and falling rocks, while inundating the sandy plains in the lower areas. Despite these risks, the establishment of the university as well as of the botanic garden were gauged as feasible, as long as a carefully drawn up zoning plan was respected during all subsequent development stages. This plan includes the delineation of areas for construction, zones with limited development potential, as well as areas not suitable for construction.

Situating and integrating pathways into the landscape of Kara University Botanic Garden. (Image: Abalo Atato)



Zoning plan Kara University Botanic Garden. (Image: Laldja Kankpenandja)

Based on this zoning plan, the definite site of the botanic garden was identified by applying the following, additional criteria:

- Hold the potential of connectivity of the various habitats represented on the grounds of the university;
- Offer zones for managed, living collections as well as fragments of wild areas;
- Permanent availability of water for irrigation;
- Make use of natural boundaries (rivers) to enhance the independence of the botanic garden in the long run.

The contour lines of the site were used to situate and delineate the individual plant collections and wild areas. In this way, the botanic garden makes maximum use of the existing topography, and, with the exception of the construction of a bridge to provide permanent access to the site, will retain most of the features of the natural landscape.

1.4.3 Projecting and Valuing the Investment – the Business Case

The business case provides a compelling argument for the added value of the project and justifies the resources needed for the investment. As such, the financial projection for the establishment and ongoing maintenance of the botanic garden (Table 1.1) constitutes the central component of the business case. It should be conducted at an early stage of the project, either as part of the feasibility study or as an independent analysis. It is critically important for the business case to be reviewed and revised during the master plan (Section 1.5.4) and detailed design (Section 1.5.5) phases. The business case may be produced by a specialist company, by the design team (Section 1.5.1) or by botanic garden staff, with substantial input from the steering group (Section 1.2.2).

Table 1.1 Botanic garden budget checklist (depending on the scale of the botanic garden project, not every item listed here may be applicable)

REVENUE	
Self-generated income:	
Admission Fees (if any)	
Events:	Public
	Private and corporate
Retail	
Catering	
Consultancy services	
External sources of income:	
Sponsorship	
Endowments	

EXPENDITURE	
Start-up costs	
Exhibition, seminar rooms and auditorium – initial fit-out	
External consultancies	
Interpretation – initial set-up	
Initial recruitment	
IT systems:	Botanical software subscriptions and training
	HR & payroll system
	Finance/accounting system
	IT equipment purchase
	IT training and support
Laboratory equipment – initial fit-out	
Launch event	
Library – initial fit-out	
Machinery and vehicles – initial fit-out	
Maintenance of pre-operations facilities	
Marketing (pre-operations promotional activities and materials)	
Multi-media guides	
Non-capex fit-out (furniture and fixtures which are not included into the capital cost)	
Nursery – initial fit-out	
Rent of pre-operations facilities	
Restaurants and cafes – initial fit-out	
Retail – initial fit-out	
Salaries	
Security equipment – initial fit-out	
Services of pre-operations activities	
Staff training	
Storage, warehouse, logistics – initial fit-out	
Telecommunications	
Utilities of pre-operations facilities	
VIP area – initial fit-out	
Other general start-up costs (including bins, fire extinguisher, internal artwork, etc.)	
Contingency	

OPERATING COSTS	
Asset repair and replacement	
Corporate social responsibilities	
Depreciation	
Education material	
Events	
External consultancies	
Field work expenses (equipment, travel cost, daily allowances)	
Finance costs (audit, bank charges, tills, legal fees, insurance)	
Fundraising	
IT software support and upgrades	
Maintenance:	Horticultural and landscape
	Exhibition
	Facilities
	Interpretation
Marketing (promotional materials, advertising, events)	
Outsourced operational activities (e.g. retail)	
Printing, stationary and postage	
Recycling/refuse collection	
Rent	
Salaries	
Security	
Staff training	
Storage, warehouse, logistics operational cost	
Sundries (e.g. staff uniforms, office artwork, etc.)	
Telecommunications	
Transport costs	
Utilities	
Contingency	

1.5 THE DESIGN PROCESS: FROM CREATIVE IDEAS TO TECHNICAL SOLUTIONS

The design process marks the beginning of an inherently creative and exciting stage of the project, transforming the vision, mission and business case of a project to physical form. While the complexity, timeframe and outcomes of each project are different, the process outlined in this section can be applied to projects of many different sizes and levels of complexity.

The terminology used to describe the design process varies widely, and different terms are often used interchangeably. However, regardless of the terminology, the design process evolves from the initial big idea to a more detailed refinement of the original concept and eventually to the production of the drawings or documents that will enable the project to be built. This is a collaborative, cumulative process, and the success of any given design project is heavily reliant upon frequent and direct communication and collaboration among all the stakeholders involved, in particular the steering group, the design team and the contractors (Sections 1.2.2, 1.5.1 and 1.6.1).

1.5.1 Design Team Composition and Design Process Options

KEY MESSAGE

While every project is different, the steering group typically works with a designer or a design team to bring the project to life.

Who should design the project?

The steering group typically works with a designer or a team of designers to translate the project goals into reality. The design team may vary considerably in size and composition depending on the specific needs of each individual project and may include:

- Landscape architects or landscape designers;
- Architects;
- Botanists and horticulturist;
- Irrigation designers;
- Lighting designers;
- Interpretation designers and education experts;
- Engineers;
- Transportation and circulation experts;
- Operational experts;
- Business planners;
- Other specialist designers and experts tailored to the project.

Which design process to select: design–build or tender–construction?

The steering group may opt to follow a design–build process for a small-scale, botanic garden project. One company is contracted to complete both the design and construction; this involves only one contract between the project owner and the contractor.

Alternatively, the tender–construction process is used for large and more complex projects and includes several separate steps:

1. A design team is hired by the project owner to complete the design work and produce the required tender documents (Section 1.5.6).
2. Potential contractors then submit bids that detail how much it will cost them to undertake and complete the construction.
3. The project owner selects the preferred contractor and awards the construction contract.

1.5.2 Request for Proposals and Scope of Work

KEY MESSAGE

One of the most valuable investments that the project owner can make is to allocate the appropriate time, effort and resources to prepare a coherent and comprehensive request for proposals (RFP) document.

To appoint a suitable design team, the steering group (sometimes with the help of a project manager) prepares a comprehensive document that outlines the aims of the project, the required professional services and expected outcomes. This request for proposals (RFP) document will allow potential bidders to produce thorough, accurate and cost-effective proposals to carry out the work. Key elements of a RFP document may include the following:

- General instructions;
- Background information, including maps and photographs;
- Scope of Work;
- Deliverables;
- Schedule;
- Financial and administrative terms;
- Submission requirements.

The scope of work is the most critical component of the RFP document. Regularly revisited and reviewed as the botanic garden project evolves, the scope of work aims to:

- Provide the potential design team with as much information as possible about the project;
- Minimize uncertainty and ambiguity about the project requirements;
- Clearly define the expertise, skills and experience that are required to produce the work.

The development of the RFP should be an open, collaborative process that includes all project stakeholders and captures the true goals of the project. This is best achieved through a series of workshops to identify the key components of the scope of work, and to establish the submission deadlines and evaluation criteria. A coherently written RFP will result in proposals that are as thorough and cost-effective as possible and can be compared against each other at the evaluation stage. This will save untold time and effort, resulting in more accurate and competitive budgets.

A shortlist of potential design teams may be developed and invited to submit proposals in response to the request for proposals, or a fully public invitation to present proposals may be issued by the steering group. Potential bidders should be required to visit the site and meet the steering group. The end result is the selection of a highly qualified and experienced design team (Box 1.2) that is informed and excited about the project.

1.5.3 Design Brief

KEY MESSAGE

The design brief includes very detailed project information to guide the design process and is a valuable strategic design management tool. It is focused on outcomes and results of the design; the more detail, the better!

Once the design team has been awarded the project, one of the first tasks to complete is the preparation of a design brief. The design brief is prepared by the project owner and the design team and provides a detailed description of the goals, objectives, and components of the project. The design brief is an expansion of the scope of work (Section 1.5.2), explaining what the design team is required to do and what programme elements are required to be included in the design (Box 1.3).

The level of detail of the design brief depends on the complexity of the proposed work. Any project – whether a small addition to an existing garden or the development of a new site – requires a design brief document to clearly state the project requirements. While the length of a design brief varies from project to project, the principle remains the same.

The design brief focuses goals and expectations, capturing the essence of the project from the outset of the design process. It is a very valuable tool that can be referred to throughout the design process, to act as a check to ensure that the project is staying on track. At the completion of the design process, the design brief provides a record of the project goals and programme elements.

The preparation of the design brief should be a collaborative process involving both the steering group and the design team, although the latter generally is in charge for managing the process and producing the document. The steering group is responsible for providing as much information about the project as possible to help the design team capture the goals and expectations of the project.

The key to developing a successful and useful design brief is open communication and collaboration. It is critical for all stakeholders and members of the project to participate in this process: informal workshops, information-gathering sessions, conversations and site visits all provide invaluable opportunities to share knowledge. Depending on the complexity of the project, several drafts of a design brief may be warranted prior to its completion and initiation of the master plan (Section 1.5.4) and detailed design documents (Section 1.5.5).

Box 1.2 Key steps to selecting a design team

1. Confirm the scope of work. What are the objectives of the project? What are you trying to achieve?
2. Determine if the professional services of a design consultant are required, or if the skills, expertise and availability to perform the design work exist within the project team.
3. Confirm the procurement requirements. What kind of process is required for you to enter into a contractual agreement with a design consultant?
4. Confirm who will write the request for proposals (RFP) document to solicit bids (proposals) from appropriately experienced design teams. Determine if the request for proposals can be written by the project team, or if an external consultant is required to write the document.
5. Prepare a comprehensive and detailed request for proposals document.
6. Develop a list of potential bidders who you may invite to respond to the request for proposals (this depends on your procurement requirements).
7. Confirm what method will be used to advertise your request for proposals.
8. How are you going to decide who you hire? Establish a proposal evaluation committee who will review the proposals.
9. Advertise your request for proposals.
10. Address queries from the bidders as required during the bidding process.
11. Organize and conduct a 'bidders' site meeting' during the bidding process.
12. Review and evaluate the proposals.
13. Develop a short-list of preferred bidders, if required.
14. Arrange and conduct interviews with the shortlisted bidders, if required.
15. Visit past projects, call references, and thoroughly research the shortlisted bidders.
16. Award the contract to the most suitable design team.

Box 1.3 Key components of a design brief

- Identity of the project owner / company profile;
- Vision and mission of the botanic garden project;
- Goals and objectives – what are you trying to achieve?
- Quantifiable expected results;
- Target user groups;
- Schedule and timeline;
- Detailed requirements for all elements highlighted in the scope of work*;
- Design references and precedents.

* *The detailed requirements for all scope of work elements are the primary purpose of the design brief document.*

1.5.4 Master Plan

KEY MESSAGE

The goal of the master plan is to provide a comprehensive document that presents a possible solution to the intended project outcome and guides all subsequent design phases leading to project realisation. The master plan is not just a drawing – it is a strategic document that includes sketches and illustrations as a key feature besides explanatory specifications and cost estimates.

The master plan is a central document of any botanic garden development that identifies activities, opportunities and facilities that need to be considered to deliver the vision and mission of the organisation. It can be used to translate the requirements defined in the scope of work and design brief into a concept design solution. It may comprise to-scale plan drawings, illustrations and sketches (Box 1.4). It may also include a cost estimate of the construction work and operations, typically prepared by a qualified cost consultant. The costs are continually refined as the design process evolves and more information becomes available. The master plan offers an opportunity for the project owner to review and confirm that the botanic garden development is in line with the available funding. It also provides an important support-building and fundraising tool should further resource mobilization be necessary.

The master plan may include a series of design options or a single design solution. It should reflect the outcomes of the site analyses, opportunities and constraints identification, and design exploration. The master plan drawings and their supporting documentation, including the cost estimates, should incorporate all programme requirements as set out in the scope of work and the design brief.

Box 1.4 Key components of a master plan document

- Vision, mission and goals of the project;
- Summary of background research;
- Relevant examples of precedent projects – photos and illustrations;
- Spacing of components and activities;
- Site analyses – biophysical, operational, contextual;
- Diagram and sketches to illustrate the conceptual options;
- Potential garden operations;
- Design options and relationship diagrams;
- Analysis of design options – strengths, weaknesses, opportunities, challenges;
- To-scale plan drawings, illustrations, sketches;
- Cost estimates.

Continued public consultation throughout the master plan development process is essential to address the needs and gain the support of all stakeholders involved. This may include a series of presentations, workshops and informal, open-house discussions. These are aimed at exploring design options in a collaborative, transparent manner, and to communicate proposed design solution(s) to the public and provide a platform for discussion. While the design team is responsible for producing any design drawings or materials used in the public consultation process, the project owner may choose to manage the development process and may contract the services of public consultation experts to facilitate the process. Expectations and requirements regarding the public consultation should be clearly outlined in the scope of work.

As with all institutions and organisations, botanic gardens operate in an environment of change. Periodical review of existing strategic documents, including the master plan, is required for the institution to remain relevant. Successful reviews are highly participative, and give an opportunity to all interested parties and individuals to comment on development intentions and design solutions (Case studies 1.4 and 1.5).

CASE STUDY 1.4

Developing a new master plan – Denver Botanic Gardens

Brian Vogt, Denver, United States

Nearly 50 years in the making, Denver Botanic Gardens had hit a crossroads in 2007. Facilities built in the 1960s were showing their age and emergency repairs had become the prime focus of fundraising. A series of failed master plans gathered dust on shelves, largely because they were created by a small number of insiders and were immediately attacked by members and neighbours. If progress was to happen, something had to change.

The Board of Trustees hired a local architect to lay the foundation for a master plan that could actually be executed. A thorough analysis of infrastructure, as well as strengths and weaknesses, began to prioritize immediate needs and the groundwork necessary to begin achieving loftier goals. An early priority was to list elements that were obvious and enduring assets, covering most of the existing gardens and buildings. This baseline reassured those engaged with Denver Botanic Gardens over decades.

Four projects were launched simultaneously. The first was to focus on a package of obvious projects to be included in the Better Denver Bond election, which entails City funding of projects. Eventually, the City selected a core infrastructure system rebuild and total replacement of the greenhouses with a new greenhouse complex, including an orchid house, orangery, horticulture offices, labs and storage. The total amount of City support would be USD 18.6 million.

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CASE STUDY 1.4 (CONT.)

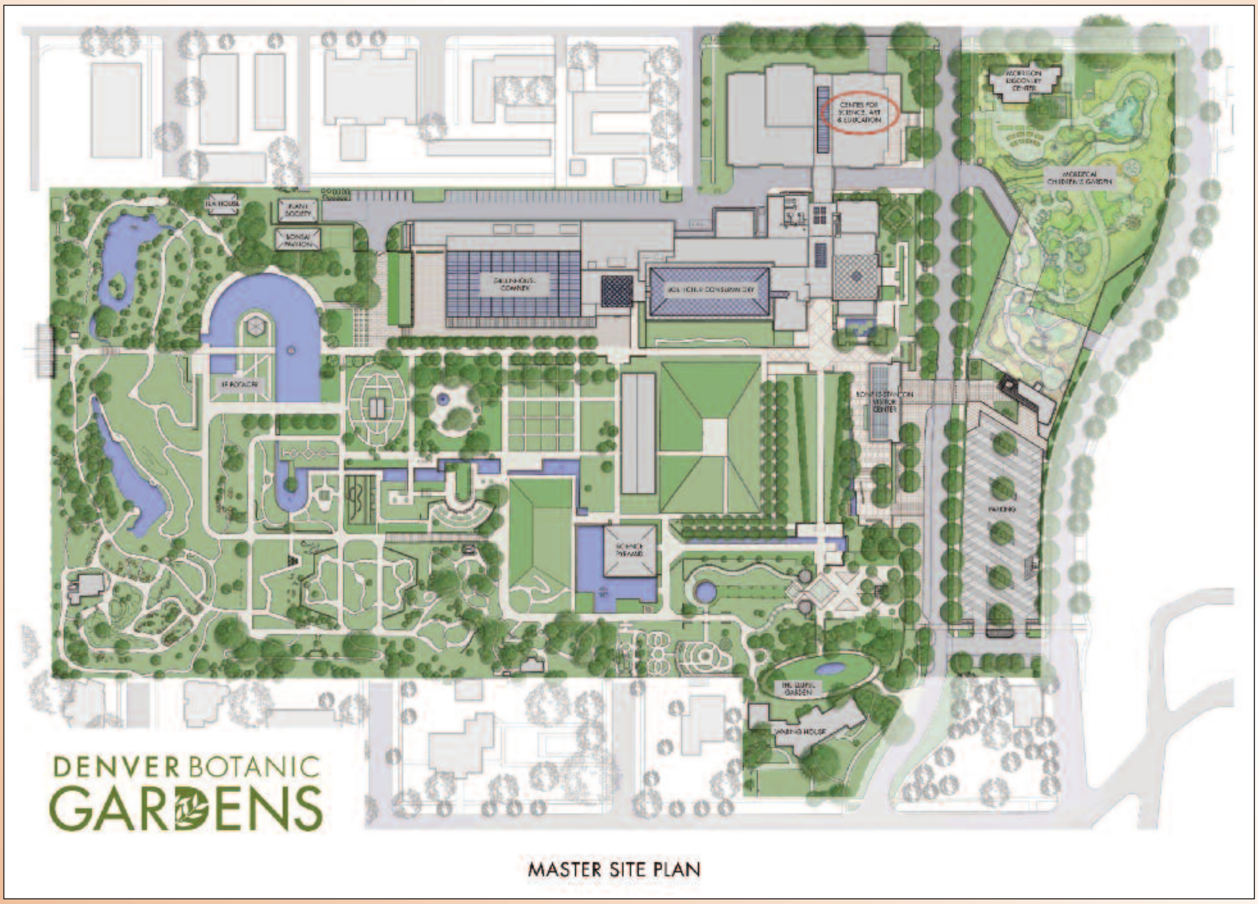
The second initiative was to rebrand the botanic garden. This involved over 100 people to review core values, the mission and programmatic goals of the institution giving not only the master development plan but also daily activities a common context.

The third initiative was the creation of the Master Development Plan (MDP) itself. Trustees worked with staff, volunteers, donors, neighbours, City officials, and specialistes to dream, refine and lay down specific visions on paper. This 'all hands on deck' approach produced a surprising revelation. There were few real arguments. As the MDP reached its conclusion, enthusiasm and confidence grew. And by the time the plan reached the City for all of the complex approval processes, it had strong support across the board, including formal resolutions by neighbourhood organisations.

The final step was to launch a capital campaign. In January of 2008, the Flourish campaign was unveiled to a packed house. The campaign's strategy was to cluster all of the projects into four phases, give the Gardens benchmarks and the chance to celebrate interim successes. A wall within the main lobby showcased every project by phase and as each one was ticked off, a 'completed' banner stretched across. Even now, visitors linger in front of the wall to see what has been accomplished, where the funding came from, and what was still in need of support. A plan that involved hundreds of people was now completely transparent to thousands more.

The Science Pyramid, Denver Botanic Gardens. (Image: Scott Dressel-Martin)

Six years later, the results of this grand convergence is seen in all aspects of the operations of the botanic garden. Over USD 64 million in projects have been completed, with only one significant project remaining. Visitation, membership and the operating budget have all doubled. Most important, the capacity and confidence of everyone involved in the Gardens has skyrocketed.



Site Master Plan, Denver Botanic Gardens. (Image: Denver Botanic Gardens)

CASE STUDY 1.5

Botanic Gardens of South Australia Master Plan Development – Adelaide, Mount Lofty and Wittunga Botanic Garden sites

Trevor Christensen, Adelaide, Australia

Master Plans were completed for the Adelaide and Mount Lofty Botanic Gardens in 2006 after a process taking some 18 months. The Wittunga Botanic Garden Master Plan was completed in 2012 after a 10 month process. These plans were developed by consultants chosen through a select tender process and in each case were prominent Landscape Architectural firms with a good understanding of the roles and functions of Botanic Gardens and the South Australian context and within the local environment.

Aims of the Master Plans

- The Botanic Gardens of South Australia (BGSA) Master Plans provide a framework for day-to-day operational and long-term decision making, facilitate prioritisation of activities and provide a basis for accountability: long-term collections development and maintenance requirements;
- Visitor facilities and services including opportunities to enhance accessibility and usability of the BGSA;
- Priority of investment programmes to facilitate dialogue during the BGSA's budget bilateral programmes and to assist negotiations with sponsors.

Accordingly, the Master Plans consider timelines of fifty and more years. In the case of BGSA, recommendations were prioritised as high, medium or low and consisted of a mixture of operational or recurrently funded projects as well as those more significant projects funded through capital budget allocation.

Ethnobotanist Saif Al-Hatmi of Oman Botanic Botanic Garden exploring interpretation signage at Adelaide Botanic Garden. (Image: Annette Patzelt)

Development of the Master Plans

The scope of work, as defined in a project brief, was further developed through the requirement for a return brief from the consultant, the aim being to gain a thorough understanding of the existing plans and policies, historical considerations and the physical features, opportunities and constraints of the BGSA. The following issues needed to be considered:

- Landscape character (including hard and soft landscape elements) and visual values;
- Thematic planning;
- Key collections and individual specimens of significance;
- Education and interpretation;
- Garden access and circulation (including entry experiences);
- Site access including public transport, management, emergency vehicle, private vehicle (including parking), bicycle and pedestrian;
- Safety and security considerations for garden users;
- Visitor facilities and services (including functions and events, future commercial or business opportunities);
- Operational facilities and services;
- Linkages to and collaborative opportunities with the community and business sectors.

The Master Plan Reference Group

The Master Plan Reference Group was a critical factor in the success of the process and ensuring community acceptance of the direction being developed for each site. This does not mean that all recommendations were fully supported by all members however it did ensure that there was at least a firm understanding of why particular directions were decided upon and recommended. The Reference Group consisted of representatives from:

- Government;
- Local government;
- Schools;
- Community Groups;
- Community members;
- Business sector;
- Board;
- Staff.

Consultation with the Reference Group was a critical factor in ensuring acceptance by its members as community representatives. A formal presentation by the Master Plan consultants was given to the Reference Group members at each of the key milestones.

Issues

- Stakeholder and Reference Group members expectations – ensure that they feel they are being heard and their ideas considered;
- Some major stakeholders (e.g. neighbours) not wanting to engage in the process;
- Practicality or relevance of some ideas presented by stakeholders;
- Expectation from Reference Group/stakeholders that everything will be implemented;
- Inadequate reference to the historical context, strategic plans and collection policies.

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CASE STUDY 1.5 (CONT.)

- Continual communication;
- Staff concerns regarding change of and impact on workload;
- Priority projects and priority setting of the Master Plan recommendations;
- Financial and human resource mobilisation to implement Master Plan recommendations.

Benefits for the BGSA

- Future planning and development with appropriate consideration of site history and site conservation analysis;
- Controlled sense of development and project development, rather than ad hoc and random ideas;
- Information and recommendations enabled development of a forward capital plan;
- Enabled development of communication channels and ongoing professional dialogue with active community groups who at times may have had conflicting or special interest ideas and priorities for Garden development, usage and future direction;
- Provides a platform to lobby the government, donors, partners and demonstrate that proposals have been thought through in a complete organisational context with proper consideration of the past and long-term future.

1.5.5 Detailed Design

KEY MESSAGE

The detailed design process advances the master plan into achievable, specific design solutions.

While a number of terms are used to describe the detailed design process including 'concept design', 'schematic design' and 'design refinement', this phase entails the refinement of the master plan as approved by the project owner, and comprises the production of detailed drawings and construction specifications. A concept design may be established first to refine elements of the master plan prior to initiating the detailed design. Informed by the master plan and tested against the content of the design brief, the detailed design explores the options for the resolution of the detailed design challenges and proposes practical and achievable design solutions (Box 1.5).

The detailed design is led by the design team, with continued involvement and input from the steering group, the project manager and other stakeholders. The detailed design may be developed by the same team that developed the master plan or a new design team may be required.

Guilfoyle's Volcano Project, Royal Botanic Gardens Victoria (RBGV), Australia – a model of project management – constructed from the renovation of a century-old reservoir and integral part of RBGV's water recycling plan. (Image: Katie O'Brien)

While any combination of drawings, sketches or illustrations may be prepared by the design team during this stage, the drawings need to achieve the objectives of the project. The goal is to demonstrate the design intent and to ensure that the project owner understands all design components. The detailed design drawings provide significantly more detail than the master plan, including preliminary construction details in order to offer sufficient information for the preparation of refined construction cost estimates.

As with all botanic garden development and review phases, continued communication between the design team and the project owner during the detailed design stage is critical to the success of the project. Design workshops form an integral part of the collaborative design development. The project owner should be familiar with the content of the drawings and review them in detail in close association with the design team. Regulating agencies may also be involved to ensure that the drawings and specifications comply with any applicable legal requirements. The end product of the detailed design stage is a suite of detailed drawings, draft specifications and detailed cost estimates that will guide the development of the tender documents (Section 1.5.6).

Box 1.5 Potential deliverables – the detailed design stage

- If required, revised design brief document;
- To-scale plan drawings, elevations and sections;
- Illustrations and sketches to convey content and character of the design;
- Preliminary construction detail drawings: how are the project components going to be built?
- Construction cost estimates;
- Presentation of drawings, supporting materials and other visuals to convey the design intent to the steering committee or stakeholders.

1.5.6 Tender Documents

KEY MESSAGE

The tender documents are used by the contractor to submit a price to construct the project, and they include the highest level of detail for all drawings and technical specifications.

Any new botanic garden project – regardless of its scale and complexity – is not built based solely on design drawings. A comprehensive set of tender documents, including both drawings and written specifications, is typically required to provide adequate detail for a contractor to prepare a thorough cost estimate and bid to undertake the construction (Section 1.6). The tender documents enable the contractor to submit a price to carry out the work, while the construction documents are used by the contractor after the project has been awarded, in order to construct the works in line with the drawings (Section 1.6.2). The tender drawings contain a project-specific selection of scaled plan drawings, cross-sections, elevations and construction details. Typically they include:

- The architectural/building plans (as articulated in the scope of work);
- Site preparation plans;
- Layout plans;
- Phasing plans;
- Grading, drainage and storm water management plans;
- Hardscape plans;
- Planting plans;
- Electrical plans;
- Irrigation plans;
- Technical construction details;
- Signage and wayfinding plans;
- Interpretation design plans.

The drawings are accompanied by written specifications (Section 1.6.2). These documents typically follow detailed industry formats and standards specifying the state the materials, equipment, systems, standards and workmanship that are required for the construction.

The tender documents are prepared by the design team, with detailed input, review and approval by the project owner. Regulating agencies may also be involved to review and approve the plans. The tender documents are a continuation and refinement of the detailed design drawings, and include the highest level of detail for all drawings and specifications. As with all other development stages, the project owner should be involved in the development of the tender documents by means of regular reviews of the plans as they evolve: the design team should submit in-progress drafts of the tender documents to the project owner for review and approval at key completion stages (i.e. at 50%, 90% and 100% completion). It is vital for the project owner to understand as much of the content of the drawings as possible by means of open and frequent communication with the design team prior to approval and initiation of the construction.

1.6 CONSTRUCTION: BRINGING THE DESIGN TO LIFE

The construction process is very complicated, and is rarely – if ever – explained to the public. The construction industry rarely publishes its own processes. As a result, this information is not widely understood within the botanic garden community.
Andrew Anderson, Landscape Architect, Oman Botanic Garden

1.6.1 Procurement

KEY MESSAGE

The evaluation of bids submitted by contractors should be based both on cost and the technical merit. Awarding the contract mainly or solely on the basis of price is not recommended.

Procurement is the widely variable process through which a builder or contractor is hired to build the project. The procurement process may be managed by either the project owner or a project manager with the direct involvement of the project owner. A selected group of pre-qualified contractors may be invited by the project owner to submit bids to carry out the work, or offers may be solicited from any interested party. The contractors prepare their bids by reviewing the tender documents to determine the construction costs. A project visit should be organized to provide potential bidders with an opportunity to view issues on-site and raise questions directly with the project owner.

It is of central importance for the project owner to award the construction of the project to an appropriately skilled and experienced contractor. The criteria for evaluating the bids should be based both on the cost and the technical merit (Box 1.6). This is the start of a new and critically important relationship between the project owner, the design team and the contractor.

BOX 1.6 What to look for in a contractor

- Relevant experience – examine previous work;
- Availability;
- Track record – check references;
- Attitude;
- Professionalism;
- Commitment to environmentally sustainable construction practices;
- Fair pricing: remember, you get what you pay for!

1.6.2 Construction Documents

KEY MESSAGE

In the case of a discrepancy between the construction drawings and the construction specifications, the written specifications typically take precedence over the drawings.

The construction documents include the drawings to build the project along with written specifications that provide further, detailed information on construction methods and materials. These documents are 'issued for construction' by the design team following the selection of a contractor. The construction documents form part of the legal contract between the project owner and the contractor. They are typically very similar to the tender documents (Section 1.5.6). Fundamentally, the tender documents enable multiple contractors to prepare and submit bids for how much the construction of the project will cost; the construction documents are used by the successful contractor to build the project.

Construction specifications are written documents that follow specific formats and standards to clearly state the materials, equipment, systems, standards and workmanship that are required for the construction (Box 1.7). Cities, municipalities or regulating agencies may have standard construction specification formats that should be followed. Construction drawings, by their very definition, are visual representations that are unique to each and every project.

The design team is responsible for preparing the construction specifications. The contractor is legally bound to adhere to these details; in case of a discrepancy between the construction drawings and the construction specifications, the specifications typically take legal precedence over the drawings.

Box 1.7 Typical construction specifications

Construction specifications are as varied as the potential design elements of a project, although they are typically organized into specific categories within the construction industry. Typical landscape construction specifications may include any of the following:

- Site clearing and preparation;
- Existing landscape and vegetation protection;
- Topsoil stripping and stockpiling;
- Grading and earthworks;
- Drainage and storm water management;
- Unit paving;
- Concrete works;
- Stone masonry;
- Bed and tree pit preparation;
- Soil preparation;
- Plant material – installation, staking, mulching.

Depending on the scope of work (Section 1.5.2), the contractor, sub-contractor or specialist fabricator may also prepare detailed 'shop drawings' that also form part of the construction documents, following review and approval by the project owner and design team. Shop drawings are very detailed construction and fabrication drawings that specify the size, shape, materials, parts assemblies and the overall installation of the item.

1.6.3 Construction

KEY MESSAGE

A collaborative culture of open communication should be established in the early stages of the botanic garden development and will prove to be critically important during the construction phase to minimise delays and unforeseen costs.

The historic building at the heart of the symmetrically designed botanic garden complex in the Flora – the Botanic Garden of Köln, Germany – reopened in 2014 after a three-year renovation period. Continued communication with all involved stakeholders ensured that the budget for the renovation was secured. (Image: Annette Patzelt)

The construction phase includes the building, supervision of the contractors, inspection of the project components during construction and after completion, as well as the overall administration of the construction contract (Table 1.2). The importance of accurate and thorough construction documents (Section 1.6.2) cannot be overstated.

Depending on the scale of the project, a variety of contractors, sub-contractors, specialist installation experts and sometimes even members of the project owner team or volunteers may be involved in the physical construction of the project. If the project follows the design–build process (Section 1.5.1), then the construction is carried out by the design team.

Table 1.2 Construction responsibilities

PHASE OF WORK	PERFORMED BY	APPROVED BY
Tender Documents	Design Team	Project Owner or Steering Group, Project Manager, Regulating Agencies
Construction Drawings and Construction Specifications	Design Team	Project Owner or Steering Group, Project Manager, Regulating Agencies
Procurement	Project Owner or Project Manager	Project Owner or Steering Group
Construction Supervision	Project Owner or Design Team	Project Owner or Steering Group
Construction Inspection	Design Team	Project Owner or Steering Group, Project Manager, Regulating Agencies
Contract Administration	Design Team, Project Manager	Project Owner or Steering Group, Project Manager
Construction	Contractor (if Tender–Construction option) Design Team (if Design–Build option) Project Owner (if sufficiently experienced) Skilled Volunteers (for very small-scale projects)	Project Owner or Steering Group

Construction contract administration includes supervision, inspection, and overall administration of the construction contract. This can be very time consuming and is often underestimated in the scope of work (Section 1.5.2). The project owner and project manager should ensure that sufficient time and resources are allocated to this task.

It is imperative for the project owner to be actively involved in the construction process from start to finish and to approve all works, while the responsibility for overseeing the contractors and inspecting the construction work typically lies with the project manager and design team. The involvement of the design team throughout the entire construction process should be anticipated and included in the scope of services during the procurement phase (Section 1.6.1). Adjustments on-site are a common aspect of any project, especially when tackling landscape construction or unforeseen issues. The design process does not end when the construction begins – on-site design refinements frequently occur throughout the construction work.

While it is the responsibility of the contractor to designate appropriately skilled and experienced staff in a supervisory role, the project manager and design team must also be involved in construction supervision and keep the project owner abreast of any new developments. Construction inspection requires technical expertise and project familiarity by the project manager, design team and relevant regulating authorities.

Construction may be divided into multiple phases for any number of reasons, although the strategy for phased construction – especially to allow for fundraising – should be integrated in the project schedule at the outset of the botanic garden development. The time allocated for construction is often underestimated, and the adherence to schedules in the detailed design (Section 1.5.5) and construction phases (Section 1.6.3) should be closely monitored by the project owner, the project manager and the design team. The schedule should be updated by the contractor throughout the construction of the project. Regular joint meetings on-site with the project owner, the design team, the project manager and contractor are vital to the success of the project. Allocating sufficient time and resources to allow for adequate site meetings should be a priority of all stakeholders.

An often overlooked aspect of the construction process is the opportunity to emphasize and demonstrate a commitment to sustainability and environmental stewardship through sensitive and appropriate construction methods and environmental protection measures, including for the existing vegetation, topography, topsoil, groundwater, etc. Equally, it is critical for the design team to integrate sustainable construction practices and environmentally responsible materials into the tender and construction documents (Sections 1.5.6 and 1.6.2).

The entire construction process should be documented for future reference for educational, training and archival purposes. 'Before and after' photographs and videos are invaluable and are a tangible record of the botanic garden development project and of the accomplishments of all those involved.

This stage also provides valuable opportunities for learning and building a sense of ownership and achievement. Every effort should be made to involve and engage all stakeholders – including the public when feasible – in the construction process: visiting the site, interacting with the contractor, asking questions and seeing the results of months or years of work appearing before one's eyes.

When followed and properly managed, the construction process should result in a project that is complete, on time and within the construction budget. The time and effort invested in a collaborative, transparent design process and in the preparation of a comprehensive scope of work as well as accurate and thorough construction documents should result in a successful project that fulfills the vision, mission and goals of the botanic garden and brings the design to life.

1.7 PRE-OPERATIONS: THE EARLIER THE BETTER!

KEY MESSAGE

The significance of pre-operations cannot be overstated – the earlier the better! While this aspect of establishing a new botanic garden is often overlooked, everything from establishing the governance and organisational structure, to building up the plant collection and initial programmatic activities, including research and education, are all important to the eventual success of the project.

This section addresses operations management prior to the garden opening to the public. It presents general considerations for pre-operations that should be tailored to the individual context of a particular site. These can be extremely complex, with many parallel work streams that need thorough coordination (Figure 1.1).

Pre-operations will transition to ongoing operational management (Chapter 2) following the completion of the botanic garden development.

Based on the vision and mission (Section 1.2.4) of the botanic garden development, pre-operations may comprise:

- Setting up a new or amending an existing botanic garden organisation;
- Recruiting and training staff;
- Developing the plant collection and documentation;
- Providing expert advice on the design;
- Developing strategic frameworks and policies;
- Carrying out horticultural and botanical work;
- Developing education, interpretation and communication programmes, including marketing.

The steering group and design team need to establish pre-operational planning and management components during the feasibility study, master plan and detailed design stages by defining priorities, identifying necessary resources and addressing strengths and weaknesses. As with the operational phase of an established botanic garden, challenges during pre-operations often relate to financial and human resource management and marketing. The development of strategic plans, institutional policies and business plans will ensure that the botanic garden has clear targets and procedures to address these issues (Case study 1.6).

CASE STUDY 1.6

Bringing a big idea to life – The Oman Botanic Garden

Annette Patzelt, Andrew Anderson, Ghudaina Al-Issai; Muscat, Oman

The Oman Botanic Garden, 420 ha in total, is a new botanic garden, currently under construction in Muscat, Oman. The botanic garden focuses on the native flora and vegetation displayed in carefully created habitats, the rich ethnobotanical relationships between plants and people, and sustainability in all aspects. The more fragile habitats of the high altitude mountains and the arid cloud forest will be displayed in large biomes; the remaining habitats will be displayed in external habitat gardens. The botanic garden will also house research facilities, a herbarium, a seed bank, seminar facilities, and a field study centre for visitors.

While construction of the main elements of the botanic garden is yet to be completed, the nursery, together with initial administrative buildings, was built in 2008. This allowed the pre-operations processes to start very early on.

This ambitious project is highly complex. The formulation of policies, development of work processes, and staff training and education are fundamental processes that continue to take place during construction.

The scale and beauty of the Oman Botanic Garden site was sensitively addressed during the design phases. (Image: Annette Patzelt)

Initial Idea

The idea to build a unique botanic garden in Oman dedicated to the presentation and interpretation of its native flora and vegetation was started in 2004. In response to this opportunity, a steering committee was formed and core elements of the botanic garden were identified.

Formulation of Vision, Mission and Strategic Documents

The steering committee – together with key staff members – formulated the vision, mission and principles to guide all aspects of the development of the botanic garden.

→→→

CASE STUDY 1.6 (CONT.)

RFP (Request for Proposal) and Design Brief

The garden produced a clear, focused RFP. A design brief was drawn up by the design consultant in close partnership with the client to guide the concept design stage. The design brief set out the parameters from the outset and has become a cornerstone document that continues to evolve with the various design phases of the project.

Master Plan Phase

A Master Plan was commissioned in 2006 and revised and updated in 2013. Its revision was prefaced by an intense period of all-encompassing critical analysis which considered authenticity, botanical content, site fragility, transport, operations, landscape, and technical responsiveness.

All Master Plan elements considered that the botanic garden should be convenient and enjoyable for the visitor and focused on visitor comfort and the overall visitor experience, while respecting the ecological integrity, beauty and the fragility of the site. Based on this vision, the consultant was tasked with creating an inspiring and immersive visitor experience.

Design

The design of the botanic garden was inspired by the complexity and the richness of Oman's flora, landscapes and ethnobotanical traditions. The design produced innovative and individual solutions that are inextricably linked and respond to the local site conditions. A holistic, multi-disciplinary, and integrated approach proved to be critical for the success during the design process.

Pre-Operations Management

While construction continues to move forward, a wide variety of pre-operational processes have continued since day one, including staff capacity building, the development of a governance model and staff structures, a comprehensive production list, as well as institutional policies. All this is occurring in tandem with the operation of a globally unique plant collection that consists of the living collection, seed bank and herbarium.

Pre-operations considerations and management are absolutely essential to ensuring that the garden will be fully operational once construction and planting are completed and the botanic garden opens its doors to the public.

Following spring rains, the site of the Oman Botanic Garden becomes green seemingly overnight. (Image: Annette Patzelt)

1.7.1 Expert Advice During the Design and Construction

Continued scientific and technical support by experienced, senior botanic garden staff will be required throughout all major stages of the development. This may include advice on horticultural or botanical aspects, operational processes, interpretation contents and social issues. Monitoring and evaluation of the design and construction outcomes should follow a multi-disciplinary approach with regular involvement of all botanic garden staff. For large, new botanic garden projects or redevelopment of existing institutions, seeking international advice is desirable to capitalise on a wide range of expertise and experiences and identify the most appropriate solutions.

1.7.2 Governance and Organisational Structure

KEY MESSAGE

A variety of governance models and organizational structures exist, and each botanic garden will need to find a model that best addresses its unique circumstances.

Very early on in the development of a new botanic garden, consideration needs to be given to the overall governance and staffing structure of the garden. For example, the organisation might be established as a government agency (under local, regional or national control), an autonomous research institution, a commercial company, an institution linked or incorporated into an existing body, an executive agency, or a not-for-profit foundation. Often, botanic gardens are established to include elements of several of these options (Wyse Jackson, 2003). Which organisational structure and governance model to adopt will generally be determined by complex and interrelated political and pragmatic realities of the specific project. The choice will also have to consider potential sources of funding and other support by stakeholders (Chapter 2). Staff structures for all departments need to be established; they will guide the staff recruitment process and will inform the business plan development.

1.7.3 Development of a Strategic Framework – Multi-Year and Business Plans, and Institutional Policies

Planning and developing action to accomplish objectives – strategic planning – provides the foundation for the management and future success of the botanic garden. Presented in strategic, multi-year plans, business plans and institutional policies, this strategic framework will ensure realistic targets and clear rules and procedures for the management of the botanic garden in accordance with its vision and mission. It may include:

- Strategic plan, usually over a period of 3-5 years and updated periodically;
- Business case and business plan;
- Institutional policies, e.g. for:
  - Plant collections including access and benefit-sharing and biosafety;
  - Research and education;
  - Staff recruitment;
  - Staff training;
  - Environmental sustainability;
  - Health and safety.

As part of the strategic planning process, priorities need to be defined, resources identified and weaknesses addressed that have a bearing on achieving the goals and objectives of the botanic garden. This is a collaborative process in which all staff are involved in one way or another. For example, at the Oman Botanic Garden, senior managers and mid-level staff participated in a series of half-day workshops, assisted by senior staff from the Royal Botanic Garden Edinburgh. The strategic framework that emerged from these workshops was circulated and presented to all members of staff in Arabic and English. This provided an opportunity to obtain feed-back and foster ownership of the objectives and targets to be achieved as set out in the strategic framework document.

The business plan outlines how an institution will be governed and run, or marketed and funded to successfully achieve the botanic garden's goals and objectives in accordance with its vision and mission. Depending on the context, the business plan may either be short-term or long-term and can include an annual financial plan that derives from the strategic long-term plans.

The business plan represents an analysis, decision-making and communications tool. It usually includes sections on goals and objectives, an institutional niche analysis, a governance, operations and implementation plan including a time schedule, a marketing strategy, revenue and funding targets, alternative options, as well as an analysis of risks and challenges. A solid business plan leads to well-informed decisions that are most appropriate for a given botanic garden setting, while failure to provide adequate level of detail, not undertaking the necessary research in the required breadth, disregarding relevant data, or making incorrect inferences, may lead to suboptimal conclusions and choices in terms of the time, money and opportunities. The business plan may be established in-house, depending on the availability of appropriately qualified staff, but often is also taken on by experienced consultants. It should be reviewed periodically to reflect change.

It is vital for all the botanic garden personnel to identify with the botanic garden's strategic framework documents. This includes familiarity of the staff with:

- Their role in the botanic garden's strategy and their place in the staff structure;
- Their responsibilities and accountability;
- Their agreed targets to be achieved;
- How their performance will be measured and evaluated.

Botanic gardens exist within a rapidly changing environment. To this end, regular reviews and amendments of the strategic framework documents are required to anticipate and respond to changes. One way of achieving this is for annual work plans to be derived from the business plan, and in this way be kept under constant review. All strategic documents drawn up during the pre-operations phase should be revisited once the botanic garden is fully operational.

1.7.4 Staff Recruitment and Professional Training

KEY MESSAGE

Staff recruitment and continued capacity building for all existing staff should not be seen as a cost but as a benefit to the botanic garden.

Early staff recruitment in line with the organisational structure is a strategic priority. The strategic framework documents, including staff requirements, determine which skills are needed. Continued and targeted training is important to develop staff to an expected level of expertise and performance. Training at all staff levels should not be seen as a cost but rather as a benefit and obligation of the botanic garden, and staff should be regarded as an asset.

On-the-job training represents a significant proportion of capacity building, for instance through the daily work in the botanic garden nursery or during field expeditions, or simply through team discussions and workshops. If sufficient budget is available, attending international training courses is always extremely valuable.

Botanic gardens themselves are leading training centres in all fields of botany, horticulture, etc. They enhance national and international capacity in plant biology and conservation science for instance through undergraduate and graduate degree programs, diplomas, internships or project partnerships.

1.7.5 Developing the Plant Collections

KEY MESSAGE

The plant collections are the very essence of a botanic garden and should be based on a thorough collection policy.

The collection, propagation or procurement of the required plant material represents an enormous task, requiring rigorous planning, data management, plant propagation and cultivation and/or purchasing detail, pest and disease control and plant maintenance. Supported by an appropriate collection record management system (Chapter 5), this may include:

- Field work to collect the required plant material;
- Propagation or acquisition of plants;
- Species identification and verification;
- Labelling and accessioning;
- Horticultural and plant maintenance protocols;
- Establishment of a seed bank, field genebanks, cryopreservation facility, etc.;
- Establishment of a herbarium and processing of herbarium vouchers;
- Facilitating partnerships locally, nationally and internationally to encourage sharing of expert knowledge.

Figure 1.2 Eurobodalla Regional Botanic Garden collection target model

Basic template offering comprehensive information on collections targeting, production and management used at the Eurobodalla Regional Botanic Gardens, New South Wales, Australia. (Image: Michael Anlezark)

Eurobodalla Regional Botanic Garden Collection Target Model (excerpt)

Creating a species Target list, species selected on their ability to provide certain qualities

Family	Genus	Species	Found in Endangered Ecological Community EEC	Desirable in Conservation Projects	Valuable in Amenity Horticulture	Not found in ERBG collection	Saleability	Found outside ERBG region	Total Score
MYRTACEAE	Eucalyptus	melliodora	3	3	2	6	4	1	19
PITTOSPORACEAE	Bursaria	spinosa ssp lasiophylla	3	3	2	6	3	1	18
CYPERACEAE	Gahnia	aspera	3	3	2	6	3	1	18
CYPERACEAE	Gahnia	melanocarpa	3	3	2	6	3	1	18
MYRTACEAE	Kunzea	ericoides	3	3	2	6	3	1	18
CYPERACEAE	Lepidosperma	concavum	3	3	2	6	3	1	18
ERICACEAE	Monotoca	elliptica	3	3	2	6	3	1	18
THYMELAEACEAE	Pimelea	axiflora	3	3	2	6	3	1	18
THYMELAEACEAE	Pimelea	curviflora	3	3	2	6	3	1	18
POACEAE	Austrostipa	rudis ssp australis	3	3	2	6	2	1	17
ASTERACEAE	Cassinia	longifolia	3	3	2	6	2	1	17

A production list should be developed with clear targets of the plant material needed, specifying species, number, size, and other information as required (Figure 1.2). The production list needs to be updated frequently. For example, the Oman Botanic Garden is updating its list weekly, incorporating the newest data from the field collection, seed bank, propagation and production. This makes the production list a very strong and strategic tool that needs to be appreciated and implemented by all relevant botanic garden staff.

1.7.6 Initiating Research Activities

A series of research activities may be initiated during pre-operations. For instance, this could include botanical, taxonomic, ethnobotanical, horticultural or conservation research relevant to the particular context of the botanic garden. Such early investment could lead to the establishment of a particular research niche or centre of excellence that establishes the institution as of national or international significance.

Such research programmes may offer contributions to solving present-day ecological problems by integrating theoretical research, applied solutions, and adaptive management to save individual species – as well as communities of species – at varying geographic scales.

Although often hidden from the public, botanic gardens have a unique opportunity to exhibit research activities to their visitors, thus also embracing their social and environmental responsibilities. Botanic gardens can act as a 'window into plant science', and it is important that these activities are included in the interpretation and visitor programmes of the botanic garden.

1.7.7 Developing Education, Interpretation and Communication Activities

KEY MESSAGE

Botanic gardens have the responsibility and the perfect opportunity to communicate the importance of plant conservation and environmental sustainability to the general public

Botanic gardens are increasingly concerned with becoming more relevant to the public by working with visitors and communities to address present-day concerns including food security, water scarcity, sustainable energy, climate change and biodiversity loss (BGCI, 2010). While there is tremendous scope and potential for botanic gardens to take on a much broader role in society, this will require in-depth, thoughtful planning and should be considered when establishing the institution's vision and mission (Section 1.2.4).

Main aims when developing education, interpretation and communication strategies during pre-operations may include the following:

- Preparing education and outreach programmes and resources;
- Formulating key interpretive messages;
- Conveying the key interpretive messages to the visiting public, for instance via interpreting displays, exhibitions, the website, etc.;
- Developing branding and marketing strategies including a pre-operations strategy and a botanic garden opening launch strategy;
- Facilitating partnerships nationally and internationally to encourage a diverse range of education and interpretation programmes.

Education and interpretation are a core priority for botanic gardens. Early during the design phase, education and interpretation strategies should be explored and decisions should be made on the key themes for the botanic garden. As the development moves on, the botanic garden should, ideally, be seen as a leader in creating the best education and interpretation possible by unlocking information on plants for the public, both on-site and online.

1.7.8 Preparing a Marketing Strategy

KEY MESSAGE

A good brand is distinctive, memorable, timeless and practical, with versatile graphics, simple in form and unmistakably conveying the institution's intended message.

During pre-operations, a marketing strategy closely linked with the education and interpretation programmes, should be established. This should include the development of a brand and a brand manual. The main purpose of a brand is to identify the garden and its products as being distinct. A brand should be immediately recognisable, inspiring trust, admiration, loyalty and an implied authority. A brand manual provides a strategic overview of how to apply the brand and logo on the institution's products, in education, interpretation and communications. The logo is one aspect of a botanic garden's commercial brand, and its shapes, colours, fonts, and images usually should be strikingly different from other logos. A good brand is distinctive, memorable, timeless, and practical, with versatile graphics and simple in form, unmistakably conveying the institution's intended message.

Marketing, in its widest sense, is at the core of a successful botanic garden. Botanic gardens live within a competitive market, and it is important to recognise which stand-alone factors attract visitors to botanic gardens, including people's motivation and objectives for coming to the garden. Communications, at any stage of the development, will use the distinctive brand of the institution, thus preparing all stakeholders for the big day – the opening of the new botanic garden!

1.8 CONCLUSION: CRITICAL SUCCESS FACTORS TO ESTABLISHING OR REDEVELOPING BOTANIC GARDENS

Botanic gardens are special places, and each one is unique. The design and construction of a new botanic garden, or the renovation or expansion of an existing one, are in many instances a once-in-a-lifetime venture. Critical evaluation and review are vital throughout the entire development process and a flexible, adaptive management approach will have a major bearing on a successful project outcome (Table 1.3).

Typically emerging out of an initial, big idea (Section 1.2), there follows a number of steps that need to be tailored to each individual project to achieve its goals and objectives. Prior to the beginning of the design process (Section 1.5), the establishment of a steering group (Section 1.2.2) and the development of vision and mission statements (Section 1.2.4) are critical first stages. The ensuing establishment of a feasibility study (Section 1.4.2) followed by the development of a business case (Section 1.4.3) and design process (Section 1.5) will build a strong foundation for the detailed design and construction phases (Sections 1.5 and 1.6).

A successful design is reliant on a highly skilled and experienced design team (Section 1.5.1) working in close cooperation with the project owner and other stakeholders. The efforts invested in finding the right design team will prove extremely valuable in bringing the project to life. Similarly, it is essential that the project is built by highly skilled and experienced contractors with the close involvement of the project owner, project manager, design team and botanic garden staff.

The significance of pre-operations (Section 1.7) cannot be overstated – the earlier the better! While this aspect of establishing a new botanic garden is often overlooked, everything from establishing the governance and organisational structure, the plant collection and initial programmatic activities including research and education, are all vital for the eventual success of the project.

Botanic gardens celebrate plants. As the collections grow and develop, it is natural for the design of a botanic garden to evolve. Design refinements will continue long after the ribbon has been cut on opening day, and will always remain an integral part of the operations of any botanic garden.

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Table 1.3 Critical success factors for new and existing botanic gardens

Organisation	New	Existing
What are the goals and objectives? Requirement for clear vision and mission statements	✓	✓
What is the best governance model?	✓	
What is the appropriate legal and administrative structure?	✓	
What is the optimal staff structure?	✓	✓
Planning	**New**	**Existing**
How to approach getting an appropriate design for the garden?	✓	✓
What is the timeline and schedule?	✓	✓
What are any likely challenges and risks?	✓	✓
SWOT analysis (strengths, weaknesses, opportunities, threats)	✓	✓
Infrastructure	**New**	**Existing**
Where will the project be located?	✓	✓
What are the required programme elements?	✓	✓
What are the overall space requirements?	✓	✓
How can the site be secured?	✓	✓
Budget	**New**	**Existing**
How much budget is required for development and construction?	✓	✓
How will the project be funded?	✓	✓
How much budget is required for operations and maintenance?	✓	✓
Contributions to the society and community	**New**	**Existing**
What contribution can it make to the scientific and cultural community, both on the national and on the international level?	✓	✓
How can support from relevant stakeholders (e.g. governmental, municipal, official and local authorities, private) be secured?	✓	✓
Pre-operations and operations	**New**	**Existing**
How many staff are required and how and from where can they be recruited?	✓	✓
How can highly and appropriately qualified and motivated staff be recruited?	✓	✓
How can an effective information management system be set up?	✓	✓
Who will be the likely visitors?	✓	✓
How many visitors and which user groups might be expected?	✓	✓
How can interpretation be capturing, making it relevant to the visitors?	✓	✓
How can the marketing be effective?	✓	✓
How can the garden provide easy access for visitors?	✓	✓
How can the garden provide an enjoyable visitor experience?	✓	✓

B Organisational and Operational Essentials

Part B: Organisational and Operational Essentials

Contents

CHAPTER 2: GOVERNANCE MODELS, HUMAN AND FINANCIAL RESOURCES DEVELOPMENT

Chapter 2:
Governance Models, Human and Financial Resources Development

David A. Galbraith, Royal Botanical Gardens, Canada

2.0 DEFINITIONS

Board of directors: See governance body.

Board of governors: See governance body.

Board of trustees: A group of individuals who are either appointed or elected to be the legal decision-making body for an organisation. As there are differences in the use of the terms director, trustee or governor from place to place, we assume that they all have roughly the same function, and will use the term board of trustees throughout. See also governance body.

Business plan: A document outlining how an institution will be governed, marketed and funded to successfully achieve its goals and objectives. Depending on the context, the business plan may either be short-term or long-term.

Chair: An individual who acts to ensure the smooth management of a committee or board, through management of agendas and rules applicable to a meeting.

Charitable organisation: A charitable organisation is usually a not-for-profit entity that carries out activities deemed 'charitable' by a national authority. As a result, charitable organisations in some jurisdictions may receive financial donations with receipts that benefit donors through a reduction of taxes payable, and which also benefit the organisation.

Chief executive officer (CEO): The chief executive officer is usually the highest-ranking staff member within an organisation, reporting to the governance body. The title is similar to that of director, president or chief operating officer.

Chief operating officer (COO): The chief operating officer may be the highest-ranking staff member within an organisation, similar to the CEO or director, or may be responsible for the actual operational aspects of the institution and report to the chief executive officer.

Conflict of interest: A conflict of interest is a situation in which an individual with decision-making responsibilities in an organisation derives actual or potential benefits from the decisions made on behalf of the organisation. Actual or perceived situations of conflict of interest can be avoided by ensuring that the individuals involved do not take part in any such decision-making processes.

Corporation: Any organisation that has been registered with a national or state government as a legal entity capable of taking in and expending monies, and in some cases borrowing monies, and operating as a legally-defined entity. Corporations may be for-profit organisations or not-for-profit organisations.

Director: 'Director' is used in three distinct, and usually separate, senses in organisations. A director may be: a member of the board of directors, the most senior staff member leading a botanic garden, or one of several senior managers leading an internal division or section of a botanic garden.

Executive director (ED): An executive director is usually the highest-ranking member of staff within an institution. Similar to the staff sense of director, chief executive officer, or chief operating officer, depending on the definitions used by the particular institution.

For-profit organisation: A for-profit organisation is governed by a board or other body that is not directly accountable to any other institution or to a level of government. Individuals may receive financial benefits for owning or investing in the organisation.

Governance: The process of making the policies by which an organisation operates.

Governance body: The group of individuals selected to be the highest decision-making body of an organisation. Depending on the type of organisation and jurisdiction, a governance body may be referred to as a board of trustees, board of governors or board of directors.

Hierarchical organisational management: There are many ways in which people can organize themselves to undertake a task. Most organisations exhibit some form of hierarchical organisational management, in which a few individuals are given leadership positions and provide direction to a work force.

Not-for-profit / non-profit organisation: An organisation in which individuals do not receive financial benefits that may be generated by the activities of the organisation. In some jurisdictions, not-for-profit organisations cannot take in more money than they expend on providing their programmes. In other jurisdictions, not-for-profit organisations can receive or earn monies in excess of their immediate costs, but then re-invest those 'profits' in the development of their programmes or capacities.

Organisational chart (or organogram): A graphical depiction of the relationships among individuals or groups within an organisation.

Outsourcing: Practice used by organisations to reduce costs by transferring portions of work to outside suppliers rather than executing it internally.

Policy: Policy includes the written directions provided by a governance body (such as a board of trustees) for what an organisation will and will not do, and often, how it will do what it does. Such documents are also prepared by staff, for example policies governing the use of facilities such as libraries. In the sense that is important here, policies should be considered as the working rules provided by an institution's governance body.

President: 'President' is used in two distinct senses in botanic garden organisations. A president may be the chair and spokesperson for the board of trustees, or may be a highly qualified and experienced staff member, perhaps the most senior staff.

Secretary (board officer): Usually, an individual member of a board of trustees who is appointed by the board or chair to ensure meetings are arranged, minutes are recorded, and meeting agendas prepared. A secretary does not necessarily have to record the minutes of meetings and undertake other work themselves, but must ensure that it is done.

Strategic plan: Description of the overarching direction or directions during a specified period, often over three to five years. Strategic plans set the tone and targets for the entire organisation and identify the highest programme priorities.

Treasurer (board officer): Usually, an individual member of a board of trustees who is appointed to keep track of financial records.

Trustee: See board of trustees

Volunteer: Anyone who carries out a function for a botanic garden and who is not paid for their services. Volunteers may be involved in the governance and management of a botanic garden, in gardening, running gift shops, or any other activity or function. Typically, all members of the governance body of a botanic garden are volunteers.

2.1 INTRODUCTION

KEY MESSAGE

Invest in people and they will invest in you.

Botanic gardens are much more than landscapes holding beautiful gardens, useful plant collections, and other features and amenities. They are also organisations of people. How those people are organised, function, and change over time is the primary determinant of success for a botanic garden. This is because it is the people who innovate and direct their passion and skills to problem-solving, making improvements and finding resources.

When challenged by the question "What is a garden?" many answers come to mind. Only one seems universal: "A garden is what a gardener makes." If this is true, then botanic gardens are places where many different kinds of gardeners must come together for success. Commonly, botanic gardens hold documented collections of living plants for the purposes of scientific research, conservation, display and education (Wyse Jackson, 1999). There is no question that to create and maintain a successful botanic garden requires top-flight, professional horticultural expertise, passion and creativity. It also takes a myriad of other skills, from education and interpretation to administration and marketing, from communications and human resources management to operational programming and governance oversight.

The purpose of this chapter is to introduce the fundamentals of organisational structure and management applicable to botanic gardens. Because of the diversity of organisations that fall into this category, there are few rules that apply to all. Rather than being prescriptive, this chapter presents general considerations that are intended to help the reader understand the basics of organisational structure and design.

2.2 GOVERNANCE MODELS

2.2.1 What is Governance?

Hortum meum, praecepta mea
(Latin – My garden, my rules)

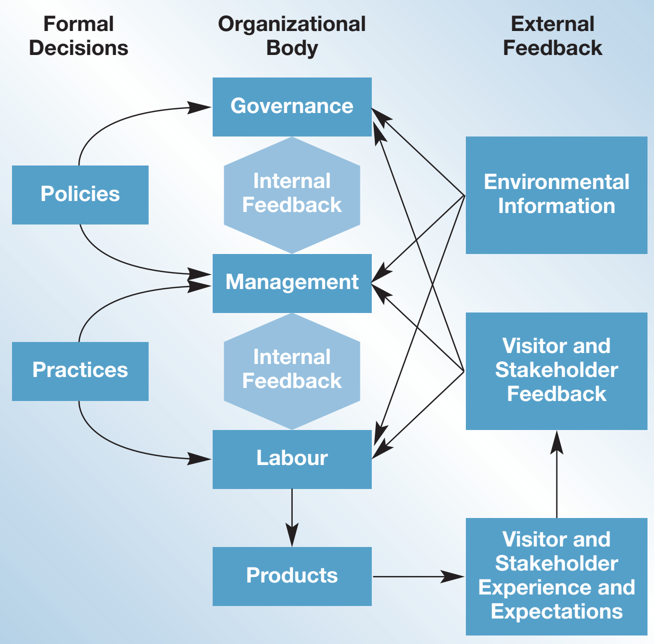
Governance is a multifaceted concept that encompasses all aspects of how decisions are made and information is used within an organisation. The term derives from the Greek word for 'steering', and describes how groups of people – from small companies to national governments – set rules, apply them to their activities, and adapt them to changing needs.

For a botanic garden, governance in its broadest sense is the set of processes by which all aspects of the institution are organized. More specifically, governance is the process that sets the rules that individuals within the organisation must follow. In a legal sense, an organisation must adhere to the laws of the municipal, state, and national governments in which it operates. However, in addition to adhering to statutory laws, an organisation will have its own set of 'voluntary' rules that govern the way in which it conducts its business. These rules are an important part of the ethos of an organisation, and the culture that the botanic garden wants to create.

Regardless of the kind of organisation, its functions may be divided for convenience into three major categories: governance, management and labour. Typically, the activities of these three functions are assigned to discrete groups of individuals. As defined above, governance is the function of making the rules by which the organisation will work. These rules are often called policies, and for convenience the group of people responsible for them is referred to as a governance body. Management is the function by which the rules or policies set by governance are enacted, progress made is reported on, and which guide and coordinate labour. Labour encompasses all of the functions that 'get the job done' in a practical sense, whether that's tending a botanic garden, managing plant records, producing a financial report, designing an advertising poster, writing a scientific paper, or any of the other myriad functions that take place to operate a botanic garden (Figure 2.1).

European Botanic Gardens Consortium, a regional network with a diverse institutional representation. (Image: BGCI)

Figure 2.1 Simplified diagram of an organisation's internal structure and flows of information



This model indicates separations between governance and management, and between management and labour that are sometimes incomplete in smaller organisations. 'Products' are all of the end results of the work of the organisation. In the case of a botanic garden, these may include educational programmes, scientific or research output, contributions to conservation programmes, events, food services, or any other deliverables or services that stakeholders and the public might value. Most organisations have these three high-level functions in some form, but how they are arranged varies as do the numbers and specialized skills of individuals.

The governance function is usually performed by a board of trustees, board of directors, or board of governors. These titles vary depending on jurisdiction and tradition, and upon the kind of organisation itself. The management function is generally carried out by one or more individuals with experience in facilitating and directing the work of others. The labour function is usually performed by individuals or smaller groups that each report to a manager responsible for their specific tasks. In this chapter, 'labour' is not meant to only mean organized labour in the sense of one or more unions, but instead the totality of the work force. Furthermore, the functional levels are not necessarily exclusive: in many organisations, individuals who may be classified as 'managers' (in the sense that they supervise others in the organisation) are also involved in the direct delivery of a service or programme that might be classified as the products of labour. An example would be the head of a department or the most senior staff member of an organisation delivering a presentation to another organisation, or being a domain expert in botany or horticulture.

This arrangement of function is essentially hierarchical. The governance body bears ultimate responsibility for the institution and delegates authority to management who then further delegate tasks to labour. There are other ways that groups of people can be organized, but for our purposes, we will consider just this basic model.

How information moves between these functional groups is critical to the success of the organisation, and it cannot move in one direction only. While the governance body is usually directly responsible for setting the direction and working rules by which an organisation functions, it is often individuals in management or labour who have the richest understanding of the 'on-the-ground' situation of the institution: its environment, performance and immediate challenges. The 'management' level must also serve as an effective gatherer and synthesizer of information that reaches governance.

While these points about the functions of basic groups within an organisation may seem obvious, it is worth repeating that how these three groups are established, function, interact and change over time is the primary determinant of organisational success. Having a clear appreciation of the requirements for each is therefore fundamental to establishing and managing the operational essentials of a botanic garden.

2.2.2 Institutional Types and Governance Arrangements

KEY MESSAGE

There is no 'standard model' for how a botanic garden functions, and numerous categories exist depending on their overarching, institutional goals.

Apart from maintaining well-documented collections of plants for manifold purposes, there are few characteristics of botanic gardens that could be considered as universal. It is possible, though, to identify several major institutional types, and understand how their governance and operational management corresponds to what they actually do, and how. It is also possible for an individual institution to move from category to category over time, as resources and organisational structures change.

Staff of the Royal Botanical Gardens, Canada, reviewing organisational structures. (Image: David Galbraith)

Friends of the Central Experimental Farm, Ottawa, at work. (Image: Central Experimental Farm)

- **Volunteer-based or community institution**

A volunteer-based or community botanic garden is an institution that has been established and is operated through 'grass roots' organizing. Often, these are driven by a single enthusiastic individual, or a small committee of volunteers, and then managed by a wider circle of volunteers. In some cases, volunteer or community botanic gardens may represent the only practical option if budgetary or other restrictions limit the capacity of the organisation to pay staff.

In other circumstances, an established botanic garden may be reorganized and lose staff to the point where it is operated solely by volunteers. This will be one possible outcome of a severe loss of income to the institution, such as having government funding support removed. An example of this situation is the ornamental garden at the Central Experimental Farm in Ottawa, Ontario, Canada, where management of the garden and arboretum was turned over to a volunteer group, the Friends of the Central Experimental Farm, formed in 1988.

Governance and organisation:

Volunteer botanic gardens often have individuals fulfilling many roles. They may be on the governance body but also be actively involved in planning developments or events (management functions) or carrying out on-the-ground work.

- **Government agency**

A government agency is defined here as an institution that is owned and managed by some specific level of government, whether at a municipal, regional, provincial, state, or national, level. Botanic gardens that are government agencies may be wholly supported by state funding, and might even be open to the public without admission charge. More often than not however, even state-supported botanic gardens need to raise some of their operating revenues through means similar to a not-for-profit organisation.

Governance and organisation:

Government agencies will often have a specific organisational structure imposed by their parent body, and therefore might have a governance body independent of the government department to which they report. However, some government-based botanic gardens may also establish or be affiliated with quasi-independent organisations to assist in delivery of their mission. An example of this is VanDusen Botanical Garden in Vancouver, British Columbia, Canada. Here, the management itself is performed by the Vancouver Park Board, but educational and other associated functions are provided by the not-for-profit VanDusen Botanical Garden Association, formed in 1966. The Association has an elected board of directors and supports ten full-time staff.

- **University or college institution**

A university botanic garden is defined here as an institution owned and managed as an academic unit of a university or college. University botanic gardens are more likely to be directly engaged in research and higher education teaching than others, but in a world of changing academic priorities even research is not a given for university botanic gardens. Some allow free admission to the public or to members of the university community, while others charge and raise funds for operational needs.

Governance and organisation:

A variety of organisational models are found among botanic gardens associated with universities or colleges. In some cases they are strongly associated with a research-based department and exist to support its programmes (Case study 2.1). In others they may be considered as amenities for the university community or for the larger community, and may have fundraising and decision-making capacity separate from the university department. As is the case with government-based botanic gardens, university botanic gardens may have organized volunteers, 'friends' groups, or other affiliated agencies that contribute to their missions.

VanDusen Botanical Garden, Vancouver, Canada – an example of a government-based institution closely affiliated with a not-for-profit organisation. (Image: David Galbraith)

CASE STUDY 2.1

Adapting to changing needs – Cambridge University Botanic Garden

Beverley Glover, Cambridge, United Kingdom

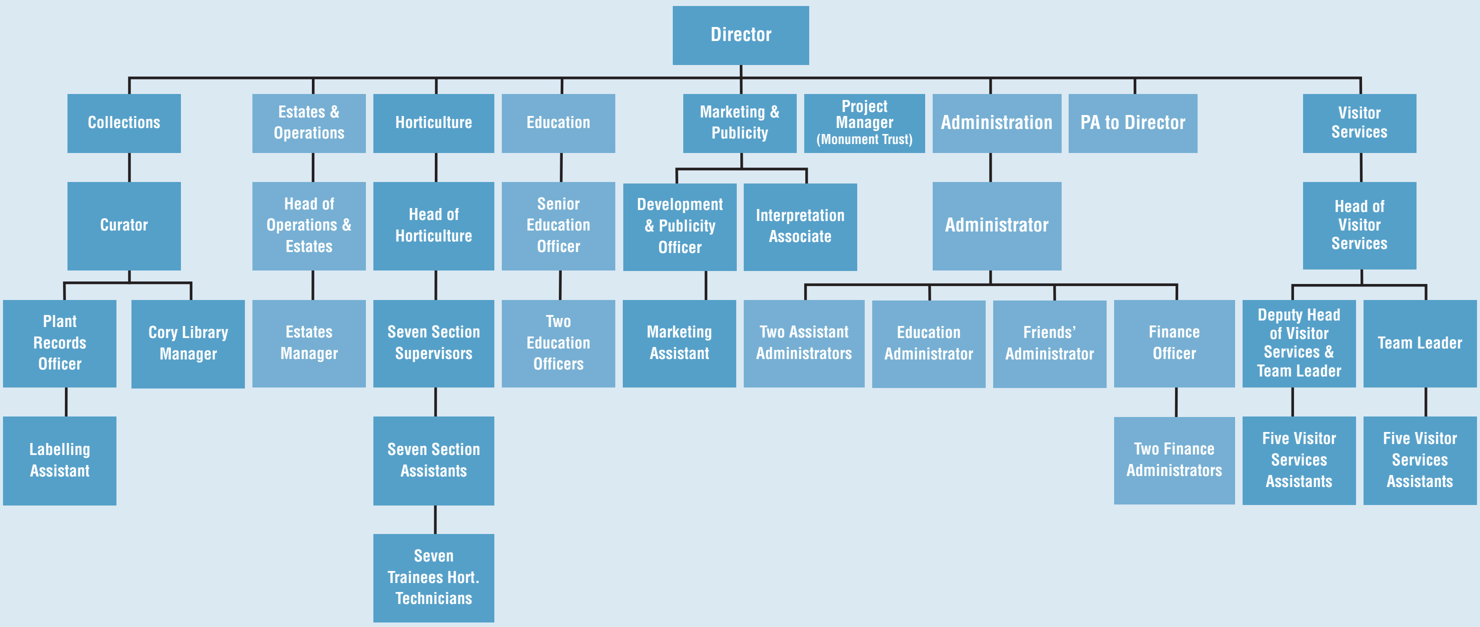
Cambridge University Botanic Garden (CUBG) was founded in 1762 on an old site in the centre, of Cambridge, England. The botanic garden moved to its present 16 hectare site in 1846. This university botanic garden is a sub-department of the Cambridge University Department of Plant Sciences. In 2012/2013, its annual operations resulted in an expenditure of GBP 1,970,100 (USD 2,825,000). Income comes from a variety of sources, including support from the University (35%), trust funds (23%), admission fees (16%), the Science and Plants for Schools Gatsby Funded Programme (9%), support from the Friends of CUBG (8%), earmarked funds (3%), donations and miscellaneous income (3%), education income (2%), and projects and grants (1%). The work force includes about 57 paid staff and some 75 volunteers.

The botanic garden is organised into nine units, each let by a department head. The mission statement for CUBG emphasizes the importance of maintaining Cambridge University's teaching and research collections of living plant species. The Collections Department, headed by a Curator who also serves as Deputy Director, is responsible for the development and implementation of

Cambridge University Botanic Garden. (Image: Pete Atkinson)

the plant collection strategies. When asked how the organisation is changing, the Director, Professor Beverley Glover, notes *"We have recently restructured – turning the unwieldy 'Collections and Estates Department' into two separate units. Equally, to deal with growing visitor numbers, we have established a separate 'Visitor Services Department' formerly part of our administration unit when visitor services were a minor part of our role. It helps to have regular, fortnightly meetings of all department heads to promptly address and respond to changing organisational needs."*

Staff organisational chart of Cambridge University Botanic Garden, United Kingdom (as of 2015)



Norfolk Botanical Garden, Virginia, an example of a not-for-profit organisation. (Image: Norfolk Botanical Garden)

- **Not-for-profit or charitable organisation**

Many countries provide legal means to create a corporation that does not exist to return dividends or profits to shareholders. Such 'not-for-profit' or 'non-profit' corporations are often established to promote a social purpose such as education, research, or conservation. It is a mistake, however, to assume that a not-for-profit organisation or corporation should not raise funds in excess of their operating costs (colloquially, to 'turn a profit'). In some countries this may not be allowed, but in others, funds in excess of operating costs should be raised and then re-invested in the purpose for which the organisation was formed. What differentiates a not-for-profit corporation from a for-profit corporation is that individuals own shares in a for-profit corporation and receive dividends (a share of the profits) from that ownership. In a not-for-profit organisation no individuals own shares and no one should benefit in any financial way, except for employees providing their labour to the institution. Such organisations are also sometimes identified as being 'without share capital'.

A charitable corporation and a not-for-profit corporation are not always the same thing. Tax law in some jurisdictions allow for donations or contributions to be made to a charitable organisation that then brings some benefit to the donor, often in the form of a reduction in taxes the donor will have to pay on income. Charitable organisations usually have to fit some established criteria as to what constitutes 'charity' in the eyes of the government of the day. Charities are also usually not-for-profit organisations.

Depending on the jurisdiction, charitable corporations may or may not have to pay property taxes. Not having to pay property taxes is a distinct benefit for institutions that own and manage considerable acreages.

Governance and organisation:

Not-for-profit organisations are usually required to have a clear governance structure in which the board of governors or board of directors are volunteers elected by members or appointed by stakeholders. Technically, the governance body may actually be considered to be the corporation itself, for which paid employees (or volunteers) then work. Separation of the day-to-day work and governance in not-for-profit organisations is sometimes not complete. Some boards may be described as 'management boards' in which various individuals contribute directly as senior volunteers to day-to-day work necessary to operate the institution (often in highly technical areas such as accounting or finance). This is often the case when an institution is too small to have all of the necessary functional positions actually filled by staff. By way of contrast, organisations with 'governance boards' are those for which all of the functions necessary for administration, finance, or other roles can be carried out solely by staff, and the governance body is free to focus on longer-term planning, policy and fundraising.

The separation of governance and management functions in not-for-profit organisations is important to ensure that conflicts of interest do not arise.

A further distinction is whether a not-for-profit organisation is actually considered 'private'. A private not-for-profit organisation is one that is governed by an independent board that is not directly answerable to a parent government organisation.

- **For-profit, private organisation**

A for-profit, private organisation is governed by a board or other body that is not directly answerable to any other organisation or to a level of government, and which is not defined as a charity or not-for-profit organisation. Some major public botanic gardens are privately owned and managed as for-profit enterprises.

The Butchart Gardens, Victoria, Canada, an example of a family-owned institution established in the early 19th century on a quarry and cement plant site. (Image: The Butchart Gardens)

Governance and organisation:

For-profit, private botanic gardens may be set up and managed as with any other business enterprise or corporation. Many of the same concerns shared by not-for-profit organisations are applicable to the for-profit world. There must be a clear means to avoid conflicts of interest in decision-making, and the relationships between governance, management, and labour are, overall, very similar. In the case of sole-proprietorships, one individual owns a for-profit organisation, and might even be the sole manager. In the for-profit world, individuals who sit on governance bodies are often paid for their time.

- **Hybrid organisation**

The list of types of organisations above does not necessarily include every kind of botanic garden governance. In some cases, botanic gardens have strong working relationships with one or more levels of government, or some parent institution, and yet are also self-governing and perhaps registered as a charitable organisation. Some university botanic gardens, for example, are owned by and function as an academic or operational unit of the university, but are also registered as a charitable organisation and are able to receive donations and other funding from outside agencies. For instance, the Jerusalem Botanical Gardens were established as a university botanic garden in the 1950s. Opened to the public in 1985, and expanded in the late 1980s and early 1990s, the institution is now run by a not-for-profit organisation governed by six bodies: the Hebrew University, the Jerusalem Municipality, the Jewish National Fund, the Jerusalem Foundation, the Kaplan family, and the Friends of the Botanical Gardens.

Governance and organisation:

The potential for different kinds of governance structures is broad, but the notes above should include most of their salient features.

Jerusalem Botanical Gardens. (Image: Judith Marcus)

2.3 THE HUMAN ELEMENT: HUMAN RESOURCES DEVELOPMENT

2.3.1 A Diversity of Roles, a Diverse Work Force

KEY MESSAGE

Q: What happens if we invest in the development of our people and then they leave?
A: What happens if we don't, and they stay?

The structure of the work force within a botanic garden can vary immensely. This section is intended to highlight the basic questions that must be addressed when starting up a botanic garden or when the organisational structure and work force needs to be reconsidered and, perhaps, different structures selected.

What are the major functions necessary to operate a botanic garden? Here are most of the major functions with short definitions of each. These are not necessarily the only functional areas of work within a botanic garden, and their arrangement is arbitrary.

- **Leadership and overall management**

It is difficult to envision a botanic garden without an individual providing the leadership necessary to bring the many different functions together. This most frequently is expressed as someone with a title such as director, managing director, executive director, chief executive officer, or president. Historically, and in many research-focused institutions today, the most senior staff member will be a very experienced botanist or horticulturist. Increasingly however the demands of managing complex organisations, large, diverse work forces, and significant funding programmes brings a diversity of backgrounds and experiences to the leadership role within botanic gardens. While many years of experience within the botanic garden sector is advantageous for those in a leadership role, other skills that are complementary to traditional strengths in horticulture are today also found in the director's office.

Most organisations operate on a hierarchical basis in which one or more individuals assume responsibility for guidance and decision-making at the highest staff, or management level:

- **Director:** For a long time, the highest-ranking manager in a botanic garden was given the title 'director'. This term is in flux today, and is often considered confusing because of the use of the same designation at the governance level.

- **President:** A senior staff member identified as the president of an organisation is usually serving in a leadership capacity, and may delegate operational and management oversight to others. Confusingly, in private business, a president is usually subordinate to a chief executive officer (CEO), and often the roles are combined.

- **Executive director:** An executive director is usually the highest-ranking staff member within an institution, reporting directly to the board, and to whom, ultimately, all of the employed staff members report. The term itself is most often used in the not-for-profit sector, and executive directors may or may not also hold the title of CEO.

- **Chief executive officer (CEO):** The term chief executive officer (CEO) is often used in for-profit business for the highest-ranking staff member of a company. In private business, the CEO is often looked upon as the primary leader responsible for raising funds. The CEO may be complemented by a subordinate chief operating officer. In some instances, the president of the governance board may also serve as the highest executive officer, leading to such titles as 'president and CEO'.

- **Chief operating officer (COO):** A chief operating officer (COO) is a highly qualified staff member in a larger institution, possibly the most senior staff, who is responsible for the smooth operation of all of the day-to-day work of the organisation.

• Garden and landscape management

A botanic garden requires gardeners, and tending of plants. Many botanic gardens position themselves as horticultural displays for the public in addition to their collections-focused roles and functions. Providing visitors with an attractive landscape is now central to the missions, and in many cases the financial survival, of botanic gardens. Being able to manage existing gardens and landscapes – from trimming lawns and hedges to planting annuals and pruning woody plants – are all necessary skills and capacities.

The function of horticulture (Chapter 6) is central to any botanic garden. As both an art and a science, horticultural expertise is acquired through many years of training and experience. This expertise is often distributed among many of the staff of a botanic garden, but may find its greatest expression in those directly responsible for the management and condition of display gardens and specialized plant collections.

An important question is whether landscape management is considered to be the role of the horticulture team or is placed under operational management. For example, many botanic gardens own and manage open spaces or park spaces that may require extensive landscape management activities of which horticultural work that takes place within gardens areas is a comparatively small part.

• Collections management

Collections are at the heart of what a botanic garden is all about (Chapter 3), and the management of living collections requires several different skill-sets. The most senior staff member responsible for a collection is usually termed the curator of that collection. Curators are responsible for both the management of a collection and also for setting its direction and guiding its use. Curators are much more than book-keeping technicians; they are the domain experts who bring their respective collections to life for their users.

- **Living collections:** Living collections present a wide range of management challenges. Not only is the management of a living collection a specialized field, it demands experience and training in both the biology of the organisms involved – the horticulture and botany of the plants in question – but also in the technical aspects of dealing with collections, from identification and documentation to databasing and legal mechanisms for exchanging plants among institutions. Furthermore, unlike non-living collections, living collections require constant investment in the care of the plants themselves. This in turn requires a very strong working relationship between horticultural management and collections management.

- **Herbarium:** Numerous botanic gardens maintain and use herbarium collections for documentation of wild plants or for horticultural vouchers. Many of the capacities required for herbarium management are complementary to those for living plant collections, such as competent record keeping, skills in plant identification and database systems. The complementarities are so strong that botanic gardens are increasingly instituting common database systems that can hold the records of both living and non-living plant collections.

- **Library and archival collections:** Many botanic gardens operate specialized libraries. Often, especially older botanic gardens have developed large library collections, but the roles and structures of libraries in general are undergoing profound change through the development of digital resources.

  Library and archival collections are generally assembled for two purposes: to meet the needs of the managers and staff of a botanic garden, and/or to serve the public and visitors. Understanding who the users are is central to how libraries are developed. In the late 20th and early 21st centuries, libraries in general have been changing at a very rapid pace, as electronic resources become more available, and as budgetary pressures reduce the capacity of institutions to operate more conventional libraries.

  Archival collections may complement the programmes and knowledge base of a botanic garden too, through holdings that reflect this history of the institution or materials related to institutional foci, such as botanical art, manuscripts or artefacts.

Many botanic gardens both employ and train students. Here, first-year students attend 'Demonstrations' in horticultural practice. (Image: Niagara Parks Commission Archives)

- **Conservation**

Conservation (Chapter 7) is a key goal of many botanic gardens and their national, regional and global networks, requiring specialised staff expertise and capacity. However, there is a plethora of different forms of conservation to which botanic gardens may contribute. *Ex situ* conservation programmes (such as living plant collections, seed, plant tissue or DNA banks) are often developed by botanic gardens but, increasingly, they also directly undertake the management and restoration of natural areas in which wild plant species are at risk *in situ*.

- **Research**

Botanic gardens began in part as research centres, making use of both their living collections and the scientific expertise of their staff. Today botanic gardens based at universities are often involved in research, as are other types of botanic gardens, but the kind of research undertaken has broadened considerably (Chapter 7). Once concentrating heavily on whole organism science (e.g. plant taxonomy) today botanic gardens are also involved in such varying fields as conservation genetics, DNA barcoding, plant biochemistry, ethnobotany, seed biology, GIS and spatial modelling, ecological restoration, horticultural science and so on. Research is also often undertaken at botanic gardens through partnerships with other institutions. Staff involved in research generally fall into two major categories: they may be researchers in their own right, undertaking original studies in pure or applied fields, or they may contribute to research through the development and management of collections and other facilities of use to researchers.

Wuhan Botanical Garden, Chinese Academy of Sciences – an example of a long-standing research tradition on aquatic plants – with remarkable aquaria displays for public outreach. (Image: David Galbraith)

- **Education**

Education at botanic gardens is a broad and mature field, with professional practitioners contributing to many aspects of the related activities (Chapter 7). This may include presentation of educational programmes for the general public, or for visitors, or more formal educational offerings directed at school groups that might visit the institution. Educators are also often in charge of signage, interpretation or animation within the botanic garden, bring educational experiences into the space provided amongst collections and plantings. Botanic garden interpretation and educational skills are comparable with those of personnel at museums and other science centres aimed at the wider public as their key target audience (Case study 2.2).

- **Administrative services**

Communications and public relations, accounting, payroll, human resources, and other kinds of supporting services are as important in a botanic garden as they are in any other organisation. Depending on the scale of the institution, specialized staff may be needed (Chapter 7).

- **Fundraising and development**

Raising funds through donations, gifts, endowments and planned giving is a complex and skilled field. Specialized practitioners in charitable fundraising are important members of the teams of many botanic gardens, and may also be charged with managing the development of members and volunteers.

- **Visitor services and business operations**

It is necessary for most botanic gardens to secure sources of income from a variety of sources, and this in turn requires specialized staffing and skills to deal with retail operations, food services, management of admissions and provision of services to visitors.

The physical infrastructure of an institution – the buildings, equipment, and systems that underpin all of its activities and programmes – also requires staffing to provide maintenance, upkeep, and housekeeping services, and may be central to many of the business activities within a botanic garden. This is especially true for institutions with buildings and facilities that can be rented for special events, weddings and other functions.

CASE STUDY 2.2

Tver State University Botanic Garden, Russia – visitor numbers rising steadily through close community engagement

Yuri Naumstev, Tver, Russia

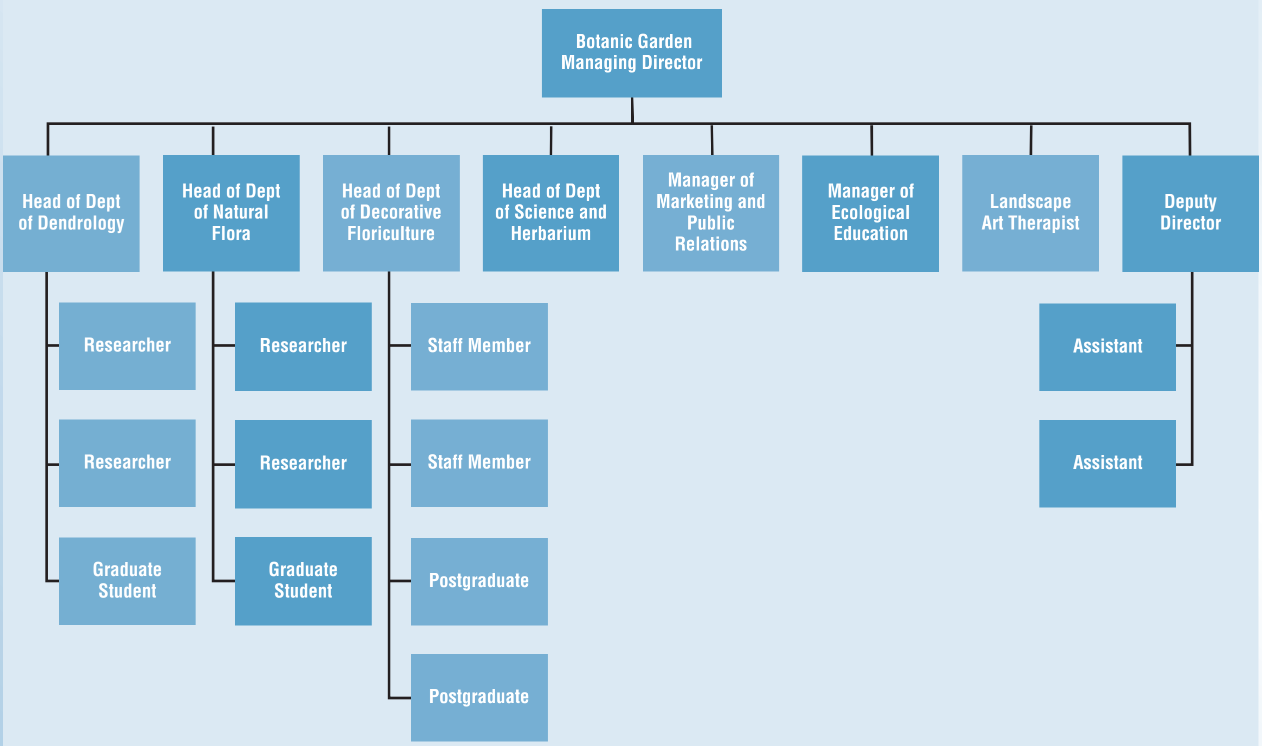
The Botanic Garden of Tver State University, located at the confluence of the Volga and Tvertza rivers, occupies land that was once the site of a monastery in the oldest settled part of Tver. The origins of the botanic garden are traced back to a private garden planted in 1879 by a prominent merchant. In the late 1930s the garden became affiliated with the Pedagogical Institute, but suffered many losses of plants during the Second World War. The botanic garden was restructured in 1949 to support education, plant introduction and acclimatization studies. In 1971, Tver State University passed responsibility for the botanic garden to the municipality, and some of the collections were moved to an agro-biological station operated by the University. Since 1989, the botanic garden has been associated with Tver State University once again, and the gardens and collections have been reconstructed and redeveloped.

Opened to the public in 1996, the operating budget is approximately USD 100,000 per year, with some 45% being self-generated, 22% from state support, grants totalling about 10%, and the remainder contributed to by donations. The paid staff complement is 16 supported by approximately 200 volunteers, many working on a seasonal basis.

The Managing Director, Dr. Yuri Naumstev, describes the botanic garden as reaching out strongly to the local people: *"We sincerely believe that the success and recognition of our botanic garden by the city and the region depends on how our work is understood and accepted by the local community. It is important that our employees are conscious not only of why their science is important, but also how this work is relevant to the people. Our work is organized so as to show that our botanic garden is a good example of sustainable operations of a unique natural, historical and cultural site in the city and within modern society. We are running a variety of social and community projects with a scientific basis and competent marketing. Our mission is to open to our guests the world of plants, to show the importance of its conservation, and thereby the relationship between people and nature. One of the main results of this policy is a significantly increased number of visitors – from several hundred to more than 45,000 people a year now."*

Engaging local schools. (Image: Tver State University Botanic Garden)

Tver State University Botanic Garden, Russia



2.3.2 Getting it Done: Decisions about Staffing, Volunteers, Partnerships and Outsourcing

KEY MESSAGE

It is particularly important that the institution provides training and other support to those working on the 'front-line' so that everyone – volunteers or staff – are presenting the same, consistently high levels of service and information to visitors.

As a botanic garden develops the question of which parts of its functions are delivered by paid staff, and which may be supplied by alternate options, is always important. In addition to paid staff, further means are at the disposal of many institutions in delivering programmes, products and functions, including volunteer labour, partnerships and outsourcing.

- **Paid staff**

The core of the work force for most botanic gardens includes at least some paid staff members. In very small organisations, this might be just an executive director of the charitable organisation, who raises funds and oversees the administration of the botanic garden which is managed by volunteers. At the other end of the spectrum, there are a few botanic gardens in the world with staff complements in the hundreds, where the scale of the operation demands specialized divisions dealing with administration, human resources, finance and other organisational underpinnings. All of this is in addition to workers that plant, tend, and interpret the botanic garden, manage collections, present educational programmes or undertake research. Regardless of the scale of the operation, staff costs are usually the largest single part of the annual operating budget of any botanic garden.

- **Volunteers**

The idea of voluntarily contributing one's time and efforts on behalf of an organisation varies culturally from place to place. Making good use of volunteers within a not-for-profit organisation can be a complex process. As nice as it sounds to have 'free labour' it should be understood that volunteers, like paid staff, require oversight, attention to their needs, personal development and training. If volunteers are a significant part of the work force of a botanic garden, it is generally a good idea to set up a volunteer coordinator, as a paid staff position, to serve as the primary point of contact between the paid work force and the volunteers.

Even larger organisations often benefit immensely from the help of volunteers. At the Royal Botanical Gardens in Hamilton and Burlington, Ontario, Canada, for example, the paid staff complement of approximately 100 people is augmented by the efforts of the Auxiliary of Royal Botanical Gardens, which includes approximately 320 individuals who have organized themselves into their own charitable corporation.

Volunteers can contribute to nearly every aspect of the operation of a botanic garden, from assisting with record keeping and retail operations, to participating in horticultural and collections management, and many other tasks. Docents are particularly important in many institutions. These are volunteers who have been trained as the interpreters and guides for visitors to the gardens. When volunteers are serving as 'front-line staff', interacting with the public and visitors, it is particularly important that the institution provides training and other support for them, so that everyone, volunteers or staff, are presenting the same, consistently high levels of service and information to visitors.

- **Partnerships**

Some functions within botanic gardens may be amenable to ongoing relationships with outside organisations or companies. If the relationship is simply a fee-for-service, this is referred to as outsourcing. However, if a commercial company undertakes to do work on some other basis (such as providing a free service in exchange for positioning or advertising) then a partnership may be the answer. Partnerships may be relevant to ongoing functions such as food and beverage service, or for specialized and more intermittent functions such as hazardous tree management or they may be on a peer-to-peer basis, such as one institution providing another with access to digitizing equipment for herbarium records. The exchange of seeds among botanic gardens through *indices seminum* is an example of a large-scale, distributed partnership.

- **Outsourcing**

Outsourcing is the purchase of services necessary to support the work of an organisation from a separate company or organisation. Whether a particular organisation elects to undertake all of its own work, or to contract others to provide services is a matter of assessing the costs of providing the services through staffing as opposed to through a service contractor. Specialized services that many other organisations also use, such as housekeeping, waste management, security, auditing, and food services, are all examples of necessary functions that may be less expensive to secure through a commercial provider rather than 'in-house' (Case study 2.3).

Volunteers at work at the Royal Botanic Garden Edinburgh. (Image: Kate Hughes)

CASE STUDY 2.3

Maintaining Singapore Botanic Gardens through contract companies

Nura Abdul Karim, Singapore

Founded in 1859, the Singapore Botanic Gardens (SBG) are managed by the National Parks Board (NParks), a statutory board of the Singapore Government. Since 2010, the Government has been taking measures to reduce the dependence on foreign workers as this had been rapidly increasing due to the growing trend to outsourcing of work to many companies and organisations. The foreign worker levy payable by the contractors was increased and mandatory quotas which require the landscape industries to have two full-time Singaporean workers for every three foreign workers were put in place. This quota and levy have indirectly affected the construction and service industries. In late 2012, a change was made to the contract tender specification for outsourcing landscape works at SBG. NParks management moved away from awarding a single three-year tendered contract to one licensed private landscape company for groundworks in SBG. In its place, this contract was divided into horticulture, arboriculture, turf and cleansing contracts, respectively. This was in order to attract more companies specialising in these areas to bid for tenders with the intention of lowering the value of bids. By 2013, new three-year open tenders for contracts on these areas were awarded to different landscape and cleansing companies. These are performance-based contracts and require the contractors to supervise all routine works and ensure availability of sufficient workers to care for the living collections and the landscape of SBG. The horticulture, arboriculture, turf and cleansing management are now under the direct control of the contracted companies. The companies' supervisors are expected to submit their planned work schedules for these areas prior to the commencement of work every month for comments and approval by SBG. There are 50 full-time horticultural staff employed by SBG to oversee the contracted teams.

SBG has the right to modify and make necessary changes to the work schedule, to ensure good standards of maintenance for the living plant collection. Horticultural staff control the overall management of works and ensure high standards are delivered by the contracted companies through daily site inspections and weekly assessments. They do this by inputting an average score which affects the final payment for the month of service rendered by each contractor. Ad hoc horticultural work, not included in the daily schedule, can be arranged with the contractors by giving sufficient notice. This work is paid according to the schedule-of-rates stated in the contract. Such arrangements require staff to plan ahead and anticipate the costs of such work.

Contractors are still heavily reliant on foreign workers, therefore communication between staff and the contractors' employees is one of the main problems encountered. There is also a great responsibility for the staff to be extremely diligent in their checks that the contracts are being fulfilled correctly. This includes supervision of the contracted workers and supervisors who sometimes do not have the relevant certificates or work permits. SBG staff are also required to monitor the work of the contractors who may lack good horticultural practice. This problem arises because there is a shortage of good quality training in horticulture and arboriculture in the South East Asian region. The amount of time spent on administrative work, such as reporting and assessing contractors, has meant that staff tend to be less hands-on in the daily maintenance as their role is now more supervisory, policing and administrative.

However, with these outsourced contracts, SBG has also benefited from the capacity of private landscape contractors to purchase new horticultural and arboricultural equipment at short notice, and also to supply and trial new fertilisers, pesticides and growth enhancers faster. Such arrangements also ensure that the operational costs are kept within the budget allocation.

There are advantages and disadvantages to this model of meeting the labour requirements to maintain a botanic garden. Success is dependent on appropriate selection of the contracted companies and robust contracts, as well as the dedication and skill of the employed staff in training contractors to the standard demanded by SBG for the management of its plant collections and premises.

Tree pruning by contractors at Singapore Botanic Gardens. (Image: Nura Abdul Karim)

2.4 MOBILIZING FINANCIAL SUPPORT: SOURCES OF INCOME

Organisations often differentiate between operating and capital funding. Operating funding is defined here as income and expenditures required to carry out day-to-day work over the course of a year. Capital funding is required for securing major resources that will deliver their value over multiple years. Buildings are the most common category of capital expenditure, but other major investments such as computer technologies, networked databases, and the collections themselves can be viewed as capital. An overview of income sources and expenditures is in Chapter 1, Table 1.1.

2.4.1 Earned Income

KEY MESSAGE

A diverse range of income sources is a highly desirable component of a robust business model for a botanic garden, as it helps to ensure resilience during times of low economic growth or recession.

- **Gate receipts**

While some botanic gardens are free for the public to attend, many charge admission fees. The entry fee selected by any particular institution will be based on an assessment of the value to the visitors, the time needed for a satisfying visit, the costs of providing visitor services, and the competitive environment for entertainment experiences in the local area.

Charging admission is a useful source of revenue, but also comes with costs. Botanic gardens that do not charge admission fees also do not need to employ staff at the gates or maintain point-of-sale mechanisms to receive and track the monies received.

Entrance turnstiles for visitor admission at the Shanghai Chenshan Botanical Garden, Chinese Academy of Sciences. Tickets are purchased at a separate desk. (Image: David Galbraith)

The Gateway Restaurant of the Royal Botanic Garden Edinburgh. (Image: Annette Patzelt)

- **Retail operations**

Retail operations are any activities that sell a good or a service to visitors while they are at the botanic garden, or at a distance, for example through internet sales. Commonly encountered retail operations at botanic gardens include plant sales, sales of food and beverages and gift shops. Plant sales have been a traditional source of income for botanic gardens for many years. They are sometimes prepared and run by volunteers. Food and beverage sales (more generally 'food services') can be put in place to support visitors to the botanic garden or as part of packages for weddings, conferences or other special events.

- **Earned income**

A multitude of options exists to earn income as the key source of revenue (Case study 2.4):

- Specially-ticketed events, designed to draw visitors into the botanic garden for a unique experience. Included in this category could be special displays, art exhibits or concerts;

- Educational services that are provided to specific audiences may be offered with an associated fee. Informal education includes public programmes in horticultural or botanical subjects. Formal education may be geared to a school programme or curriculum, and are usually arranged in collaboration with teachers. Professional educational offerings could include short courses or workshops intended for specific audiences, such as providing plant identification training for naturalists or consultants;

- Rental of space or facilities for special events such as weddings, memorial services, corporate functions, conferences, or other meetings;

- Consulting services in botany, horticulture or other fields of institutional expertise, where there is sufficient capacity among staff to divert attention away from their day to day duties;

- Provision of plant material for commercial research and development, including pharmaceutical, horticultural, agricultural or other uses. Relatively few botanic gardens generate income from such activities due to the complexity of ownership and intellectual property rights under national and international laws.

CASE STUDY 2.4

Capitalising on earned income – Santa Barbara Botanic Garden, California

Steve Windhager, Santa Barbara, United States

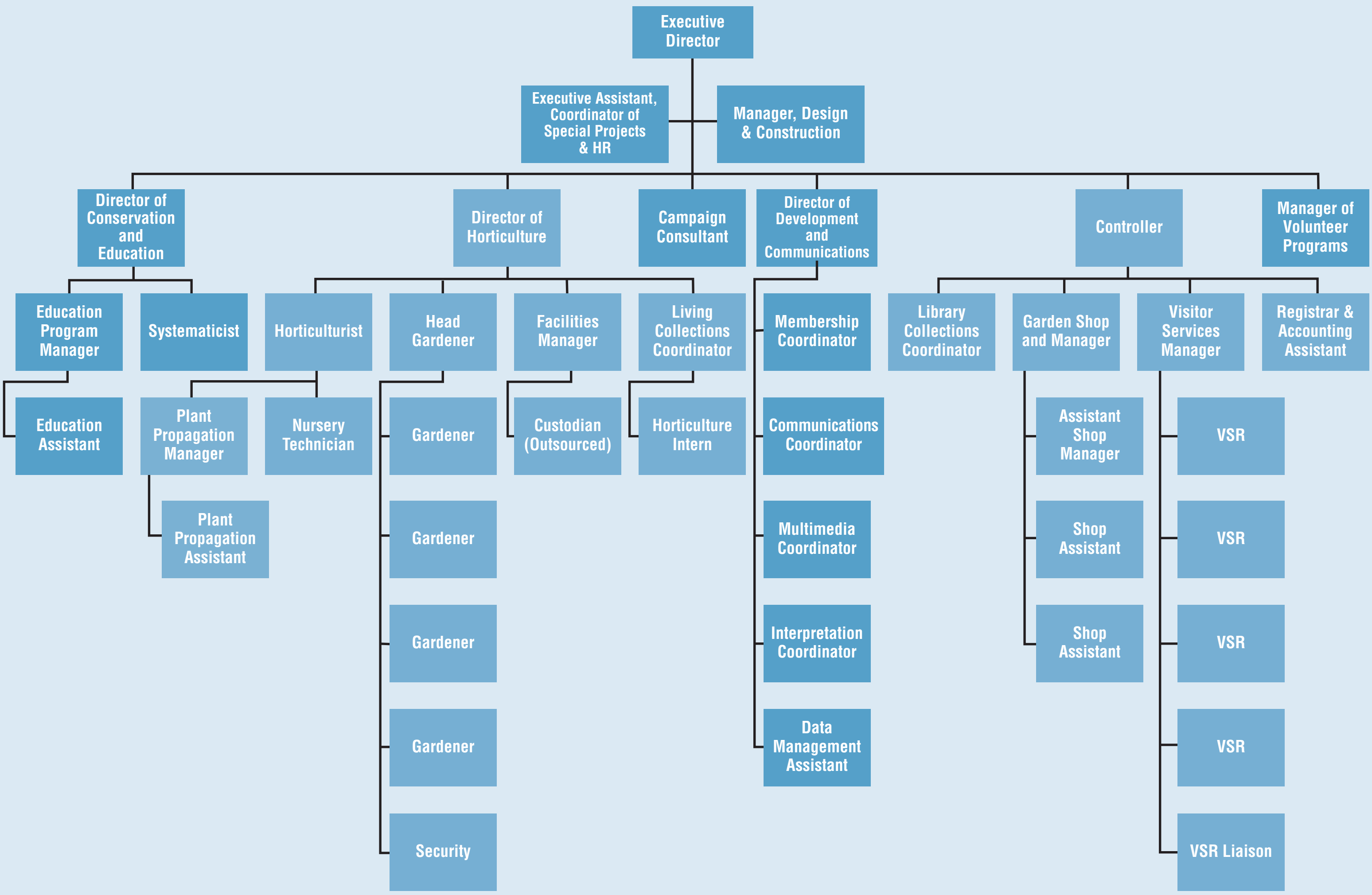
'The Santa Barbara Botanic Garden fosters the conservation of California's native plants through our gardens, research and education, and serves as a role model of sustainable practices' (Mission Statement). Opened to the public in 1926, it was the first botanic garden in the United States to focus exclusively on native plants in North America. It features both horticultural gardens and trails through canyon areas showcasing the natural vegetation and habitat types of southern California.

The institution is accredited as a botanic garden by the American Association of Museums, and is operated as an independent US 501c3 not-for-profit corporation. After nearly 90 years in operation, Santa Barbara Botanic Garden has an annual budget of USD 2,400,000. Its revenues are mixed, however with a major, 44% coming from earned income (admissions, fees for services), followed by 27% from membership and donations, 19% from investment sources, and 11% from trust and endowment funds.

Approximately 41 paid staff work at the garden, contributing approximately 31 FTEs (Full-Time Equivalents of 40 hours per week), supported by the efforts of 200 volunteers. Staff are organized under an Executive Director, into four major divisions: Conservation and Education, Horticulture, Development and Communications, and a multifunctional group including library, gardens shop, accounting, and visitor services staff. In addition to the leaders of these divisions, the Executive Director has four other direct reports: an Executive Assistant with additional roles in Human Resources and Special Project Coordination, a Manager of Design and Construction, a campaign consultant for fundraising, and a coordinator of volunteers.

Dr. Steve Windhager, the Director, notes about the organisation that *"With limited budgets, there must be less specialization and more generalist employees at the garden. I think we have to make botanic gardens more relevant, and that means linking our classic work in collections to issues that are more front and center for much of the population – showing how plants are essential to life and how we are the ones with the knowledge of both botany and horticulture."*

Staff organisational chart of Santa Barbara Botanical Garden, Santa Barbara, United States (as of 2014)



2.4.2 The Charitable Dimension: Donations, Grants and Gifts

KEY MESSAGE

"Philanthropy is involved with basic innovations that transform lives, not simply maintaining the status quo or filling basic social needs that were formerly the province of the public sector." David Rockefeller

The social benefits of botanic gardens provide justification for considering them to be not-for-profit organisations or, in the cases where this is possible, as charitable enterprises. Many botanic gardens receive substantial support from philanthropic sources, such as donations, gifts specified in wills ('planned giving'), or through grants from foundations or other charities that make such contributions. Funds received from philanthropic sources may either be received as 'unrestricted' support, to be used at the discretion of the management of the organisation, or may be 'restricted' or 'ear-marked', in their use for a specific purpose specified by the donor or contributor.

Philanthropic contributions vary in scale and frequency depending on many factors, including of course the condition of the local economy, but also the culture of the area involved. Major gifts and donations from philanthropists can form the basis for significant sources of support for projects such as capital improvements, but also nearly always require the investment of a great deal of time and effort to secure.

2.4.3 Membership and Community Support

KEY MESSAGE

Membership often represents a predictable, steady source of funding for a botanic garden. However, if the interests and needs of members are not actively cared for, individuals will not renew their support.

Depending on the botanic garden's financial and governance situation, it may be possible to develop and grow community support through membership. If it is possible within the governing documents of a botanic garden, members may be both financial supporters and also help to select members of the Board of Directors. Purchasing a membership often allows individuals to secure defined benefits, such as free admission or discounts for goods and services at the botanic garden. The development of a membership base for a botanic garden requires investment of time and attention, and if the interests and needs of members are not actively cared for, individuals will not renew their support.

2.4.4 Government or Parent Organisation Support

KEY MESSAGE

The convenience of public funding support should be balanced against the fact that the level of funding allocated is rarely under the control of the botanic garden leadership.

Some botanic gardens are units of larger organisations, such as national networks, universities or government departments, and as such, may receive full or partial funding of their operations. Most botanic gardens that can welcome visitors without charging admission fees will receive ongoing operational support from a parent agency. Some botanic gardens for example, are fully funded by their national governments (Case study 2.5) and open to the public free of charge. Operating support from a parent body is often necessary for a botanic garden to function and invest in its scientific, conservation or cultural activities, but such support is also subject to decision-making processes beyond the control of the individual botanic garden. Over recent years, there has been a steady decline in government support for botanic gardens in some parts of the world (e.g. Europe) but increased support in others (e.g. Asia).

2.4.5 Capital Project Funding

KEY MESSAGE

The long-term operating costs associated with maintaining a capital infrastructure (e.g. a new glasshouse) are often overlooked when capital funding is raised.

New developments, including new visitor facilities, research centres or conservatories may be such major expenses that they far surpass the botanic garden's annual operating budget. They may be facilitated by large funding programmes through government, support from corporate sponsorships, or through a fundraising campaign that can stretch out over many months or years to raise the required sums. As is the case for general philanthropic support, the size, form, and duration of capital campaigns varies from place to place.

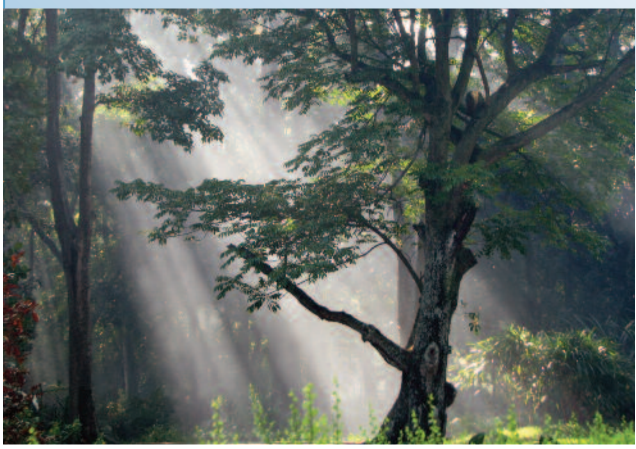
CASE STUDY 2.5

Towards diversifying funding sources – Purwodadi Botanical Garden, East Java

R. Hendrian, Purwodadi, Indonesia

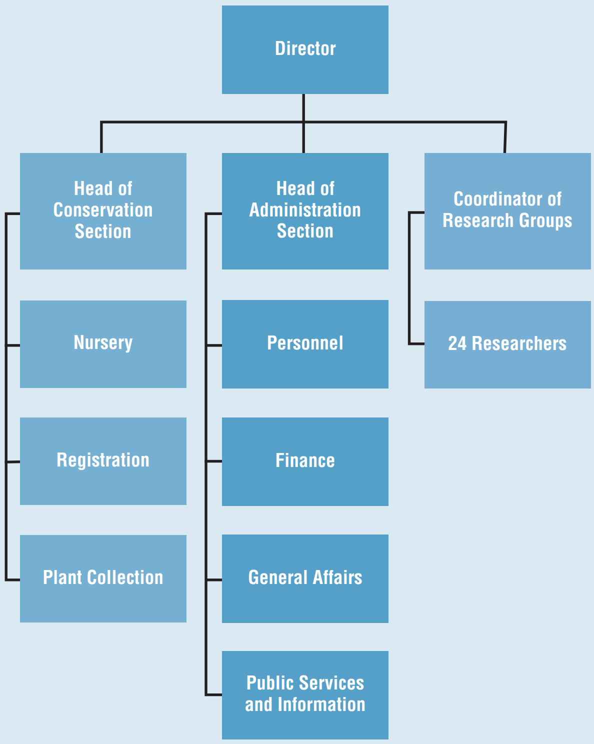
Purwodadi Botanical Garden in East Java, Indonesia, was founded in 1941. It operates as a state botanic garden, with a paid staff complement of 174 and no volunteers. The annual budget is approximately IDR 10-11 billion (USD 75,000-82,500), all provided by the government.

Under its Director, the botanic garden is organized into three major divisions, including Conservation, Administration and Research. A Research Coordinator oversees the work of over 20 research staff. The Director, Dr. R. Hendrian, notes *"In the future, it is very obvious that we should look for other sources of funding besides the annual budget from the Government. Collaboration with the private sector and receiving donations are prospective options. While almost all of the plant collections are those from the lower and dry areas of Indonesia, with many endemic and threatened species that undoubtedly need to be conserved, the botanic garden's horticultural knowledge of propagating some of the species of socio-economic interest is extremely valuable for the development of commercial opportunities."*



Purwodadi Botanical Garden. (Image: Esti Ariyanti)

Organisational chart of Purwodadi Botanical Garden, Indonesia



2.5 CONCLUSIONS

Just as there are many different ways that botanic garden collections, spaces and facilities can be arranged, there are many different ways that the people who manage the institution can be organized. The actual organisational design selected for any particular botanic garden will always be a function of the type of governance involved, the funding mechanisms that must be employed, and the particular mix of amenities and attractions for visitors, as well as collections management, horticultural functions, conservation, educational, and scientific programmes. Organisations change over time, too, as do their contexts. The successful management of a botanic garden will depend on being able to respond rapidly to changes and appropriately deploy both financial and human resources to meet new challenges. While a great deal of attention is often paid to the physical and biological resources of a botanic garden, the importance of the human element (staff, volunteers, partners and visitors) should never be underestimated.

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C The Plant Collection – Linchpin of the Botanic Garden

Part C: The Plant Collection – Linchpin of the Botanic Garden

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Chapter 3: No plant collection without a strategy or policy

Part C: The Plant Collection – Linchpin of the Botanic Garden

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Chapter 3:
No Plant Collection without a Strategy or Policy

Dave Aplin, BotanicalValues, United Kingdom

3.0 DEFINITIONS

Accession: Plant material (individual or group) of a single taxon and propagule type with identical or closely similar parentage acquired from one source at the same time. For tracking purposes, an accession is catalogued and assigned a unique identifier (number or code) associated with additional information.

Acquisition: Plant material prior to being accepted into the plant collection and catalogued as an accession. The term can also denote the process of gathering plant material before its incorporation into the plant holdings of the botanic garden.

Collection policy: A written, accessible document outlining the purpose and scope of the plant collection along with specific guidelines for the botanic garden aiding acquisition, management and de-accessioning of the plant material.

De-accessioning: The process of removal of all or part of the accession from the botanic garden, while related plant information is retained in the database.

***Index* (pl. *Indices*) *seminum*:** A catalogue, published periodically by botanic gardens or arboreta, with seed gathered from the wild and/or through cultivation. Seeds are offered for free, or for exchange, to other botanical institutions.

Material Transfer Agreement (MTA): A document sent in advance outlining the conditions of transfer of plant material to another organisation. It specifies the donor's terms and restrictions on the use of the material by the recipient organisation that must be agreed prior to the plant material transfer.

Provenance: The original source of the plant material. The term is used both to denote a location (wild population or nursery-grown) and a concept (wild-collected or cultivated stock).

Taxon (pl. taxa): A group of plants that form a botanically named unit, including all their components, e.g. *Fagus sylvatica, F. sylvatica* 'Aspleniifolia', *F. sylvatica* Atropurpurea Group, *F. sylvatica* f. *purpurea, F. sylvatica* var. *purpurea* and *F. sylvatica* 'Purpurea Tricolor' are six taxa of the same species.

3.1 INTRODUCTION

KEY MESSAGE

A collection policy is a fundamental and strategic document for any botanic garden. It guides the development and management of the plant collections, and prevents managers from straying from the collections' intended content and function.

The global botanic garden community holds an abundance of plant material and related data with great environmental, socio-economic and cultural relevance to research, conservation, education, display and amenity. However, botanic gardens need to be aware of current and future challenges when developing their collections and acquiring new plant material. At a time of rapid global change and unprecedented threats to plant diversity, high quality collections curated for a clear purpose are the backbone of any botanic garden. A comprehensive collection policy will articulate the rationale for the plant holdings of a botanic garden, and will provide informed guidance for management and future development of the collections.

3.2 CULTIVATING PLANTS FOR A PURPOSE

The term 'collection policy' refers to both, living (e.g. plants, seed, fungi, lichens) and non-living (e.g. data records, herbarium vouchers, photographs) elements maintained in botanic gardens. Plant material will come with associated, documented information as discussed in this chapter which characterises an institution as a botanic garden.

Why is a collection policy important?

A collection policy is a vital and strategic document for any botanic garden. Without such a policy, collections can easily stray from their intended content and function (Rae, 2006a; Rae, 2006b; Gates, 2007). A collection policy provides content and management guidance and ensures that plant holdings reflect the organisation's vision and mission (Chapter 1, Section 1.2.4). The absence of a clearly defined collection policy may result in inefficient use of core funds that can challenge the future justification and viability of an organisation. In spite of this, many botanic gardens have pursued an ad hoc approach to collections acquisition and retention. A global survey of botanic gardens (Aplin, 2014) revealed that 61% of 172 responding institutions had no formal, written policy guiding curatorial activity. A collection policy helps a botanic garden to:

- Set overarching principles and guidance, enabling staff to make decisions more efficiently without constant reference to senior managers;
- Create confidence and stability in collection development and management so that key decision-making is unaffected by staff turnover;
- Promote good governance to facilitate resources being targeted where they are most needed;
- Focus fundraising efforts and provide confidence to funders that money is wisely spent;
- Ensure plants are grown for their intended purpose and in the required quantities;
- Facilitate proactive or forward-thinking management;
- Provide an opportunity to review current curation practice and highlight opportunities for improvement and development;
- Enhance communication between departments.

3.3 SCOPE AND DEVELOPMENT OF THE COLLECTION POLICY

KEY MESSAGE

Every collection policy is different reflecting the specific vision and mission of the institution. The process of policy development, however, is similar with any botanic garden in that every stage should involve close stakeholder consultation and review.

3.3.1 Scope of the Collection Policy

There is no shortcut to developing a collection policy. Many aspects are specific to the institution and should be discussed with all relevant stakeholders. Collection policies vary in the amount of detail included but generally address a standard set of topics (Box 3.1). A typical collection policy will provide specific advice on the acquisition and transfer of material and standards of documentation, and may include specific topics, such as 'Collection of plant material in the field' and 'Procedure for labelling'. The collection policy often interconnects with areas beyond the direct responsibility of the living collections, for instance with the herbarium or the botanic garden's approach to interpretation (Chapter 7, Section 7.3). For this reason, it is important for all stakeholders involved in collection management to contribute to setting the scope of the collection policy prior to its development (Case study 3.1).

Staff of the Ethiopian Biodiversity Institute share ideas for developing a collection policy for Shashamene Botanic Garden during a BGCI training workshop. (Image: BGCI)

CASE STUDY 3.1

Developing collection policies for botanic gardens in Ethiopia

Kirsty Shaw, Richmond, United Kingdom

Situated in the Horn of Africa, Ethiopia holds one of the richest assemblages of plants on the African continent. The Ethiopian government, notably the Ethiopian Biodiversity Institute (EBI) which is mandated to coordinate work of botanic gardens in the country, as well as universities across the country, are committed to establishing and reviving botanic gardens across Ethiopia to develop their diverse collections. New institutions have been established, including the Gullele Botanic Garden in Addis Ababa as well as Shashamene Botanic Garden and Jima Botanic Garden. Projects have been initiated to revive existing arboreta that were initially set up to trial exotic species for forestry. A new, state-of-the-art seed bank has been built by EBI so collections can be duplicated within the country.

With multiple institutions at similar levels of development, Botanic Gardens Conservation International (BGCI) has partnered with EBI to deliver annual training courses to support botanic garden development in the country. Representatives from leading international botanic gardens deliver training alongside BGCI and EBI to share experiences and examples of best-practice. During an initial training workshop, the importance of developing a policy to guide collecting efforts was presented by Chicago Botanic Garden (CBG). Showcasing how CBG's own policy has led to the development of a collection with more than 2.6 million specimens from 9,200 taxa over a period spanning more than 4 decades, the importance of the local climate and soils in determining CBG's selection of species from around the world was highlighted. In a subsequent training workshop, a template for the development of a collection policy was presented by the University of Oxford's Botanic Garden and Harcourt Arboretum, whose plant holdings of more than 8,000 taxa are used in teaching, research and conservation.

Workshop participants were asked to consider the purpose of their botanic garden, and develop a draft collection policy for their institution using the headings in the template provided. The drafts were reviewed and discussed, and the benefits of assigning plants of a particular region or taxonomic group to each institution, and sharing material across institutions for maximum conservation impact, were highlighted.

During visits to three institutions situated in close proximity to each other – Wondo Genet College Arboretum, Shashamene Botanic Garden and the Wondo Genet Agricultural Research Centre Medicinal Plant Garden – participants discussed how these botanic gardens could share material and identify signature plants or collections that support the varying objectives of each institution, ensuring they support conservation of the local flora, whilst maintaining a unique identity. Working alongside colleagues within one's own region or country, and learning from the experiences of well-established institutions with a clear focus, will significantly contribute to a well-thought-out and tailor-made collection policy.

Box 3.1 Components of a collection policy (Adapted from Michener, 2011)

1. Collections' mission – this relates to the overall vision and mission of the botanic garden.
2. Collections' scope – for instance in relation to issues of invasive species or the relevance of specific collections based on conservation priorities.
3. Cost estimate – assessment of the funding needs for maintenance of the collections.
4. Acquisition and documentation standards – these relate to plant records management.
5. De-accession/plant disposal standards – these relate to plant records management.
6. Access, intellectual rights and ethics – for instance in relation to issues of traditional knowledge.
7. Evaluation – this relates to maintaining and increasing the value of plant collections.

3.3.2 Development of the Collection Policy

- **Initiating discussion**

Normally, a key individual leads and guides the process to develop the collection policy (Figure 3.1). This can either be a senior member of staff, or an independent consultant. Engaging an experienced consultant has its advantages if senior staff operate under time constraints. Consultants may also bring an objective approach but will need to have full access to pertinent information regarding the botanic garden's collections and strategic direction. They should also spend sufficient time with staff and other stakeholders for detailed discussions.

Senior staff should develop a list of topics to be included in the collection policy. This activity focuses the discussion for subsequent stakeholder meetings. These will comprise individuals from different disciplines with varied experience. It is important, therefore, to introduce the concept of the collection policy to the group, explaining the advantages to the organisation. All participants should be encouraged to discuss the extent of detail needed in the document. The meetings should yield a provisional list of topics to be included and provide an indication of the depth of information required.

- **Drafting and completing the collection policy**

Based on the information garnered during the discussion phase, a draft collection policy will be prepared. This document is then sent to all stakeholders for review and comment. The best use of time is for stakeholders to discuss their specialist areas with their peers (e.g. horticulturists, curators, education specialists) and provide feedback on the draft document. It is also helpful for all stakeholders to comment on other areas of the document where appropriate. Suggestions are then incorporated into a second draft and redistributed for additional comment. Depending on the complexity of the information to be covered, this may happen a few times before an acceptable draft is ready.

Following the distribution of the final draft to all stakeholders, a further stakeholder meeting will be convened where the final draft document is presented. This will allow an opportunity to resolve any outstanding issues prior to completing the collection policy.

Figure 3.1 Development stages of a collection policy

- **Periodic review**

Although the collection policy is a vital document for a botanic garden, it should also be regarded as a 'living' document, able to address emerging issues of local and global concern such as species extinctions in the wild and climate change. Consequently, the collection policy should undergo periodic revision, ideally at five-yearly intervals, to ensure its relevance in a changing world. Throughout the lifespan of the collection policy, botanic garden staff should be reminded of its contents and prompted to employ it rigorously thereby ensuring the policy's purpose and objectives.

3.4 PLANT ACQUISITION

KEY MESSAGE

Botanic gardens require plants for a diverse array of reasons. It is therefore imperative to base selection on a range of agreed criteria to maintain the focus of the plant collections.

Botanic gardens are dynamic places where plants are constantly added and removed. This section covers all major aspects and prerequisites for acquiring plants, types of plant material, sources of plant material and the management of potential risks associated with newly acquired plants. A global survey (Aplin, 2014) found that a majority of botanic gardens maintain plant collections for education and conservation and, to a slightly lesser degree, research. This may include the development of eye-catching displays or showcasing native plant species (and animals) in 'wild' areas to highlight the conservation purpose of a botanic garden. The collection policy will set out criteria for plant acquisition (Sections 3.4.1-3.4.5), acting as a filter to maintain focused plant holdings that reflect the objectives of the botanic garden. Accepting or rejecting plant material is an important undertaking that places acquisition at the heart of the collection policy.

Various ways of acquiring plant material exist, including collection from natural habitats, exchange between botanic gardens, donations from private collections or purchase from commercial enterprises. Prior to being formally accepted into the botanic garden collection, the plant material is termed 'acquisition'. This is defined as an individual or group of plant material of a single taxon with identical or closely similar parentage acquired from one source at the same time. The acquisition is given a unique number (Chapter 5, Section 5.5.2) allowing it to be tracked in the collection. This action is often referred to as 'accessioning'. Once established in the collection of the botanic garden the acquisition is named 'accession'.

Showcasing native orchids in the 'wild' areas of botanic gardens. (Image: Dave Aplin)

3.4.1 Prerequisites for Acquisition

In order to facilitate incorporating new plant material, botanic gardens are advised to ensure that the associated documentation demonstrates responsible and legal acquisition (Section 3.4.2). In addition, if plant material is sourced from another institution, recipient botanic gardens need to know that the type of material offered has sufficient associated information to fulfil its intended purpose. Botanic gardens may correctly list the provenance of an accession as 'wild-collected', yet lack specific collection data to confirm this. Therefore a conversation should take place between the provider and recipient botanic garden at an early stage to check if the plant material fulfils the expectations. Unfortunately, this type of communication often does not happen, and as a result, vital information fails to be exchanged (Aplin *et al*., 2007).

3.4.2 Acquisition and the Law

KEY MESSAGE

Botanic garden staff must ensure the acquisition, receipt and intended use of plant material conforms to national legislation and international treaties and agreements.

The first criterion for sourcing plant material and deciding whether to accept an acquisition is to ensure it has been legally obtained. This is a complex issue especially in the international context of laws and policies governing the exchange of plant material (Chapter 4). Special attention is required when receiving plant material from private individuals. Material should only be accepted if it had been collected legally and supplied with all the necessary documentation. Privately donated material should be accompanied with at least the minimum standards (Section 3.5) of data required by the receiving institution. Care should also be taken when receiving cultivars that might be subject to plant breeders' rights and protected by law (Chapter 4, Section 4.7).

Once established that the target material was legally obtained, the decision to proceed with the acquisition should be based on two key factors: First, the 'institutional need' or acquisition criteria for the taxon (Case study 3.2), and second, the quality of associated information accompanying the acquisition (Section 3.5).

CASE STUDY 3.2

Acquisition criteria at the Finnish Museum of Natural History

Marko Hyvärinen, Helsinki, Finland

Key criteria have been developed for accepting plants at Kaisaniemi and Kumpula botanic gardens in Finland. Staff at these institutions – part of the Finnish Museum of Natural History (FMNH) – viewed this as a positive, pro-active exercise that provides focus and accountability about the current holdings of the botanic gardens and helps guide future acquisition decisions that are largely independent of staff turnover. The ten criteria include:

1. **Research:** Acquisitions should have sufficient associated data to make them legitimately useful in research.

2. **Conservation:** FMNH principally focuses its conservation effort on species within Finland followed by those beyond its borders (e.g. Russia, Baltic countries, Central Europe). One particular interest is climate change. Genetic material enabling studies on assisted migration is favoured.

3. **Education:** Plants that fulfil the teaching obligations of FMNH and have wider education value. Academic topics of particular relevance include evolution and systematics.

4. **Display:** Providing an attractive public display throughout the year is important. On occasion seasonal annuals are cultivated solely for this purpose. In such cases, provenance information is deemed unimportant and the plants are not databased. However, these plants can only be cultivated at locations agreed on by a curator.

5. **Rarity in the wild and in cultivation:** Botanic gardens often have taxa seldom grown elsewhere. These are given special attention, and their cultivation requirements are recorded. This criterion is of enormous value to science, conservation and horticulture.

6. **Provenance – latitude:** Plants cultivated in the open air that principally come from areas of the world that, more or less, bio-climatically correspond to hemi- and southern-boreal zones in Finland.

Kaisaniemi Botanic Garden, central Helsinki, Finland. (Image: Mikko Heikkinen)

7. **Provenance – longitude:** Plants under glass primarily selected from areas that fall within the longitudes delimiting Finland (21°E to 29°E). This encompasses countries of South East Europe, the Balkan Peninsula and Turkey. Countries in Africa, particularly the eastern part of the continent such as Egypt, Ethiopia, Kenya, Uganda, Tanzania, Rwanda, Burundi, Malawi, Mozambique, Madagascar and South Africa are also included.

8. **Provenance – tropical islands:** Endemic flora from the world's tropical and sub-tropical islands.

9. **Economic plants:** Displays of economic plants engage the public and university students, helping them to form links between nature and everyday life. These include plants that provide examples of species (and sometimes their cultivars) suitable for cultivation in Finnish botanic gardens.

10. **Historic plants:** Although the goal of FMNH is to cultivate plants of documented wild origin, exceptions exist. Historic cultivars developed in the territory during the Russian period of the early 1800s are actively sought after and curated.

Best practice at FMNH is to select acquisitions capable of fulfilling a number of different acquisition criteria. These are termed 'multifunctional accessions' once in the collection. In so doing, the same accession used for display and education can also be utilised for research and conservation.

3.4.3 Acquisition Types and Source

KEY MESSAGE

Plant material sourced specifically for conservation and research should, with few exceptions, represent a good proportion of naturally occurring genetic variation if they are to serve restoration, population reinforcement and reintroduction programmes.

There is a vital need to understand the genetic diversity present in natural populations as well as in plant collections of botanic gardens (Griffiths *et al.*, 2015). This will inform the effective management of germplasm as an insurance policy for the future (Rao and Hodgkin, 2002).

- **Acquisitions of seed**

The most common and best method for capturing and storing genetic diversity is from seed.

Collecting seeds from wild, natural populations

In order to establish a collection that can be used for legitimate conservation and research purposes, botanic gardens collect plant material from wild, natural populations. This approach is important because it differentiates collection from populations that have become naturalised in a given area and may have been subjected to different selection pressures compared with those in naturally occurring populations.

Collecting from such populations is a complex undertaking that needs to be well-planned. The collection team needs to understand that data recorded at the point of collection are as important as the collection itself because without this information the seeds are of limited future value. A number of detailed best practice procedures are available that highlight responsible collection, thus avoiding illegal practice and adverse ecological consequences for the natural population (Chapter 7, Section 7.1).

Collecting seeds from cultivated plants

Seed collection within botanic gardens should only be conducted on the understanding that it holds little value for research and conservation compared with wild-gathered seeds. This is especially true for short-lived taxa such as ephemerals, annuals and some perennials. The main reasons for this are:

- Cultivated plants are susceptible to hybridisation. This is particularly true in botanic gardens where a wide range of similar taxa is grown in close proximity. This may allow closely related species, which would naturally be geographically isolated to come into contact and hybridise. Successful hybrids may demonstrate hybrid vigour and subsequently escape into nature where they can become invasive.
- Cultivated plants encounter vastly different selection pressures from those in wild populations due to eco-geographic selection and the unwitting, natural temptation for horticulturists to select the 'best-looking' plants.
- Genetic variability of seeds collected from cultivated individuals will, in the majority of cases, represent a fraction of the potential found in natural populations.
- Documentation may be poor with a high frequency of collections having unknown provenance due to poor record keeping in the past.

Requesting seeds from exchange lists – *Index seminum* (pl. *Indices seminum*)

The distribution of seed material between gardens through seed exchange lists or '*Indices seminum*' is believed to have started in the late 16th century. Today, over 500 institutions distribute seed lists annually (Aplin *et al.*, 2007). Typically, seed lists comprise wild collected and/or botanic garden gathered seeds (Aplin and Heywood, 2008). Generally, the use of botanic garden-gathered seeds should be limited to display and education, whereas well-documented wild collected seeds from natural populations can be used for research and conservation.

However, prior to acquiring the seed material, it is essential to check that all wild gathered seeds are accompanied by comprehensive field data prior to ordering. It is then the curator's responsibility to assess the information and decide if the seeds are fit-for-purpose. Experience has shown that data sometimes needs to be specifically requested from providers because it is not always standard practice to automatically supply it (Aplin *et al.*, 2007).

Requesting seeds from seed banks

By their very nature, seed banks (Chapter 7, Section 7.1.3) store and distribute seed for specific research and conservation purposes. Accessions from specialist seed banks are likely to have as good or better data than those offered in many seed exchange lists (Aplin *et al.*, 2007).

- **Acquisitions of vegetative material**

The majority of acquisitions will arrive as seed, but some will come as vegetative material. This may be because the taxon in question does not produce seed and cuttings are the only practical way of obtaining material, or plants are purchased or donated. In each case, it is the role of the curator to decide the merits of the acquisition before accepting it into collection (Case study 3.3).

CASE STUDY 3.3

Vegetative propagation from wild, natural populations at the Royal Botanic Garden of Jordan

James Hearsum, St Andrews, United Kingdom

On occasion, there will be good reason to collect vegetative material from wild populations for propagation. This may be due to a population being at imminent risk of destruction, taxa that rarely or never produce viable seed, intensively grazed populations where seed production is prevented or as an alternative method for increasing accessions of particular target taxa. The Royal Botanic Garden Jordan (RBGJ) uses vegetative propagation as one of its approaches for acquiring plants because many natural sites are heavily grazed.

Gathering vegetative material needs best practice techniques to ensure that the collection captures as much genetic diversity from the target population as is possible without endangering it. There are a number of important considerations that need to be taken into account when planning a trip of this nature.

- Material should only be taken where it will not jeopardise a parent plant or population.
- Sampling methodology needs to be developed to decide on the selection of material from populations and individuals.
- Vegetative propagation results in a clone of the parent plant. Therefore, *ex situ* genetic diversity can only be increased by sampling as many parent plants as possible. The aim is to collect as many cuttings as deemed necessary (prior propagation knowledge is helpful to guide the numbers required) from as many individuals within a target population as deemed appropriate.

Collecting vegetative material for propagation at RBGJ from a highly grazed location on Mount Nebo, Jordan. (Image: Dave Aplin)

- Material from each population should be bagged separately and given a unique number. If however, only a few individuals exist within a population (but sufficient material to justify collection) then each individual should be bagged and labelled separately.
- Prior knowledge is needed about the target taxa and the type of vegetative material required for the correct method of propagation.
- Vegetative material needs to be maintained in excellent condition in the field before arrival and processing at the nursery.
- As with other collections from the wild, prior informed consent (Chapter 4, Section 4.5.1) must be obtained, giving full details of the collection and its intended use.

3.4.4 Arrival of and Responsibility for New Acquisitions

KEY MESSAGE

Vigilance is needed when receiving new plant material. Prior to incorporation in the collection, the material should be kept initially in a quarantine area where the plants can be monitored for pests and diseases.

The arrival of plant material can be labour-intensive for nursery and curation staff. Consequently, it is imperative for collectors and staff receiving the plant material to maintain close coordination, to ensure clarity regarding specific instructions on the type and quantity of material acquired along with any special instructions if necessary.

Immediate care of new plant material and processing of its associated data is vital. As it can be easy to accidentally mix a batch of seeds and cuttings, great caution and attention at this point is essential.

- **Receiving unknown taxa**

Horticulture and curation staff are responsible for the care and upkeep of new material even prior to the curator accepting its addition to the collection. In the instance of a taxon being unknown, research will be required to investigate possible germination and cultivation requirements. If identification is not immediately possible, collection data highlighting the site and habitat (including neighbouring species) can provide vital clues. This information, together with broader investigation on traits of related taxa (if known) should provide a genetic and/or environmental basis to support any decision about subsequent cultivation. For these situations, there are a number of resources available to guide botanic garden staff in making informed decisions (Chapters 6 and 7).

- **Biosecurity**

The receipt of exotic plant material is a common way to introduce new plant pests and diseases. Placing newly acquired plants into designated, enclosed quarantine areas allows close monitoring and treatment of potential exotic pests and diseases to prevent accidental introduction into the wider collection or natural environment. These risks should also be considered in the context of climate change which has the potential to create additional, suitable habitat through the changing conditions (Symes, 2011).

Horticulture and curation staff will need to be regularly trained to recognise the early signs of potential problems and be aware of taxa that are susceptible to new pests and diseases. There will also need to be communication mechanisms in place to ensure all staff are aware of emerging threats. Increasingly, botanic gardens are developing specific policies for handling newly acquired plant material to help address and reduce risk. Further information on the introduction and care of new plant material which could present a potential pest and disease hazard is provided in Chapter 6, Section 6.8.

- **Threats from exotic, invasive plant species**

Botanic gardens have been responsible for a number of exotic invasive species that have escaped into the wild. These species have caused massive losses in habitat in many countries (Cronk and Fuller, 2014; Hulme, 2015). The invasive *Pittosporum undulatum*, for example, was initially spread by the network of British colonial botanic gardens (Dawson *et al*., 2008) in the 19th and 20th centuries. Botanic gardens therefore need to learn from the past, be vigilant about the collections they maintain and ensure they do not spread to areas beyond the botanic garden and threaten native wildlife.

It is difficult to predict which species are likely to become invasive, although common characteristics include isolation from natural enemies, rapid growth and early maturity, abundant production of seeds, ability to reproduce vegetatively, extensive seed dispersion and quick germination. Complexity is added in that there is often a lengthy lag phase between when a species becomes naturalised and represents no more than an innocent introduction, to when it may become highly invasive. In addition, climate change may provide opportunities for some exotic taxa to spread that otherwise are considered benign.

Curators should adopt routine monitoring to investigate the risk of the spread of exotic plants both within and in the area surrounding the botanic garden. Major guidance for developing a botanic garden policy on invasive plant species is provided by the Invasive Plant Species Voluntary Codes of Conduct for Botanic Gardens and Arboreta and the European Code of Conduct for Botanic Gardens on Invasive Alien Species (Heywood and Sharrock, 2013).

Fairy Lake Botanical Garden, CAS, Shenzhen, China, is specialised in research into the Asian longhorn beetle (Anoplophora glabripennis) to develop effective control strategies and policies. This species has been introduced to the United States in the mid 1990s, causing havoc outside its natural range to a number of trees including poplars, maples, willows and birches. (Image: Chris Malumphy)

3.5 STANDARDS OF INFORMATION

KEY MESSAGE

It is the information and documentation associated with the plant collections that makes a garden a botanic garden.

In order for curated germplasm to be considered of research and conservation value, accessions must comprise two vital elements: i) the living genetic material and ii) its associated data component. Botanic gardens may however have large disparities in data quality across their collections. Generally speaking, older accessions may have less associated information than more recent ones, as many taxa were collected prior to the institutionalisation of dedicated research and conservation programmes and/or before the operation of advanced plant record management systems (Chapter 5, Section 5.2).

3.5.1 Linking Accessions to a Database System

Each accession needs to be labelled and linked to a plant record system. Responsibility for labelling, entering and updating data is normally delegated by the curator. This may be the responsibility of a single member of staff, normally designated as plant records officer, or extended to a group of people.

It is vital that all information pertaining to a new accession is entered into the database as soon as possible and that the accession is given a unique code. In addition to the accession number, plants also need to receive a location code on arrival showing where they will be placed in the botanic garden (Chapter 5, Section 5.4.3).

3.5.2 Data Standards for New Material from Wild, Natural Populations

Those involved in plant collecting trips should be aware that gathering live material is only a part of the collection effort. Material derived from wild, natural populations must be accompanied with as much data as possible. Most information can be quickly captured *in situ* to avoid the onerous task of filling it in retroactively with potentially erroneous data.

It is essential to collect the right type of data and record them in a standardised way in a collection data form (Figure 3.2). Relevant information includes data on the taxon but also biotic and abiotic aspects of the collection site. This information is extremely valuable because it links the taxon with its natural environment and may yield important details for the regeneration or reintroduction of the taxon that may not be recorded elsewhere (Moss and Guarino, 1995). Consequently, it provides information to aid future conservation efforts beyond the life of the acquisition.

It is important that the collection data form is filled in as complete as possible while still in the field (ideally using a computerised device) and that the curator scrutinises each potential accession on arrival. The curator should be prepared to reject plant material if it arrives with sub-standard data. This is an important undertaking because all accessions incur a cost to the botanic garden (e.g. maintenance, heating, data recording) independent of the standard of associated data; once an inferior quality accession has been accepted into the collection it may reside there unnoticed for many years.

Figure 3.2 Example of a collection data form

Collection Data Form

Collection date: 13 / 07 / 2015

Accession ID: 2015-234
Collection no.: 13
PRO signature and date: Robert Robinson 10/10/2015

Collector(s)	Institution	Main Collector (Yes/No)
Green, D.	Mirpur National Botanic Garden	Y
Hasan, H.	Bangladesh National Herbarium	N

SITE DATA

Country	Sri Lanka
Major Area	Central Province
Minor Area	Udawattakele National Forest
Locality	70 yards west off the forest trail

Geo-reference Unit (circle one) UTM / Decimal Degrees / Degrees & Decimal Minutes / Degrees, Minutes & Seconds
Geo-reference Method (circle one) Map / GPS / Google Earth / Google Map GPS Datum: WGS84

Latitude/Easting	7.29	UTM Zone No.	44
Longitude/Northing	80.64	UTM Zone Letter	N
Altitude (m)	512	Method Altitude Determined	Altimeter

HABITAT DATA

Habitat and Assoc. Species	Forest Myroxylon balsamum, Swietenia macrophylla, Acronychia pedunculata
Modifying Factors	Non-native invasive species

Land Form	Hill ridge		
Land Use	Protected area	Slope°	10
Geology	Precambian strata	Aspect	South
Soil Colour	Munsell	Soil pH	6
Soil Texture	Loam	Drainage	Well-drained

COLLECTION DATA

Family	Calophyllaceae
Genus	Mesua
Species	ferrea
Infra-specific	

Vernacular Name	Cobra's saffron	Language	English
Material Verified*	Flowering stem	Date Verified*	12/08/2015
Verified By*	Hasan, H.	Institute*	Bangladesh National Herbarium

*Only to be completed if the collection has been verified

TYPE OF MATERIAL TAKEN

	Number of mature plants sampled	Number of mature propagules taken
Seed	65	55
Stem cuttings	10	15
Root cuttings		
Spores		
Plants		
Other...........		

ETHNOBOTANICAL DATA

Circle all applicable.

Food Food Additive Animal Food Bee Plant Invertebrate Food
Materials Fuel Social Use Vertebrate Poison Non-Vertebrate Poison
Medicine Environmental Use Gene Source

HERBARIUM DATA

Date Collected	10/08/2015	Voucher Number	13
No. of Specimens Collected	4	Plant Height (m)	15

Plant Habit: Tree / Shrub / Liana / Erect Herb / Creeping Herb / Climbing Herb...
Plant Description: Greyish-green foliage, with large fragrant white flowers. The trunk base is 1 m diameter. Opposite leaves.

In advance of any collecting trip, all collectors should receive a copy of the collection data form along with any interpretation notes. It is the responsibility of the curator and expedition leader to make sure all participants understand the form, the type of data to be collected and the importance of filling in the form in full. This ensures a standardised approach to data gathering and provides valuable information that may help identify or further investigate newly discovered taxa.

3.5.3 Data Standards for New Material from Cultivated Origin

Not every botanic garden has a focus on research and conservation. Many devote the majority of their efforts on engaging the public. In so doing, they provide a valuable contribution to health, well-being and tourism, and provide a service to those who wish to discover more about plants, nature and the environment. In these botanic gardens, there is likely to be less emphasis on wild-collected material and a greater use of plants from cultivated origin. However, there is nevertheless the need for essential information including accurate taxon and family names, restrictions on the future use of material, source (where it was obtained from), number of plants, seeds, cuttings, etc. originally received, date when the plant material arrived in the botanic garden, accession number and location.

3.5.4 Standards for Record Keeping Once in the Collection

To ensure that changes in the plant collections are reflected in the records of the collections' database, a number of routine operations should be observed once an acquisition has been accepted into the collection. Standardised recording forms for updating collections with information such as scientific and common plant names, plant label data, location, propagation details, etc. are essential. They should be passed on to the plant records officer at regular intervals for database upkeep, and, in turn from the plant records officer to horticulture staff for updating information in the living collection (Chapter 5, Section 5.4).

3.5.5 Associated Information

- **Herbarium vouchers from cultivated accessions**

It is a worthwhile to prepare herbarium (Chapter 7, Section 7.1.3) samples from the living collections for a number of reasons:

- Cultivated plants can often be phenotypically different from those collected from the wild, making cultivated accessions particularly useful for identification purposes in living collections;

- For identification purposes, a wide range of features can be collected over time, e.g. buds, flowers, fruits, seeds, seedlings;

- Vouchers allow cultivated plants to be identified by visiting specialists at any time of the year and can be sent to willing taxonomists by post.

Representative material should be selected as appropriate, e.g. leaves, stems, branches, buds, flowers, cones, fruits, seeds and spores. Sterile collections (i.e. just leaves) should be avoided wherever possible. It is a good idea to research the most useful characteristics for aiding the identification of a particular target taxon.

Records of all vouchers taken from the living collection should be recorded in the database, indicating where they are deposited in the herbarium. It is recommended that vouchers are deposited in the general herbarium (if there is one) because they will then be seen by visiting taxonomists that can confirm identity. Many herbaria place vouchers from cultivated material in coloured folders to easily distinguish them from wild-sourced material. It is a good idea to insert a feedback form with each voucher to aid the return of updated information to the plant records officer, for updating the living collection database and associated material. This is particularly important where botanic gardens run the herbarium and living collection as separate entities.

- **DNA samples**

It is increasingly common to store material containing DNA from wild-collected specimens in order to assess the natural genetic variation within a given population. The extraction and storage of DNA is a technical process that not every botanic garden has resources to perform. To overcome this challenge, botanic gardens may choose to develop partnerships with laboratories (or other botanic gardens) which can provide this service. The Global Genome Biodiversity Network encourages the receipt of DNA from verified plant material for long-term storage.

- **Wood samples**

Samples of wood collected from cultivated plants can be valuable for research. Wood sections can often be dated precisely and may also be useful in verifying the identity of a species. Material can be gathered from routine tasks such as pruning or after storms or winter damage, or when a woody plant is removed from the collection.

The sample should be collected, preferably, from the trunk of the tree, to include a piece 5-10 cm thick, with its characteristic bark. In the case of large trunks, a section of bark and wood to the pith is sufficient. Each sample should be accompanied with the minimum set of data including information about where on the tree or shrub the piece of wood was removed from.

- **Photographic records**

A systematic collection of high quality digital photographs is a valuable data addition that aids scientific curation as well as education, display and marketing. A good digital single lens reflex (SLR) camera can achieve spectacular results and show features of the plant that may be overlooked otherwise. While no substitute for living plants or vouchers, high quality, close-up images can aid plant identification. This is especially true when good provenance data is available or when the genus has relatively few species. Photographs (that highlight salient identification features) can then easily be sent to specialists to help with identification (Case study 3.4). Image resolution should be as high as possible. Photographs taken with a digital SLR camera with over ten megapixels will be sufficient to produce a quality image of around 2000px in height and width. A tripod and a macro lens are necessary to achieve quality close-up shots of essential plant characters. Special photographers' light-tents enable close-up photographs to have an uncluttered and contrasting background.

Images linked to the living collections database can aid the duties of horticulturists in the botanic garden if the database is accessible through the intranet. Photographs can be used for multiple purposes, e.g. interpretation, display, publicity and marketing. Technological advances (for instance handheld barcode readers) can make use of images by allowing the public to download these while visiting the botanic garden.

Image files should receive a unique code that includes the accession number, not the taxonomic name, thus avoiding having to change file names at a later date if the accession is re-identified.

CASE STUDY 3.4

Quality images can facilitate taxonomic identification – Botanic Garden Meise, Belgium

Dave Aplin, Dorchester, United Kingdom

Images of salient characteristics can help or confirm a species' identification as they can easily be shared with taxonomic specialists in botanic gardens around the world. Once a name has been obtained, a note can be written in the database explaining the outcome of this remote method of identification or verification.

Several photographs of an unidentified species of *Clavija* (Primulaceae) were sent by the Botanic Garden Meise, Belgium, to Professor Bertil Ståhl at the University of Uppsala. On receiving the images the plant was identified as *Clavija cauliflora*. Coincidently Professor Ståhl was completing a monograph on *Clavija* and the e-mailed image highlighted the first functional female flowers of this taxon he had seen. In turn, preserved flowers were requested and provided, and offered valuable information for the monograph.

Clavija cauliflora grown at the Botanic Garden Meise – initially identified via photographs. (Image: Dave Aplin)

3.6 TRANSFERRING AND REMOVING PLANTS

KEY MESSAGE

A botanic garden cannot uphold high standards with ever-increasing numbers of accessions. There comes a point when less valuable plants, or specimens that have served their purpose, need to be removed from collection. This is a normal part of curation that helps maintain the focus and quality of the collection.

Plants enter a collection to fulfil a specific, or range of purposes. During an accession's time in the botanic garden, part or all may be donated to other organisations. Alternatively, the accession may be deemed to be of no further use or it might die. Through the processes of acquisition, transfer and de-accessioning, curators are able to maintain relevant, valuable collections for specific reasons. If material is to be transferred, maintaining close communication with the recipient institution(s) in order to ascertain that the material is fit for purpose, is vital prior to making the formal transfer arrangements. A short conversation can save many hours work if the accession is found to be unsuitable.

3.6.1 Transfer of Material

The transfer of material must be carried out in accordance with the access and benefit-sharing (ABS) provisions of the Convention on Biological Diversity (CBD), and more particularly, in compliance with the Nagoya Protocol – the legally-binding instrument that covers the transfer of living genetic material and national ABS legislation (Chapter 4, Section 4.5). Any transfer of material must be in accordance with the terms under which that material was originally acquired and such terms will need to be passed on to subsequent recipients. In addition, there may be further accession- or taxon-specific legislation or codes of conduct that must be respected, such as phytosanitary regulations (Chapter 6, Sections 6.3.3 and 6.8).

Prior to transferring plant material it is good practice to provide a document that sets out the terms and conditions of transfer, known as a 'Material Transfer Agreement' or MTA. Many botanic gardens will require the document to be signed and returned before material can be despatched. The following points will usually be included in a MTA:

1. Material is only provided to institutions working in the areas of research, conservation and education and not to individuals or commercial enterprises.

2. The recipient shall not sell, distribute or use for profit any of the material, its progeny or derivatives.

3. The recipient shall acknowledge (the donor botanic garden), as supplier, in all written or electronic reports and publications resulting from the use of the material, its progeny or derivatives. A copy may be expected to be sent to the donor botanic garden without request.

4. The recipient shall take all appropriate and necessary measures to import material in accordance with relevant laws and regulations and to contain the material, its progeny or derivatives so as to prevent the release of invasive alien species.

5. The recipient may only transfer the material, its progeny or derivatives to a botanic garden, university or scientific institution for non-commercial use in the areas of scientific research, education, conservation and the development of botanic gardens.

6. All transfers shall be subject to the terms and conditions of this agreement. The recipient shall notify the donor botanic garden of all such transfers.

In addition to the MTA document, information listing the accession number, the International Plant Exchange Network (IPEN) code if applicable (Chapter 4, Section 4.5.2) as well as the full scientific name should be presented. Once the MTA has been accepted and signed, the material can be transferred along with all information pertaining to each supplied accession.

3.6.2 Duplication of Accessions among Botanic Gardens and 'Safe Areas'

Botanic gardens are encouraged to duplicate accessions and share them amongst themselves as well as with other institutions. This helps safeguard vital germplasm from unforeseen catastrophe. Some botanic gardens are situated in areas where extreme weather events are a natural occurrence. Palm collections, for example, are often prone to damage by severe tropical storms. In an unlucky event, important accessions can be destroyed in minutes. In response to these threats, organisations and networks have been set up to help insure against extreme environmental hazards. For instance, the North American Plant Collections Consortium (NAPCC) – a network of botanic gardens and arboreta in North America – has adopted a programme to facilitate the curation of taxa (and accessions) in multiple botanic gardens across the continent. Combined inventories are analysed to identify gaps and redundancies while curatorial groups made up of representatives from each site govern collaborative activities.

Similarly, the International Conifer Conservation Programme at the Royal Botanic Garden Edinburgh has developed a network of over 200 'safe areas' for the cultivation of threatened conifers throughout

Montgomery Botanical Center, Florida – the day after Hurricane Wilma which destroyed half of its wild-gathered Syagrus botryophora palm collection. (Image: Harvey Bernstein)

Britain and Ireland. This strategy allows for the extensive *ex situ* conservation of trees that would otherwise be beyond the scope of a multifunctional botanic garden with limited space. It also enables taxa to be cultivated in areas that are environmentally more favourable than the domain of the botanic garden.

3.6.3 Accession Removal

The removal of plant material, or 'de-accessioning', is the process of permanently eliminating an accession from the collection. It is important to note that elimination often refers solely to the living material, while associated elements of the accession (e.g. herbarium vouchers, photographs or other data) may continue to be of value and may be retained.

There are various reasons why a living accession may be removed from the collection but the most likely causes are death and disease, or the results of an evaluation of the living collection. Accession removal is part of the normal routine work that helps focus resources on plants that are considered valuable to the organisation.

Before permanently removing accessions from the living collection, managers must consult their collections database to find out if there are any accession-specific donor restrictions about discarding material. Healthy, unwanted plants with no specific donor restrictions can be donated to other botanic gardens. It is best practice however, to provide a clear overview about why accessions have been considered obsolete. This allows potential recipient botanic gardens to make informed choices prior to acceptance of an acquisition and avoids the distribution of plants considered 'of little value'. In many cases, however, a suitable recipient may not be found, or it is impracticable to offer plants as they may simply be too large and unmovable. In these instances plants should be composted (Cronk, 2001).

Dead or unhealthy plants that cannot be saved should be discarded responsibly. It is best practice to investigate the causes of plant decline and/or death as this can contribute greatly to the knowledge of cultivating particular taxa and may curtail the spread of infestations to other plants. Many plant record management systems include fields that allow specific recording of such events (Chapter 5, Section 5.4.5).

3.7 EVALUATING LIVING COLLECTIONS

KEY MESSAGE

Only through evaluation can the suitability of a plant collection be assessed to address the current needs of an organisation. It represents one of the most important activities undertaken in the curation department, yet it in many botanic gardens this is seldom taken into consideration.

A botanic garden that aims to continuously improve quality and utility of its collections should ensure that evaluation forms an integral part of the collection policy and is part of the ongoing curation agenda. Evaluation or audits of living collections are here defined as a planned, documented activity conducted periodically by knowledgeable professionals to review the value of plants and/or management practices. It is also about assessing situations, and changing what needs to be changed (Rammeloo and Aplin, 2007; Aplin, 2013).

Audits as defined in this section do not include routine curatorial work such as inventorying, identifying and verifying, mapping and tree risk assessments. Instead they focus on strategic mechanisms to determine the value of accessions and collections to the host organisation, the public and/or funders.

Evaluations will be most effective when the botanic garden has a collections policy that guides collection development and curation, as this document provides the basis of the audit. The process can be used to evaluate, set goals, raise standards, target resources and provide justification of the botanic garden's value and sometimes even its survival. A range of audit types can be considered that specifically target living collections.

3.7.1 Important Considerations when Evaluating Living Collections

There are some important points that need to be considered prior to any audit. These help define the purpose and scope of the audit, inform stakeholders about what is happening and offer the chance to acquire information from individuals that has not been previously recorded. The points considered below can be used to guide most types of audit conducted on living collections:

- **Decide on agreed criteria for evaluation:**
  A prerequisite to evaluation is having a set of criteria used to judge the merits of each accession. This should ideally come from the living collection policy, a set of acquisition criteria and/or a minimum standards benchmark. If no such document exists then the first task should be to create one in consultation with relevant stakeholders.

- **Talk to stakeholders:**
  Plants matter but so do people. It is important to inform garden staff prior to and throughout an audit process, especially those who have tended the collection over the years. They may have important information about a particular accession or management procedure that has not been recorded.

- **Make a list of what is to be evaluated:**
  If the audit is focused on plants then make a list of all the accessions and their locations to be included in the review. Discrete groups, such as Cactaceae, trees or the seed bank provide manageable units to evaluate.

- **Ensure accessions are correctly identified and verified before auditing:**
  Correct identification of plants may seem to be an obvious priority but can sometimes be overlooked. A botanic garden needs to be sure that the basis of an evaluation is founded on hard facts and the most important one is knowing what is being evaluated.

- **Check nomenclature and synonyms:**
  Many plants have changed their classification over the last few decades. If the collection's nomenclature has not been updated then preparation for an audit is a good point to do this. At this stage it is good practice to search the entire holdings for any synonyms found because there may be duplicate taxa to those being evaluated but cultivated elsewhere in the institution under a different name.

- **Identify threatened plants:**
  It is important to review local, regional and international lists of threatened plants to help make informed decisions about retaining or discarding an accession.

- **Download and research plant records data:**
  Downloading and reviewing accession data is a key step in the evaluation process. Data is best downloaded into a spreadsheet for ease of sorting, manipulation and annotating.

- **Conduct internet research:**
  A valuable online search tool for the plant holdings of botanic gardens is the BGCI's PlantSearch database. This database is the most comprehensive global catalogue of plants held in botanic gardens and provides an indication of the number of institutions cultivating a particular taxon.

- **Identify donor restrictions for rejected accessions:**
  Depending on the type of audit, there is likely to be a list of plants that need to be de-accessioned at the end of the process.

- **Find new homes for or discard unwanted accessions:**
  Unwanted accessions with no restriction can also be donated to non-commercial enterprises such as municipal gardens, schools, hospitals and care homes. When no suitable place can be found to relocate the plants they should be composted.

Further guidance for evaluating plant collections is in 'Assets and liabilities: The role of evaluation in the curation of living collections' (Aplin, 2013).

Figure 3.3 Collection management questions that evaluations aim to answer

3.7.2 Evaluation Types

Evaluations can be designed to answer a range of questions (Figure 3.3) yielding invaluable information for curatorial management. The resulting recommendations on curatorial procedures provide good evidence on which to base change.

Examples of evaluation types undertaken at botanic gardens:

- **Evaluation of conservation and research values**

This evaluation type is not a quick and easy procedure. It evaluates associated accession data and concentrates of the potential usefulness of plants for conservation and research. If a botanic garden's aim is to improve the value of its holdings then this type of evaluation should be part of its ongoing curation agenda (Case study 3.5).

CASE STUDY 3.5

Conservation value of Cactaceae collection at the Botanic Garden Meise, Belgium

Dave Aplin, United Kingdom

One of the most common plant collections given the 'conservation' label are Cactaceae. Indeed, habitat modification and destruction, together with over-exploitation threaten many species. The vast majority of cacti taxa are therefore included either in Appendix 1 or 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

In 2006, the Cactaceae collection at the Botanic Garden Meise represented its largest living plant family under curation with over 5,000 plants (2,507 accessions) from 1,642 taxa. Some plants were maintained in a large public display glasshouse, but the vast majority were kept in glasshouses with no access to visitors. Analysis of the accession data highlighted 90% to be without data. Further, only 251 accessions were of wild origin of which only 21 had sufficient data to aid future, potential conservation efforts. This meant that only 0.84% of the entire Cactaceae collection (previously described as a 'conservation collection') could legitimately be given the conservation label. Clearly, over the years quantity had triumphed over quality.

Cacti experts Dr David Hunt and Dr Nigel Taylor spent two days evaluating and verifying the collection and came to the conclusion: "Two-thirds of the collection could be discarded without any loss in conservation or research value". Despite this sobering outcome, the audit also discovered a jewel in the collection, *Opuntia stenarthra*, a wild-collected Paraguayan species that had not been observed as a living plant for over a century.

Opuntia stenarthra, discovered in the cacti collection of the Botanic Garden Meise during an evaluation of the conservation value of the plant holdings. (Image: Botanic Garden Meise)

As a result of the audit, a large proportion of the collection was offered to other botanic gardens with a statement about the Meise findings to avoid accessions being cultivated elsewhere under the mistaken guise of conservation (Aplin, 2008; 2013).

- **Evaluation of cost-benefit**

This type of assessment, developed by the Montgomery Botanical Center, United States, is offered as a way to make objective allocations of space, staffing and funding to conserve plants through living collections. Specifically, it allows botanic garden managers to make informed decisions to:

- Determine the cost-benefit of keeping multiple plants of a given taxon;

- Provide effective practice to target funds where they are most needed;

- Give clarity about what is being curated;

- Justify the continuation of funding and the role of the botanic garden.

An important objective of living collection management is to maintain the maximum level of diversity with the greatest economic and logistic efficiency. An audit of cost-benefit helps collection managers do exactly this. This type of audit uses three defining indicators to gauge the effectiveness and efficiency of living collections including species imperilment, genetic representation and operational costs associated with maintaining accessions (Griffith and Husby, 2010; Cibrian-Jaramillo, 2013).

- **Evaluation of collection 'fitness'**

This type of audit looks at the collection as a whole and provides easy to understand information about its fitness in the form of statistics. Fitness in this instance refers to the quality of the collection, measured by the botanic garden's goals and objectives. Collection statistics are a valuable tool to monitor and measure progress (Rae, 2004). All botanic gardens should have a system of monitoring development towards their vision and mission (Chapter 1, Section 1.2.4). The typical living collection will comprise many thousands of accessions and an extensive amount of associated information. In order to make sense of this data, demonstrate the current fitness of holdings and set future targets, it is vital to summarise this information into easy to interpret, meaningful numbers.

Staff will visualise percentage figures more easily than describing the collection in general terms, for example "61% of our accessions are from wild-collected material" is more meaningful than "We have many wild-collected accessions". An added benefit to knowing the statistical information is that it has the potential to encourage staff to enhance the value of the collections: "Our target is to improve our total percentage of verified and identified holdings by 5% over the next two years". The type of criteria adopted to measure the collections will depend on the individual botanic garden, its aims and objectives, and on the focus of the plant holdings as outlined in its collection policy.

- **Evaluation of taxonomic groups**

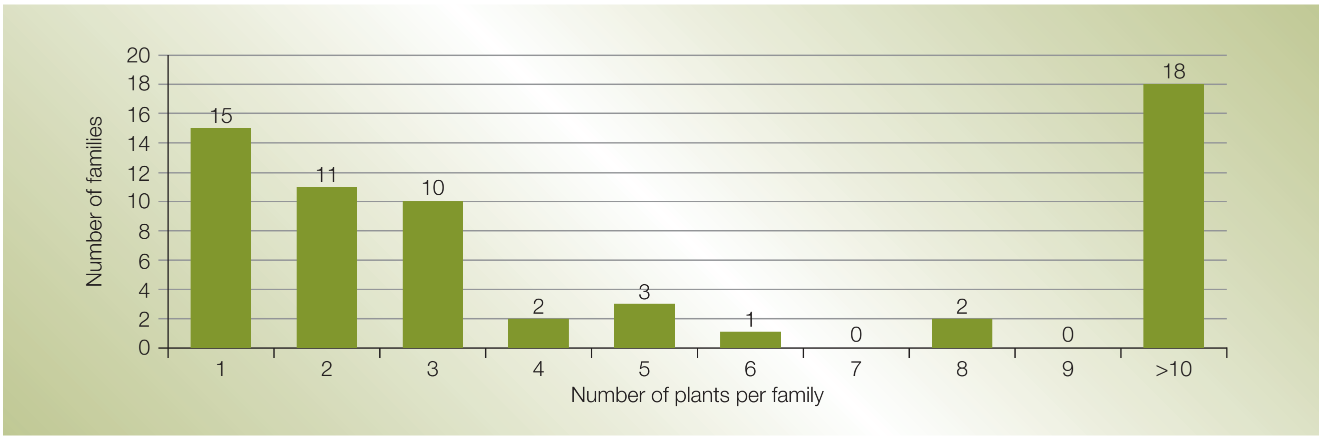
Some botanic gardens choose to focus on specific taxonomic groups because they are actively used by staff in research and/or education programmes. For example, a botanic garden may hold a living reference collection of a specific plant group utilised in its molecular work, or it may host the national collection of a particular genus. Over time, the number of taxa in the group will vary, and it is the role of this type of audit to highlight any unplanned losses or reduction in focus (Table 3.1).

Table 3.1 Audit results for the genus *Begonia* held at the Royal Botanic Garden Edinburgh

	Species	Taxa	Plants	Wild accessions	All accessions	Difference 3
1990		58	178	33	76	43%
1995		38	173	35	60	58%
2001		53	447	150	197	84%
2007	78	92	514	176	240	75%
2012	148	169	1321	351	496	73%
Difference 1		191%	624%	963%	552%	
Difference 2	90%	84%	157%	99%	107%	

The first column displays the year data was gathered for this inventory. Difference 1 represents the percentage difference between 1990 and 2001, the 'base' year when these audits started. Difference 2 relates to the percentage difference between the latest audit and the previous one. Columns 2 and 3 show the number of taxa and plants for each of the corresponding years. Columns 5 and 6 highlight the number of wild accessions and total accessions of this genus, respectively. The last column (Difference 3) highlights the percentage of wild-gathered accessions compared to total accessions. The figures show a rise since 1990 explained by increased focus on the genus for research purposes. The purpose of the five yearly audits is to monitor long-term trends in major project-related families and genera to highlight if major, unexpected, changes have taken place. The rapid rise in the number of *Begonia* taxa and plants between 2007 and 2012 was anticipated and expected as it was directly linked to a research project, but it also resulted in enhanced exchanges between the curatorial staff responsible for looking after the plants and the science staff working on *Begonia* to discuss resources and future projections (David Rae, pers comm).

Figure 3.4 Number of families versus number of plants per family, Meise Botanic Garden, Belgium



- **Evaluation of potential taxonomic vulnerability**

An audit of potential vulnerability attempts to assess the vulnerability of specific taxa within the living collection. Most botanic gardens attempt to grow as wide a range of plant families as possible. Therefore, it is sensible to look at the potential vulnerability of the families in living collections. For instance, an evaluation carried out at the Botanic Garden Meise, Belgium, found that 15 families are represented by a single plant, 11 by two individuals and ten families by just three (Figure 3.4). This information can be further examined qualitatively to determine if a family is at risk of being lost. For example, a family represented by a single plant of an established tree is likely to be regarded 'safe for now' whereas one represented by a solitary herbaceous perennial will have a greater risk therefore requiring priority attention.

3.8 CONCLUSION

Plant living collections are the centre of a botanic garden. They fulfil a range of diverse functions from scientific research and conservation to public engagement. The purpose of the collection policy is to guide strategic management of the plant holdings to ensure they are 'fit-for-purpose' and targeted.

Focusing a plant collection without a formal, written strategy is problematic, yet numerous botanic gardens lack a collection policy (Aplin, 2013). This can result in inefficiency that devalues the work of the institution. Maunder *et al.* (2004) have highlighted that, at least for conservation, botanic gardens are among the most extensive, yet underused, resources in the world.

A botanic garden's collection policy that defines its acquisition, retention and evaluation approach, is a formidable document that ensures that the plant holdings are aligned as closely as possible to the institution's mission and function. It provides clear criteria to acquire plants, supports decisions to evaluate and monitor progress, and gives confidence to remove accessions that have outlived their purpose. In conclusion, the adoption of a collection policy helps target a botanic garden's resources where most needed, and contributes to achieving a world in which plant diversity is valued and secure, supporting all life.

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Part C: The Plant Collection – Linchpin of the Botanic Garden

Chapter 4: The Plant Collection in the International Policy Context

Part C: The Plant Collection – Linchpin of the Botanic Garden

Contents

Chapter 4:
The Plant Collection in the International Policy Context

Kate Davis, Ottawa, Canada

4.1 INTRODUCTION

KEY MESSAGE

Comprehensive knowledge of global treaties can help botanic gardens grow their own influence locally, nationally and internationally.

With an awareness of the global multilateral environmental agreements (or 'MEAs') that shape many national laws and conservation initiatives, botanic garden managers can develop policies that foster outward-looking partnerships, support legal compliance, and connect with governments. This section introduces several MEAs that are particularly relevant to botanic gardens, with a focus on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on Biological Diversity (CBD). These two MEAs affect the practices of virtually all botanic gardens, the latter including the Nagoya Protocol on access and benefit-sharing. For further information on international policy relevant to botanic gardens, see also the International Agenda for Botanic Gardens in Conservation.

4.2 OVERVIEW AND TIMELINE OF THE PRINCIPAL GLOBAL MEAS

The global efforts that led to today's major MEAs began to gather force in the mid-20th century, with recognition that international cooperation was needed to tackle cross-boundary issues such as species and habitat loss and over-exploitation. CITES is the oldest of the key international treaties relevant to botanic gardens, first drafted from a resolution adopted in 1963 by the International Union for the Conservation of Nature (IUCN), finally agreed in 1973, and in force from 1975. The Ramsar Convention on Wetlands and the World Heritage Convention also entered into force in 1975 (Box 4.1).

Since the 1970s, the global environment agenda has become ever more tightly linked to sustainable development. The United Nations Conference on the Human Environment, convened in 1972 to focus on human interactions with the environment, produced the Stockholm Declaration and influenced many regional and national actions. The Brundtland Commission, another UN initiative, defined sustainability as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' in its 1987 report 'Our Common Future'. The UN Conference on Environment and Development (UNCED, also called the Rio Earth Summit), held in Rio de Janeiro in 1992, launched Agenda 21: Programme for Action for Sustainable Development, and three international treaties: the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat Desertification (UNCCD) (Box 4.1). These treaties are often called the Rio Conventions and, like CITES, they are organised under the UN Environment Programme (UNEP).

The Millennium Development Goals (MDGs), arising from the UN's Millennium Summit in 2000, provided the umbrella for all international policies for biodiversity conservation and sustainable development from 2000-2015. They committed nations to 8 international development goals to reduce extreme poverty, including (as Goal 7) 'Ensure Environmental Sustainability'. In 2002, the World Summit on Sustainable Development (WSSD, also called Earth Summit 2002 or Rio+10) evaluated progress since UNCED, endorsed the MDGs and recognised the CBD as the key instrument for the conservation and use of biodiversity that is equitable and sustainable. In 2004, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) entered into force – a treaty under the UN's Food and Agriculture Organisation that focuses on exchange of plant resources for food security. In 2010, the CBD adopted a revised Strategic Plan for Biodiversity 2011-2020 including Aichi Biodiversity Targets and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization. The UN's Sustainable Development Summit (Rio+20) in 2012 reaffirmed international commitment to the CBD, its Strategic Plan and the Nagoya Protocol. It also began the process of developing the Sustainable Development Goals (SDGs) and taking forward the post-2015 development agenda. The SDGs, 'Transforming our world: the 2030 Agenda for Sustainable Development', replace the MDGs as the new umbrella for international biodiversity policies. They provide 17 aspirational goals, with 169 targets, covering many development issues, including conservation and sustainable use of terrestrial and marine ecosystems, halting biodiversity loss and combatting climate change.

Adoption of the Nagoya Protocol on access to genetic resources and benefit-sharing at the Tenth meeting of the Conference of the Parties (COP 10), Nagoya, Japan, on 29 October 2010. (Image: Kate Davis)

A country becomes a member nation, or 'Party', to a treaty by signing the treaty and then passing it through its national legislation, a process called ratification. A certain number of ratifications are needed before a treaty comes into force. The governing body for a convention (a type of treaty) is called the 'Conference of the Parties (COP)'. COPs are large meetings where Parties review progress and make decisions, and are generally convened every 2-3 years. Only Parties (governments) can make decisions or resolutions (in the case of CITES, by a 2/3 majority, with one vote per Party; in the case of the Rio Conventions, by consensus). However COPs are also attended by many observers from NGOs, industry, academia and other organisations – including botanic gardens.

Box 4.1 Wetlands, heritage and desertification: more global conventions relevant to botanic gardens

Convention on Wetlands of International Importance (Ramsar Convention): provides a framework for the conservation and wise use of wetlands and their resources. Botanic gardens can contribute by, for example: working in partnership to manage and restore wetland areas; undertaking research on conservation, cultivation and biology of threatened aquatic and wetland plants; raising public awareness about the importance of wetland habitats through education programmes and activities.

Convention Concerning the Protection of World Cultural and Natural Heritage (World Heritage Convention): aims to protect and preserve the world's cultural and natural heritage for present and future generations. Several botanic gardens have been designated as World Heritage Sites. Botanic gardens can: promote and support applications for natural and cultural sites; work in partnership to counteract dangers to natural and cultural heritage; develop educational materials to enhance knowledge of and respect for heritage sites; conduct inventories of plant diversity for sites included in the 'List of World Heritage in Danger'.

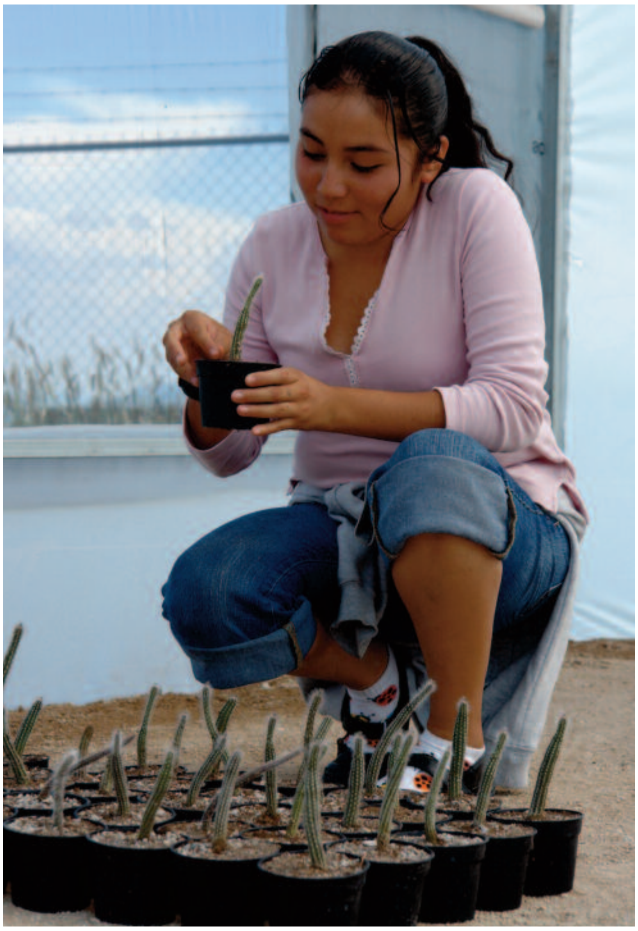
United Nations Convention to Combat Desertification (UNCCD): aims to combat desertification and mitigate effects of drought through national action programmes and international partnerships. Actions botanic gardens could take to contribute include: undertaking research on dryland plants; working in partnerships to prevent land degradation and undertake restoration; improving land utilisation by the introduction and cultivation of appropriate plants; improving and sharing knowledge of dryland plants; conserving dryland plants germplasm; providing training in plant conservation techniques for the management of dryland plant resources and ecosystems.

4.3 THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES)

KEY MESSAGE

CITES provides a legal framework to certify sustainable trade and control over-exploitation. It also assists in preventing illegally collected plants from coming into the botanic garden collections.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) – also known as the Washington Convention – provides an international legal framework for the regulation of trade in those plant and animal species that are exploited commercially for international trade – and covers many of the species that botanic gardens collect, cultivate, and exchange. Although trade issues can be complex and political, CITES is a relatively straightforward treaty; its provisions are translated into national legislation by Parties and there are strong enforcement measures.



Transplanting Echinocereus schmollii, a Mexican cactus. The vast majority of taxa of Cactaceae are listed either on CITES Appendices I or II; the Annotations specify which parts and derivatives are exempt from controls. (Image: Jardín Botánico Cadereyta, Mexico)

CITES operates through the issue and control of import and export permits for species listed in three Appendices (Box 4.2). CITES certifies sustainable trade in plant species that can withstand current rates of exploitation, but prevents trade in those that face extinction.

CITES provides a baseline for national legislation. Countries may develop measures that are stricter than the provisions in CITES. Countries that have developed stricter domestic measures include Australia, the USA, and the member countries of the European Union. Within the EU, CITES is implemented by EU regulations that require import permits or notifications for all CITES-listed species (and some others; all are organised into four Annexes) in addition to the basic CITES export permit from the country of origin.

4.3.1 The Appendices

The three Appendices (Box 4.2) contain many thousands of plant species: approximately 300 in Appendix I and over 28,000 in Appendix II, which includes the entire orchid and cactus families. The Appendices also include some other succulents, cycads, a range of timber and medicinal plants, and certain genera and species of geophytes, carnivorous plants, tree ferns, and palms. The Annotations to the Appendices specify exactly which parts and derivatives of species are controlled or exempt from CITES controls.

Box 4.2 CITES Appendices

Appendix I:
Lists plant species threatened with extinction, for which international trade must be subject to particularly strict regulation, and only authorized in exceptional circumstances.

Appendix II:
Lists species that are not threatened with extinction at present, but may become so if uncontrolled trade continues. Trade is permitted of both wild and artificially propagated material provided an appropriate permit is obtained.

Appendix III:
Lists species that are threatened locally with extinction through commercial exploitation and therefore subject to trade controls within certain nations. International trade in this material requires an export permit from the country that listed the species, or a certificate of origin.

4.3.2 CITES Authorities

International implementation of CITES is facilitated by the CITES Secretariat, based in Geneva, Switzerland. Several technical Committees meet between COPs: the Standing Committee provides policy guidance to the Secretariat and oversees the budget, while the Plants Committee and Animals Committee provide scientific guidance to other CITES bodies, deal with nomenclatural issues, review species to ensure appropriate categorisation, conduct reviews of significant trade, and draft COP resolutions. The Plants Committee meets once per year.

Each CITES Party is required to designate one or more national 'Management Authority' to administer the licencing system in that country. Management Authorities implement national policy on wildlife trade issues, provide information on CITES, issue permits and certificates, and inspect and monitor incoming plant material in cooperation with national customs officers. They also detain illegally traded material and pursue prosecution of the trader, undertake training, coordinate with the CITES Secretariat, liaise with the National Central Bureau of Interpol, monitor the levels of trade (via annual and biennial reports to CITES), and set up strategies for confiscated material.

Each CITES Party must also designate one or more 'Scientific Authority' to provide independent scientific advice to the Management Authority on the effects of trade on the status of the species. Scientific Authorities may be government agencies, research institutions or committees with membership reflecting the wide variety of CITES-listed species. The Scientific Authority is responsible for carrying out 'non-detriment findings (NDF)' for species listed in Appendix I and Appendix II prior to the granting of permits by the Management Authority – that is, advising that the export (or import) will not be detrimental to the survival of the species in the wild. The Scientific Authority has a wide range of other tasks, including monitoring exports and determining when export levels should be limited, advising as to whether scientific institutions meet the criteria for CITES registration, ensuring that recipients of Appendix I species have suitable facilities to care for them, and analysis of species' biological status to inform proposals to amend the Appendices.

The CITES website contains a country directory with full contact details for all CITES Management Authorities and Scientific Authorities.

4.3.3 Permits and Certificates

All specimens of species listed on CITES Appendices must have an 'export permit' (or re-export permit, for subsequent international transfers) from the country of export, obtained from that country's CITES Management Authority. The issuance of the permit confirms that the removal of the plant will not pose a threat to the survival of that species in the wild, that the export is in accordance with national law in the exporting country and, in the case of live Appendix I plants, that the proposed recipient can house and care for them.

Wild collected specimens of Appendix I species also require an 'import permit' (or re-import permit) obtained from the CITES Management Authority of the country to which the specimens are being imported. Many countries with stricter domestic measures also require an import permit for Appendix II species in addition to the export permit from the exporting country (for example, EU member countries require an EU import permit; see European Commission and TRAFFIC, 2015).

For Appendix III specimens, an export permit is required from the country that listed the species on Appendix III if the specimen is being exported from that country. If an Appendix III specimen is being exported from any other country, a 'certificate of origin' (or re-export certificate) is required from the CITES Management Authority of that other country.

To export a specimen that was acquired before the species concerned was first included on the Appendices (a 'Pre-Convention specimen'), a 'pre-Convention certificate' is required, issued by the Management Authority of the country of export if it is satisfied that the specimen was acquired before that date. The import must still be declared to customs.

When a specimen of a CITES-listed species is transferred between a country that is a Party to CITES and a country that is not, the country that is a Party may accept equivalent documentation that conforms to the CITES requirements for permits and certificates in addition to the basic CITES export permit from the country of origin.

4.3.4 Exemptions

KEY MESSAGE

Become a CITES registered scientific institution: this scheme facilitates scientific exchanges between institutions.

Certain types of specimens and exchanges are exempt from the requirement for CITES permits. For botanic gardens, the most relevant exemptions are for artificially-propagated plants and for scientific exchange between registered scientific institutions:

- Artificial propagation: CITES defines artificially propagated plants very specifically as those that are (a) grown under controlled conditions; and (b) grown from seeds, cuttings, divisions, callus tissues or other plant tissues, spores or other propagules that either are exempt or have been derived from cultivated parental stock. CITES also defines 'under controlled conditions' and 'cultivated parental stock' carefully; such stock must have been legally established in accordance with CITES provisions and national laws, and in a manner that is not detrimental to the survival of the species in the wild, and is maintained with only minimal or no augmentation from the wild.

- Registered scientific institutions: CITES also allows an exemption for non-commercial loan, donation or exchange between scientific institutions that are registered by their Management Authority. Herbarium specimens, other preserved, dried or embedded museum specimens and live plant material of CITES-listed species can be exchanged using a 'CITES label' issued or approved by the Management Authority; DNA samples are also covered. Both sender and recipient institutions must be registered, and all material must be accompanied by the CITES label, which contains the CITES logo, the names and addresses of the sender and recipient institution, the unique 5-digit CITES registration numbers of both institutions, and a description of the material. The label should then be fixed to the outside of the package. Any material collected in another country by collectors who are not working with a national registered institution and intend to take the material back to their home country will need a CITES export permit. The CITES website holds the updated global register of scientific institutions, including institutional details and registration numbers. It is important to remember that CITES regulations do cover the exchange of herbarium specimens and DNA for research, and the label scheme significantly facilitates the process between registered institutions; botanic gardens can benefit greatly by being included on their country's register.

4.3.5 Botanic Gardens and CITES

Botanic gardens have moral and legal responsibilities with regard to CITES and must be seen to be within the law and above reproach (Case study 4.1). Botanic gardens can also play a major role in improving implementation and awareness of CITES (Oldfield and McGough, 2007; BGCI, 2012). A botanic garden's collection policy (Chapter 3) should articulate how the botanic garden will comply with CITES, based on the individual institution's priorities for plant holdings.

For basic CITES compliance, botanic gardens should:

- Check collections for CITES-listed species, and maintain complete documentation;

- Assign clear staff responsibility for CITES matters;

- Always obtain CITES permits and labels when appropriate – work with collaborating institutions to compile procedures for obtaining the necessary export and import documents and remember that CITES also covers herbarium specimens, spirit collections, tissues and DNA samples as well as other specimens/samples of CITES-listed species;

- Disseminate CITES information and/or training to staff, and ensure they understand CITES issues to prevent infractions;

- Prevent any illegally collected plants from coming into the collections 'through the back door';

- Contact and find out about their national CITES authorities, and consider registering the institution with the Management Authority.

Other contributions comprise:

- Participating in the CITES process: Botanic gardens might seek to become members of their governmental delegations to the Plants Committee, and should be included on the regional representatives email list to keep up to date with activities in their region. Botanic gardens can participate at Plants Committee meetings and COPs, as active observers or on their government's delegation. They can also provide venues for regional or national CITES plants meetings and training workshops. Botanic gardens may also play a vital role as Scientific Authority in their own right or as part of a committee structure.

- Providing information for CITES: Botanic gardens with expertise in threatened plant groups can provide input for the development of CITES amendment proposals, development of NDFs and management plans for CITES-listed plants, and Significant Trade Reviews for plants. Botanical information is needed by national CITES Management and Scientific Authorities and internationally by the CITES Secretariat, CITES Plants Committee and relevant international organisations such as IUCN and TRAFFIC.

- Offering rescue centres for confiscated material: Botanic gardens can provide appropriate expertise and facilities for holding material that has been taken from individuals by the statutory authorities, either temporarily after initial confiscation, or permanently following formal seizure or successful legal action. Botanic gardens do need to consider carefully the implications of looking after this challenging material, which is unlikely to have phytosanitary documentation and may be in poor condition. However, confiscated material has value as prosecution evidence, and can raise public awareness of conservation, augment the botanic garden's collections, and potentially be used for the conservation of the species; on the other hand, this can also bring an additional onus on the institution as the plant material can neither be destroyed, exchanged or transferred.

- Advising and training customs and legal authorities: Botanic gardens staff with particular expertise in plant identification and horticulture can help members of the customs or legal professions with CITES enforcement issues, for example by identifying plant material, determining whether the material is of wild or cultivated origin, or providing advice on the commercial value of plants and their country of origin. Botanic gardens can also help to develop training guides and workshops for CITES enforcement personnel.

- Publicising CITES involvement: Botanic gardens can also support CITES by explaining and publicising their involvement, interpreting the need for sustainable trade in plants to the public, and encouraging the public to think about the origin of rare plants in trade. Botanic gardens can also encourage other gardens to become involved and register with the CITES Management Authority.

CASE STUDY 4.1

Botanic gardens and sustainable trade – conservation and cultivation of *Galanthus woronowii* in Georgia

Catherine Rutherford, Richard Wilford, Noel McGough London, United Kingdom; Kate Davis, Ottawa, Canada

The Royal Botanic Gardens, Kew (in its role as UK CITES Scientific Authority for Plants), the CITES Authorities of Georgia, Microsoft Research (Cambridge, UK), the Tbilisi Botanic Garden, the Institute of Botany and Batumi Botanical Garden are working in partnership to ensure sustainable harvest of snowdrop (*Galanthus woronowii*) bulbs for the international horticultural trade.

Georgia has been exporting *G. woronowii* since 1997, with the European Union as the major importer and the Netherlands dominating this trade. All *Galanthus* species are listed on CITES Appendix II, and CITES requires that the Scientific Authority in the country of export must provide a 'non-detriment finding' for international trade in wild-harvested Appendix II species – a statement that the trade will not be detrimental to the species' survival. The CITES Plants Committee expressed concern at the high level of *Galanthus* exports from Georgia, but there was little information on the conservation status of the species in trade, the full extent of *G. woronowii* populations in the wild in Georgia, levels of artificial propagation, how CITES non-detriment findings were made, or the scientific data behind the setting of export quotas. A CITES project funded by the Netherlands was established in 2008 to review the conservation status and distribution of *G. woronowii* in Georgia and determine whether the annual harvest of 15 million bulbs from the wild was sustainable.

The project partners conducted field surveys in 2009 at 41 sites to assess the status of wild populations, including some in semi-natural habitats (wild areas in Batumi Botanic Garden) and agricultural habitats, and assessed the conservation value of each site. A workshop held later in 2009 delivered the results of the surveys and training on artificial propagation and cultivation. The partners also surveyed 23 cultivated populations in 2009 and 2010, interviewing local traders, landowners and local government representatives about the sites' histories. Potential sustainable harvest was then modelled to recommend annual export quotas and the management systems needed to meet CITES requirements. Additionally, a checklist was developed for local application of the CITES definition of Artificial Propagation and a registration system for propagation fields was established and embedded in government regulations.

The project continues, with funding from Germany, to establish the sustainable export quota for wild-sourced *G. woronowii* for 2014-2016, assess the artificial propagation of the species in cultivation fields, and review and enhance the monitoring scheme for wild populations, cultivation fields and registered artificial propagation sites. The partners hope that this extensive research will provide an exemplar and benchmark on how to harvest wild resources for the sustainability of both the wild plants and the livelihoods of the local and national stakeholders.

One of the largest Galanthus woronowii populations in Georgia, extending over 30-50 ha of alder woodland near Kirnati, Khelvachauri municipality, Adjara Autonomous Republic. (Image: David Kikodze)

4.4 THE CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

The Convention on Biological Diversity (CBD) – also called the Biodiversity Convention – is the key international instrument for the conservation and sustainable use of biodiversity, and its Strategic Plan is the overarching framework on biodiversity for the entire United Nations system. The CBD came into force on 29 December 1993, and has been ratified by all but three countries (the USA, Andorra and the Holy See). Although the USA is not a Party, many US botanic gardens are actively implementing the CBD, and they are affected by other countries' CBD-related laws when they work internationally.

4.4.1 CBD Bodies and National Authorities

Several CBD bodies support the COP. The CBD Secretariat is based in Montreal, Canada. The Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) provides recommendations to the COP and various working groups are set up to tackle complex issues. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) convenes Task Forces and Working Groups on many of the technical issues identified by SBSTTA. The mainly web-based Clearing House Mechanism (CHM) facilitates global information exchange on CBD implementation. At the national level, each Party must designate a National Focal Point (NFP) to provide information on national CBD actions. Countries may also choose to nominate additional NFPs to handle certain areas of the CBD. A list of NFPs is available from the CBD website.

4.4.2 Objectives, Programmes, Strategic Plan and National Actions

KEY MESSAGE

Each country decides how it will address the CBD's objectives and targets – botanic gardens can play key roles in their development and implementation.

The CBD's three objectives are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the utilisation of genetic resources. Its scope covers all levels of biodiversity, though human genetic resources are excluded. Its text includes articles on identification and monitoring, *in situ* conservation (including provisions on traditional knowledge and invasive species), *ex situ* conservation, sustainable use, research, public education, access to genetic resources, technology transfer and scientific cooperation.

To tackle this ambitious mandate, the CBD established thematic and cross-cutting programmes of work focusing on seven major biomes and issues relevant to all biomes, then adopted a Strategic Plan in 2002. The revised Strategic Plan for Biodiversity 2011-2020, comprising five strategic goals and the 20 Aichi Biodiversity Targets, captures elements of all of the programmes and is now the primary structure against which countries develop national strategies and report progress, although the original cross-cutting programmes are still relevant. Key programmes for botanic gardens include the Global Strategy for Plant Conservation, invasive alien species, traditional knowledge, and access to genetic resources and benefit-sharing; additional relevant cross-cutting issues are introduced in Box 4.3.

Box 4.3 Other CBD cross-cutting issues relevant to botanic gardens

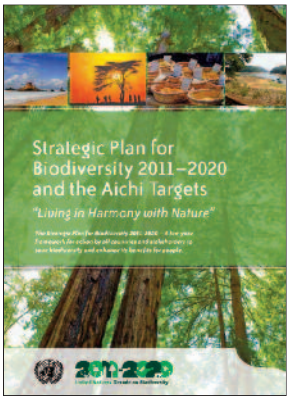
In addition to the GSPC, invasive alien species and ABS, botanic gardens can also make important contributions to the following CBD programmes:

Communication, education and public awareness (CEPA): seeks to communicate the scientific and technical work of the CBD, to integrate biodiversity into education systems, and to raise awareness of the importance of biodiversity to our lives and its intrinsic value. Botanic gardens offer enjoyment and learning and are perfectly placed to engage and inform the public about biodiversity.

Global Taxonomy Initiative (GTI): recognises that taxonomy is crucial to CBD implementation so tackles the 'taxonomic impediment' caused by lack of taxonomic knowledge and experts. Botanic gardens with active taxonomic research can contribute to GTI implementation through their GTI National Focal Point, or consider becoming the GTI National Focal Point.

Sustainable use of biodiversity: one of the CBD's objectives, also covered in the GSPC and Aichi Targets; this programme produced the Addis Ababa Principles and Guidelines. Botanic gardens can be powerful advocates for sustainable use of plant diversity by adopting sustainable management practices, by conducting research on sustainable uses of plants, and by raising public awareness of the issue.

Technology Transfer and Cooperation: helps countries to achieve equitable benefit-sharing and conduct their own research and development; the CBD website hosts a technology transfer database. Botanic gardens make use of many technologies and can offer technical advice, training opportunities, or funds for equipment and renovation to other gardens.



The Strategic Plan for Biodiversity 2011-2020 provides the framework for international and national action on biodiversity.

The CBD sets out general provisions and international targets but respecting countries' sovereign rights over their biological resources allows each country to determine how it will implement the CBD. Parties are expected to develop National Biodiversity Strategies and Action Plans (NBSAPs) as a starting point, and to update them in line with the Strategic Plan, integrating national targets that are based on the Aichi Biodiversity Targets. Then, depending on existing national circumstances, each country decides its actions to meet CBD goals. Countries provide updates on their implementation via periodic national reports.

4.4.3 Global Strategy for Plant Conservation (GSPC)

Originating from the botanic gardens community and adopted by COP in 2002, the Global Strategy for Plant Conservation (GSPC) is an international framework to support and facilitate plant conservation at all levels. It piloted the use of 16 measurable, time-limited, outcome-oriented targets in the CBD, organised in five objectives (Box 4.4).

A number of countries have developed national plant conservation strategies, with national targets relating to the 16 GSPC targets. There are also several regional responses, such as the European Plant Conservation Strategy, and regional GSPC implementation workshops in Southeast Asia and Central America.

Updated GSPC 2020 targets were adopted in 2010, for attainment by 2020. The GSPC targets provide more focus to aid practical implementation by plant conservation stakeholders (Case study 4.2) than do the much broader Aichi Biodiversity Targets, but botanic gardens that wish to have their GSPC actions and accomplishments noted by national authorities and the CBD via National Reports may need additionally to relate them to the corresponding Aichi Biodiversity Targets (see also Box I Introduction).

Box 4.4 Objectives and targets of the Global Strategy for Plant Conservation (GSPC)

Objective I: Plant diversity is well understood, documented and recognized

Target 1: An online Flora of all known plants.

Target 2: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action.

Target 3: Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared.

Objective II: Plant diversity is urgently and effectively conserved

Target 4: At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration.

Target 5: At least 75 per cent of the most important areas for plant diversity of each ecological region protected, with effective management in place for conserving plants and their genetic diversity.

Target 6: At least 75 per cent of production lands in each sector managed sustainably, consistent with the conservation of plant diversity.

Target 7: At least 75 per cent of known threatened plant species conserved *in situ*.

Target 8: At least 75 per cent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.

Target 9: 70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge.

Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded.

Objective III: Plant diversity is used in a sustainable and equitable manner

Target 11: No species of wild flora endangered by international trade.

Target 12: All wild-harvested plant-based products sourced sustainably.

Target 13: Indigenous and local knowledge, innovations and practices associated with plant resources, maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.

Objective IV: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted

Target 14: The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes.

Objective V: The capacities and public engagement necessary to implement the Strategy have been developed

Target 15: The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy.

Target 16: Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy.

CASE STUDY 4.2

Botanic gardens hitting the targets: examples of GSPC actions

Kate Davis, Ottawa, Canada

The GSPC's success depends on local, national and international partnerships between many actors: botanic gardens, government agencies, non-governmental organisations and communities. Recent examples of botanic garden involvement include:

Target 1: The World Flora Online project involves botanic gardens worldwide in a growing consortium, spearheaded by the Missouri Botanical Garden, the New York Botanical Garden, the Royal Botanic Garden Edinburgh and Royal Botanic Gardens Kew. It is bringing together existing resources and collecting and generating new information to build an open access compendium of all known plants.

Target 8: The Millennium Seed Bank Partnership is the largest ex situ plant conservation programme in the world. Led by RBG Kew, it involves a network of partners including many botanic gardens in 80 countries, and aims to save 25% of species with bankable seeds by 2020.

Project Budburst. (Image: Carlye Calvin)

Targets 2, 7 and 8: The Zero-extinction Project, led by the Xishuangbanna Tropical Botanical Garden (XTBG) of the Chinese Academy of Sciences, addresses the loss and fragmentation of highly biodiverse forest in Xishuangbanna, and aims to reduce plant extinctions to zero over a five year period. After initial assessments, field surveys are checking the endangered and data-deficient species (T2) and identifying unprotected forest fragments of high conservation value to be recommended for addition to the protected area system (addressing T5 and T7). Seeds of endangered and vulnerable species will be collected for storage in the XTBG seed bank or grown in the living collections (T8).

Targets 3, 8, 14 and 16: The Phoenix-2014 Project involves 16 botanic gardens, seed banks and plant conservation centres in the Asociación Iberomacaronésica de Jardines Botánicos. It aims to develop protocols for the germination and cultivation of endangered and endemic species in Spain (T3), to optimise the timing for re-introduction to their natural habitats, to cultivate and exhibit selected species in botanic gardens (T8) and to develop plans for public awareness of these endangered species and the problem of biodiversity loss (T14). The project also builds partnerships in the national network (T16).

Target 4: The Ecological Restoration Alliance of Botanic Gardens brings together botanic gardens, arboreta and seed banks on six continents in a plan to restore damaged, degraded or destroyed ecosystems in biologically and culturally diverse contexts.

Targets 5 and 13: As part of the Micronesia Challenge, a regional conservation programme that aims to preserve the natural resources crucial to the survival of Pacific traditions, cultures and livelihoods, New York Botanical Garden scientists are collaborating with local researchers to document plants and their traditional uses, with the goal of identifying key habitats for conservation (addressing Target 5) and producing a checklist of vascular plants, an ethnobotanical manual, and a primary healthcare manual based on traditional plant medicines (T13).

Targets 14 and 16: Project Budburst, led by Chicago Botanic Garden and involving other botanic gardens as well as wildlife refuges, national parks and community partners (T16), is a network of people across the United States who monitor plants as the seasons change, engaging the public in the collection of plant phenological data (T14), to learn more about the responsiveness of species to climate change.

4.4.4 Invasive Alien Species (IAS)

The spread of alien, or non-native, invasive species is one of the most important drivers of biodiversity loss. The CBD (in Article 8(h)) determines that Parties should prevent the introduction of, and control or eradicate those alien species that threaten ecosystems, habitats or species. GSPC Target 10 and Aichi Biodiversity Target 9 call for effective management plans for invasive species. Many global and national organisations are tackling invasive species issues; cooperation between core international organisations (including CBD and CITES) is facilitated by the Inter-agency Liaison Group on Invasive Alien Species. A number of countries maintain lists of known invasive species, and there are also global information resources that can be used by botanic gardens to find out about invasive species, share information and develop partnerships, such as the Invasive Species Compendium, the Global Invasive Species Database and the Global Invasive Species Information Network.

4.4.5 Traditional Knowledge, Innovations and Practices (TK)

As biodiversity loss accelerates, traditional communities that have lived closely with, used and managed such resources for thousands of years are also under threat, as are the knowledge, innovations and practices (often abbreviated to 'TK') that they have developed. The CBD recognises that TK of indigenous and local communities relevant for the conservation and sustainable use of biodiversity should be respected, preserved and maintained with the approval and involvement of the holders (Article 8j). The GSPC's Target 13 emphasises the importance of TK for sustainable livelihoods, local food security and health care. Aichi Biodiversity Target 18 further points out that TK should be fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels. The Nagoya Protocol covers the sharing of benefits from utilisation of TK associated with genetic resources. The Tkarihwaié:ri Code of Ethical Conduct (SCBD, 2011a) was adopted in 2010 as a model to assist the development of codes of ethical conduct for research, access to, use, exchange and management of information concerning TK for conservation and sustainable use for different countries', communities' and stakeholders' circumstances. The code sets out general ethical principles (e.g. transparency, prior informed consent and/or approval and involvement, and benefit-sharing), specific considerations (e.g. recognition of community social structures, repatriation of information, and supporting communities' research initiatives) and methods (e.g. negotiations in good faith, participatory approach and reciprocity).

4.4.6 Botanic Gardens and the CBD

KEY MESSAGE

Botanic gardens can be the problem or the solution: accept and dispose of plants carefully, monitor collections for signs of invasiveness, and share information.

As with CITES, the CBD is of major relevance to the work:

Participation in the CBD process: Botanic gardens can participate actively in CBD meetings as government representatives or observers at COP, SBSTTA and other CBD meetings, and can potentially play a role as a National Focal Point for programmes such as the Global Strategy for Plant Conservation or the Global Taxonomy Initiative. Botanic garden personnel are included in the IPBES Task Forces and Expert Groups.

Global Strategy for Plant Conservation (GSPC): The GSPC provides the clearest framework for CBD implementation by botanic gardens, except for the complex issue of ABS (Section 4.5). Botanic gardens are at the forefront of implementing many of the GSPC targets, especially those on taxonomy, development of protocols for conservation and sustainable use, *ex situ* conservation, education and public awareness and capacity-building. Countries with botanic garden-based GSPC National Focal Points currently include Belgium, Brazil, Canada, China, Colombia, Finland, France, Honduras, Ireland and Russia. The

Tree nursery at Brackenhurst Botanic Garden, Kenya, part of a larger project to restore native trees in the Kenyan Highlands, addressing GSPC targets on ecological restoration, important areas of plant diversity and integrated in and ex situ conservation. (Image: BGCI)

Global Partnership for Plant Conservation (GPPC), which includes many botanic gardens, provides coordination to support international and national GSPC implementation. BGCI has produced a GSPC Toolkit that includes a simplified guide (Sharrock, 2011) and a website to provide updated information and resources for each target.

To take action on the GSPC, botanic gardens should:

- Find out about and participate in GSPC-related international and national network initiatives;
- Include GSPC targets in the botanic garden's institutional policy and use them to focus activities;
- Report progress to GSPC National Focal Points, BGCI and national botanic garden networks;
- Educate staff about the GSPC and encourage them to find opportunities to share knowledge and develop partnerships;
- Publicise the GSPC and CBD via displays and education.

Invasive species: Many invasive plants have been introduced as ornamental plants and therefore owe their introduction to botanic gardens and nurseries. Botanic gardens need to be aware of their responsibilities to prevent future invasions. Several codes of conduct have been developed by and for botanic gardens, for example the Invasive Plant Species Voluntary Code of Conduct for Botanic Gardens and Arboreta and the European Code of Conduct for Botanic Gardens on Invasive Alien Species.

To take action on invasive species, botanic gardens should:

- Find out about local/national/regional guidelines and policies;
- Address the issue in the institutional policy by endorsing a code and/or by setting out specific measures to be taken, e.g. avoiding known invasives, monitoring plants for signs of invasiveness, conducting risk assessments, disposing of unwanted plant material carefully, sharing information, educating visitors, and refraining from supplying invasive plants via plant sales or *Indices seminum* (Chapter 3, Section 3.4.3);
- Ensure all botanic garden staff are aware of the issues and problems posed by invasive plants.

Traditional knowledge: Botanic gardens can play a valuable role in raising awareness of TK and helping to promote and preserve TK, but must be mindful of their responsibilities to involve and acknowledge TK holders. Botanic gardens with ethnobotanical research programmes or that share information on traditional knowledge should work within relevant codes of conduct, community protocols and customary laws. The International Society of Ethnobiology's Code of Ethics is a useful tool for botanic gardens.

To operate responsibly and ethically with respect to TK, botanic gardens should:

- Find out about national and customary laws on TK and indigenous and local communities;
- Comply with relevant codes of practice and/or community protocols and the ethical principles of the Tkarihwaié:ri Code of Ethical Conduct;
- Conduct research and share information with the approval and involvement of communities;
- When working with TK already in the public domain, consider how to acknowledge and share benefits with the original knowledge-holders.

4.5 THE NAGOYA PROTOCOL ON ACCESS TO GENETIC RESOURCES AND THE FAIR AND EQUITABLE SHARING OF BENEFITS ARISING FROM THEIR UTILISATION

The Nagoya Protocol (SCBD, 2011b) is a treaty under the CBD that focuses on the implementation of the CBD's third objective, the fair and equitable sharing of benefits that arise from utilisation of genetic resources. It also covers traditional knowledge associated with genetic resources. The Protocol came into force on 12 October 2014. Its governing body is the Conference of the Parties serving as the meeting of the Parties to the Nagoya Protocol (COP-MOP).

4.5.1 Access and Benefit-Sharing (ABS) in the CBD and the Nagoya Protocol

KEY MESSAGE

The ABC of ABS: Access (to genetic resources), Benefit-sharing (from utilisation) and Compliance (with national laws).

The CBD's core provisions on access to genetic resources and benefit-sharing (ABS), which apply to post-CBD material (obtained after the CBD came into force on 29 December 1993), are that:

- Access is subject to the 'prior informed consent (PIC)' of the provider country (i.e., intended uses need to be declared up-front), unless the provider country determines otherwise;
- Access should be on 'mutually agreed terms (MAT)' (agreed between provider and user);
- Benefits from utilisation of genetic resources should be shared fairly and equitably with the provider country.

These provisions (set out in CBD Article 15) have been interpreted very differently by different countries. The voluntary Bonn Guidelines (SCBD, 2002) provide more detail but were felt to be too weak to ensure benefit-sharing; consequently, the legally-binding Nagoya Protocol was developed.

The Nagoya Protocol provides a detailed framework for ABS implementation, including new measures to ensure that users are complying with provider countries' laws and MAT. ABS obligations thus depend both on the laws of the countries providing genetic resources and on the laws of the countries where resources are utilised. Countries that require PIC must have clear and fair procedures for granting it, involving local communities where relevant. The Protocol also sets out requirements for users to gain PIC or the approval and involvement of the indigenous and local communities that hold traditional knowledge, to establish MAT with them and to share benefits with them. ABS National Focal Points provide ABS information to applicants and Competent National Authorities are responsible for granting access or providing evidence that access requirements were met; their details and other national ABS information are made available via the ABS Clearing House (ABS CH).

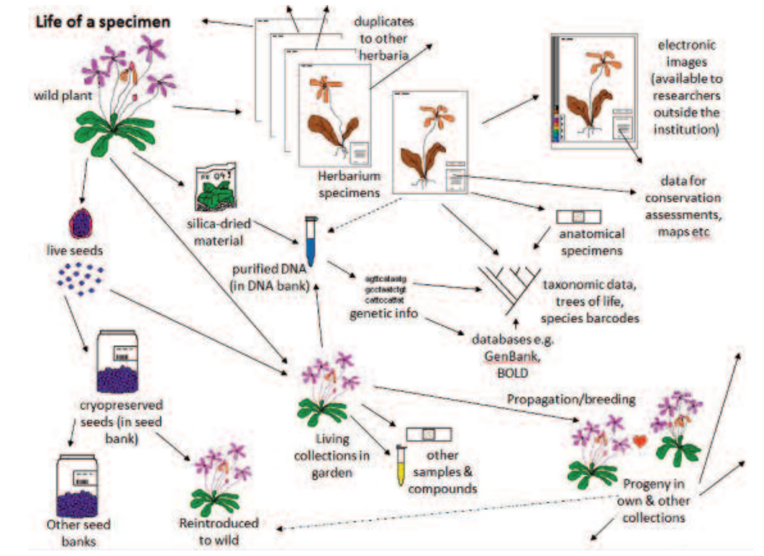
The Protocol defines 'utilisation' as research and development on the genetic and/or biochemical composition of genetic resources. Much non-commercial research (e.g. molecular systematics) is covered, though countries are meant to encourage such research, for example via simplified access measures. The Protocol requires the 'monitoring of the utilisation of genetic resources', with designated 'checkpoints' in each country to collect information to check that PIC has been obtained and MAT established (countries decide for themselves the nature of the checkpoints, e.g. patent offices, research funding agencies). Internationally recognised certificates of compliance (trackable permits with details of PIC and MAT) serve as evidence of compliance with provider country laws, and will be posted on the ABS CH. The Protocol encourages different sectors to develop voluntary measures such as 'guidelines and codes of conduct', and 'model contracts'; these will also be posted on the ABS CH.

4.5.2 Botanic Gardens and ABS

As users and providers of genetic resources, botanic gardens must be aware of their responsibilities and relevant laws when acquiring, using and providing plant material and associated traditional knowledge to other botanic gardens, academic and commercial sectors and the public – whether or not an institution is situated in a country that is a Party to the Nagoya Protocol. Botanic gardens collecting or requesting wild-collected plant material originally gathered on or after 29 December 1993 should have records demonstrating that the material was obtained according to the national laws or policies of the country providing the resource.

PIC, MAT and monitoring: For CBD and Nagoya Protocol compliance, botanic gardens need to obtain PIC (if required) and establish MAT with providers. Parties to the Protocol will be issuing internationally-recognised certificates to serve as evidence of users gaining PIC and establishing MAT, and their checkpoints will expect to see evidence of those certificates at later stages. Model agreements can be used to set out MAT (e.g. Biber-Klemm *et al.*, 2016). Post-Nagoya, botanic gardens will need to document exchanges and uses of material (Figure 4.1) – particularly

Figure 4.1 Life of a specimen



Life of a specimen: the 'chain of use' is not linear. Botanic gardens should keep information about the original provider and terms of use linked with material, however the material has been sampled and wherever it moves. (Image: Kate Davis)

'utilisation' of genetic resources – thoroughly, for example by using Material Transfer Agreements (Chapter 3, Section 3.6.1) to communicate terms and keeping links to any permits, agreements and internationally-recognised certificates. Increasingly, *ex situ* collections will be expected to use unique identifiers to assist in the tracking of genetic resources (e.g. IPEN numbers (Box 4.5)). Botanic gardens will need to ensure that their data management systems can handle ABS-related information (Chapter 5, Section 5.2). Some botanic gardens are depositing records with their ABS National Focal Point (NFP) of all their pre-Nagoya collections so that it will be clear in future which material is potentially outside the scope of the Protocol.

KEY MESSAGE

Don't pick without PIC and keep track of terms, materials, uses and benefit-sharing. A policy, data management system and staff training are key ABS tools.

Benefit-sharing: Botanic gardens can share a huge range of benefits, though many arise through partnerships rather than through actual utilisation of genetic resources. Possible benefits include: joint expeditions, collaborative research, sharing research results; sharing taxonomic and/or horticultural knowledge and resources; staff exchanges, training courses, workshops; sharing educational materials; technical support; donations of equipment; access to collections, databases and publications; sharing results with communities; helping to establish local gardens/microenterprises; and monetary benefits, e.g. direct financial contributions to partners, access fees, salaries, and royalties/licences in case of commercialisation projects. It is a good idea to document shared benefits (and report them to NFPs) to demonstrate commitment to the CBD's objectives and build trust with partners and their governments.

Box 4.5 ABS policy-building tools for botanic gardens

The Principles on ABS offer a one-page general framework to help botanical institutions develop a customised policy to cover all of their ABS-related activities. They can be used to cover living and preserved collections and non-commercial and commercial uses. They provide concise guidance on getting PIC from *in situ* conditions and *ex situ* collections; outline procedures for the use, exchange and supply of material, and responsibilities for benefit-sharing; and stress the importance of documentation for curation and tracking.

The International Plant Exchange Network (IPEN) provides a system to facilitate the exchange of living plants for non-commercial purposes. IPEN member botanic gardens sign and abide by the IPEN Code of Conduct, which sets out responsibilities for acquisition, maintenance and supply, and associated benefit-sharing. The first botanic garden to introduce an accession to IPEN keeps full documentation linking the accession to the original provider (PIC and MAT), and assigns an IPEN number, a unique identifier that encodes provider information and travels with the material. Transfers outside IPEN require an IPEN Material Transfer Agreement, and, for uses not covered by the Code of Conduct, new PIC from the country of origin.

The CETAF Code of Conduct and Best Practices is a post-Nagoya ABS tool developed by European museums and botanic gardens. It offers a Code of Conduct, based upon the Principles but comprehensively updated to assist compliance with the Nagoya Protocol. Several annexes provide more detail and support for the implementation of the Code: best practices, a statement on use of material (for institutions seeking PIC from providers), templates for material transfer agreements, and a glossary. This tool provides helpful guidance that is tailored to the needs of taxonomic research institutions but can also assist other institutional types.

A botanic garden's collection policy (Chapter 3) should reflect the ABS responsibilities that arise from the institution's living and preserved collections, its research and horticultural activities, and its partners. The policy should also indicate how pre-CBD (accessed before 29 December 1993) and pre-Nagoya (accessed before 12 October 2014) material will be handled. Though PIC may not have been required before the CBD, it is good practice to consider benefit-sharing for resources accessed pre- and post-CBD. Botanic gardens have developed several voluntary initiatives to guide ABS policy and practice (Box 4.5 and Case study 4.3). For basic ABS compliance, botanic gardens should:

- Find out about national ABS laws, procedures, authorities and relevant stakeholders in the botanic garden's country and in countries where it conducts work and, if traditional communities are involved, about relevant customary laws, codes of practice and community protocols;
- Address ABS in institutional policy (e.g. by using the policy frameworks referred to in Box 4.5);
- Always get appropriate PIC and MAT detailing how the material will be used back at the institution (never assume permits can be shared between institutions);

- Use written documents to record PIC and MAT (e.g. permits, benefit-sharing agreements, internationally-recognised certificates of compliance, Material Transfer Agreements);
- Use and transfer material only as those terms allow (new PIC may be needed if the original terms do not cover a new use or a different user);
- Train staff, associates and volunteers, and assign ABS responsibilities regarding how acquisitions and transfers will be handled;
- Share benefits;
- Keep track of terms and, as far as possible, use, transfer and benefit-sharing.

CASE STUDY 4.3

Compliance with CBD and ABS provisions – Royal Botanic Garden Edinburgh, United Kingdom

Kate Hughes and David Rae, Edinburgh, United Kingdom

The Royal Botanic Garden Edinburgh (RBGE) uses a range of tools to ensure that its extensive collections of living plants, herbarium specimens, DNA and pollen specimens are managed in compliance with the CBD.

Policy: RBGE's Collection Policy (Rae *et al.*, 2006), distributed to all staff, lays down the rules of engagement, regulations and procedures to be followed by all staff and associated workers, and states RBGE's commitment to comply with both the law and spirit of the CBD and GSPC. RBGE has endorsed the Principles on ABS and is a member of IPEN.

Agreements and permits: All wild collections are made and brought to the botanic garden with the appropriate permits. RBGE has Memoranda of Understanding with a number of overseas botanical and research institutes, typically including agreement to share collections, to provide and attend training sessions, to publish the outcomes of collaborations jointly and, importantly, to act within the CBD.

Database: All plant material is given a unique identifying number allocated by the centralised plant record system (BG-BASE software) on entry to the collection, whether herbarium, living or DNA material, and regulatory documents such as permits, phytosanitary certificates and plant passports are permanently linked to the relevant accessions in the database (which can also be used to record publications and studies generated from plants and samples). New herbarium specimens are barcoded but a backlog of non-barcoded historic material remains.

An example of benefit-sharing: Royal Botanic Garden Edinburgh staff demonstrating Rhododendron propagation at Cibodas Botanic Garden, Indonesia. (Image: BGCI)

Material Transfer Agreements (MTAs): RBGE publishes a catalogue online so that organisations and individuals can request plant material. A 'Conditions of use' form must be completed before material is released (RBGE, 2014a; 2014b). An IPEN number is generated for material destined for IPEN botanic gardens. The IPEN number and/or the Conditions of Use form serve as MTAs. The plant record system links these MTAs to accessions so that RBGE can keep track of all material which has been sent out. RBGE's shop only sells commercially available plants, not wild collected material.

Benefit-sharing: Benefits frequently result from years of inter-institutional staff collaboration. For example, an RBGE staff member is a professor at the University of Bogota, resulting in a number of Colombian PhD studies being completed in Edinburgh, supporting Colombian botanical research. RBGE also has long-standing working relationships with several botanical institutions in Chile, resulting in many Chilean collections at RBGE and extensive experience in cultivating Chilean species. In early 2014, collaborators in Chile sent spores of an endangered fern to RBGE to establish horticultural protocols for the species which can then be used in Chile. Similarly many Chilean individuals have travelled to Edinburgh to study the cultivation of Chilean and other flora with the prospect of applying this knowledge on their return.

Other benefit-sharing examples include joint expeditions, delivery of training workshops and courses, study visits to RBGE by partners, and the publishing and distribution of resources such as books, field guides and websites. Projects have also included the testing of ABS protocols for the commercialisation of selected plant species, covering issues of prior informed consent, monetary benefits and monitoring of material transfer from the provider country to the UK.

Rice farming in Ninh Binh, Vietnam. Oryza is one of the crops listed on Annex 1 of the ITPGRFA. (Image: Kate Davis)

4.6 THE INTERNATIONAL TREATY ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE (ITPGRFA)

The CBD is not the only international treaty to address ABS. The objectives of The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) of the Food and Agriculture Organisation of the United Nations are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of benefits arising out of their use, in harmony with the CBD, for sustainable agriculture and food security.

4.6.1 The Multilateral System

KEY MESSAGE

The Multilateral System facilitates access to certain crop species for conservation, research, breeding and training for food and agriculture only – not for other purposes.

The ITPGRFA was negotiated by the Commission on Plant Genetic Resources and came into effect in 2004. It establishes a 'Multilateral System (MS)' to facilitate the exchange of 64 food and forage crop species listed in its Annex 1 (crops that account for around 80% of human consumption). Parties to the Treaty may use the MS to access these materials in other Parties' gene banks in the public domain, for research, breeding and training for food and agriculture purposes only. Exchanges within the MS use the Treaty's 'Standard Material Transfer Agreement (SMTA)'. Users agree to share freely any new developments for further research, or, if they wish to restrict material derived from the MS (for example by using plant breeder's rights or a patent), they agree to pay a percentage of commercial benefits into a common Benefit-sharing Fund, for use by farmers in developing countries. Unlike the CBD, there is no distinction between pre- or post-ITPGRFA material: Parties are invited to include all Annex 1 material that is under their control and in the public domain. The ITPGRFA also encourages private collections and non-Parties to place Annex 1 material into the MS.

4.6.2 Botanic Gardens and the ITPGRFA

Botanic gardens, especially those with seed banks, need to know when plant exchange should use the ITPGRFA system rather than national CBD or Nagoya Protocol systems.

Botanic gardens should use the SMTA for exchanges of material (rather than another MTA) if:

- The material is from Annex 1; and
- It is requested for purposes related to food and agriculture, by a potential user in a Party to the Treaty; and
- The botanic garden is in a country that is Party to the Treaty, and its collections are considered to be in the public domain; or if it has agreed to include its Annex 1 materials in the MS.

The ITPGRFA promotes farmers' rights, and it provides for several different forms of benefit-sharing including information exchange, access to and transfer of technology, and capacity-building, as well as a funding strategy to help mobilise funds for small farmers. Botanic gardens are in an excellent position to educate the public on sustainable food production, and the conservation and use of crop wild relatives.

4.7 THE INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS (UPOV)

The International Union for the Protection of New Varieties of Plants (UPOV) is an intergovernmental organisation that provides a system of plant variety protection, 'breeder's rights', to encourage the development of new varieties of plants, for the benefit of society. UPOV was established by the International Convention for the Protection of New Varieties of Plants (the UPOV Convention). The UPOV Convention has been revised several times to reflect technological developments.

To be granted breeder's rights, a type of intellectual property right, a breeder needs to show that a variety (whether developed via conventional breeding or genetic modification) is novel, distinct, uniform and stable. When a variety is protected by a breeder's right, the breeder's authorisation is needed to propagate the variety for commercial purposes – for selling, marketing, importing and exporting, keeping stock of, and reproducing. In such cases, the breeder may require a licencing fee. Breeder's rights are granted for at least 20 years (25 years for tree or vine varieties). There are specific exceptions to this need for authorisation, such as use for experimental, private or non-commercial purposes.

Botanic gardens should be aware of any plants in their collections that are covered by breeder's rights so that they can comply with the terms on the plants.

4.8 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system. The treaty came into force in 1994. The UNFCCC contains no binding emissions limits and no enforcement mechanism; it provides a framework for the negotiation of subsidiary treaties such as the Kyoto Protocol, which came into force in 2005. The Kyoto Protocol commits its Parties to internationally binding greenhouse gas (GHG) emission reduction targets, measured against 1990 levels. It requires heavier reduction targets for developed countries, and specifies commitment periods for those reductions (for emissions during 2008-2012, and during 2013-2020). UNFCCC negotiations have produced the non-binding Copenhagen Accord (2009) and Cancun Agreements (2010, at COP-16), which do not commit countries to Kyoto targets or a 1990 baseline, instead allowing developed countries to pledge reductions and developing countries to plan reductions. In 2011 (at COP-17), countries committed to the Durban Platform for Enhanced Action, which set out a process for negotiation of a new universal agreement to deal with climate change beyond 2020. In 2015, at COP-21, the Paris Agreement was signed, which is an enduring, legally binding treaty containing emission reduction commitments from 187 countries, starting in 2020. The Paris Agreement will enter into force once 55 countries covering 55% of emissions have acceded to it.

4.8.1 Reducing Emissions from Deforestation and Forest Degradation (REDD) and REDD+

The Kyoto Protocol focuses on action by developed countries to reduce emissions. However, forests store some 50% of terrestrial carbon, and their destruction and degradation result in the second largest source of global GHG emissions. Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries is an effort to combat forest loss by providing incentives and rewards for reductions in deforestation. UNFCCC talks are gradually addressing REDD. The Cancun Agreements provide a preliminary REDD framework for developing countries. REDD was expanded in 2008 to REDD+, to include the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

The core elements of REDD+ were finalised and agreed to in 2013 and REDD+ is being developed and supported by many initiatives.

4.8.2 Botanic Gardens and Climate Change Action

Botanic gardens, as custodians of living plant diversity and as landscape managers, can play an increasingly critical role by working collaboratively and sharing their specialist expertise with local communities to mitigate and adapt to climate change. A botanic garden's policy may indicate how the institution will engage in climate change issues and actions, including what measures it will take to reduce carbon emissions from its own operations.

Botanic gardens can contribute significantly to REDD+ projects, for example by:

- Informing site selection at project planning stages by providing detailed species-level data;
- Identifying local livelihood issues in proposed sites and promoting wide stakeholder consultation;
- Conducting baseline biodiversity and carbon surveys, and carrying out forest monitoring;
- Sharing skills in forest survey and mapping techniques, species identification and taxonomy, forest management, climate modelling, and working with local communities;
- Sharing species selection knowledge, seed supply and propagation protocols for afforestation programmes;
- Carrying out phenological studies to monitor the impacts of climate change on plant behaviour.

Botanic gardens can also contribute their technical expertise, propagation and seed banking facilities and collections to assist communities to respond to and adapt to climate change-related landscape and food crises (Case study 4.4). More information on REDD+ and botanic garden participation is available from Probert *et al*. (2011), which includes a REDD+ checklist; (also see BGCI, 2012).

Natural forest giving way to tea plantations, Kenya. (Image: Barney Wilczak)

CASE STUDY 4.4

Collaborative seed production for a drought-stricken community, Project Semillatón – Jardín Botánico IB UNAM, Mexico

Robert Bye and Edelmira Linares, Mexico

Due to the exceptional drought that occurred in 2011 and 2012 in Chihuahua, the Rarámuri (Tarahumara) Indians faced a scarcity of native maize seeds for the 2013 planting cycle and subsequent food shortages. The Botanical Garden of the Institute of Biology, UNAM (Mexico) responded to the Rarámuri community's request for assistance in the conservation of their maize races. With financial support from the Mexican 'Gastronomic Family' administered through Foundation UNAM, the UNAM Botanical Garden initiated a conservation programme bringing together local NGOs (e.g. Rakema, agricultural producers) with government organisations (e.g. INIFAP-SAGARPA and CONANP-SEMARNAT). All parties share a commitment to the conservation of local food crop resources through increasing the supply of local seeds for subsequent sowing and supporting their in situ conservation.

The project's objectives were: (i) to multiply seeds of five races of native maize from the Sierra Tarahumara that had seriously diminished; (ii) to distribute these seeds to indigenous farmers and key mestizos of the Sierra Tarahumara for planting; (iii) to encourage seed conservation in community seed banks so that this seed could be used to replenish supplies in case of future crop failures; and (iv) to train key community members on rainwater harvesting and soil improvement.

Seeds of six races of native maize were obtained in collaboration with local NGOs and key farmers, and suitable land was rented. In 2012, 11 ha were planted with five land races. In 2013, a further 8 ha were planted with two of the previous land races plus a scarce, culturally valued land race. To ensure the purity of the land races, corn cobs were hand-harvested from the center of each plot and distributed directly to the beneficiary farmers. Ears from the marginal rows (subjected to pollination by outside pollen) were de-grained and distributed to communities in exchange for community service. INIFAP (National Institute of Agricultural and Livestock Research of Mexico) supervised the initial planting, while CONANP (National Commission of Protected Natural Areas) of the SEMARNAT (Secretariat of Environment and Natural Resources) distributed the multiplied seed to the communities in need.

In 2013, the maize seed was distributed to 54 dispersed communities located in five counties in western Chihuahua. 561 farmers (200 women and 361 men) received maize seed for planting and a further 2,234 people benefited indirectly. This resulted in 20,870 kg of seed being sown across an estimated 1,739 ha. UNAM Botanical Garden also conducted capacity-building workshops for the Rarámuri community on: creation, implementation and management of family and community seed banks; rainwater harvest; intensified cultivation of quelites (edible native green vegetables); and conservation techniques for native maize and quelites.

The project's success was influenced by factors such as: the rapid detection of the problem (due to regular contact between the botanic garden personnel and the collaborating communities); the efficiency, transparency and integrity of Foundation UNAM in administering the donations; timely multiplication of seed; respect for traditional values; use of traditional practices where feasible; distribution and delivery through traditional social organisation; acceptance of seed for planting because of its local origin; financing by Mexico's Gastronomic Family (Cultura Culinaria AC, Slow Food Mexico, Conservatorio de la Cultura Gastronómica de México, independent chefs and cooks, as well as the general public); and the integration of government agencies with specific actions at critical steps.

Three of the six maize races multiplied by Project Semillatón: 'maíz azul', which is preferred to prepared kobisi (pinole) and remeke (tortilla); 'cristalino amarillo, used for several purposes; and 'apachito', highly valued because of its precocity. (Image: Robert Bye)

The spikes and cane above the ears of the maize plants are removed after pollination and subsequently used as forage, while the mature maize ears are hand-harvested traditionally by the Rarámuri. (Image: Edelmira Linares)

4.9 AGENDA 21

4.9.1 A Plan for Sustainable Development

Agenda 21 is a comprehensive action plan for sustainable development into the 21st century, providing the basis for a global partnership to encourage cooperation at international, national, regional and local levels. It was adopted by 178 governments at UNCED in 1992. Unlike the Rio Conventions, it is a non-binding statement of intent rather than a treaty. Governments are responsible for Agenda 21 implementation through national strategies, plans, policies and procedures, but broad public participation and NGO involvement are critical. Agenda 21's 40 chapters, in four sections, each set out a programme area with four parts: the basis for action, objectives, activities and means of implementation. Chapter 28 on local authorities' initiatives in support of Agenda 21 has led to many local authorities consulting their communities and preparing a 'Local Agenda 21', based on local priorities.

4.9.2 Botanic Gardens and Agenda 21

Botanic gardens can substantially contribute to Agenda 21 and Local Agenda 21 in many of the same ways that they can help to implement other sustainability initiatives, such as the CBD. Regarding social and economic dimensions (Agenda 21's Section I), botanic gardens can help to provide opportunities for community enterprises, to combat poverty and contribute to economic development; for example, by helping to develop non-timber forest products, medicinal crops, or floricultural techniques. Botanic gardens also attract tourists, and can raise public awareness of development and trade issues and promote fair trade initiatives. Botanic gardens can contribute to conservation and resource management (Section II) initiatives, for example by working with local partners to manage and restore natural and protected areas and to support sustainable tourism, and also by supporting equitable and sustainable use of biodiversity. Botanic gardens can also help to strengthen the role of major groups such as women, children, indigenous people, NGOs and the scientific community (Section III) via community projects and by providing a conduit and location for debates and communication. Botanic gardens also offer many means of implementation for sustainable development (Section IV), including environmental education programmes and training.

Botanic gardens can support Agenda 21 and other sustainability initiatives by:

- Finding out about, supporting and encouraging implementation of their government's national and local sustainable development policies;
- Developing an institutional policy on sustainable development, covering sustainable horticultural practices, low-impact resource use and equitable sourcing;
- Supporting the needs and interests of visitors and the local community;
- Collaborating with local partners to address plant conservation and sustainable living;
- Sharing materials and expertise in networks and participating in international partnerships.

For many practical examples showing how botanic gardens are contributing to Agenda 21, and a detailed checklist, see Anon., 1999.

Engaging visitors at the 'Wall of hopes' in the Bioenergy Garden, Xishuangbanna Tropical Botanical Garden (XTBG), showing various seeds of species with bioenergy potential in heart-shaped glass bottles. (Image: XTBG)

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Part C: The Plant Collection – Linchpin of the Botanic Garden

Chapter 5: Collection Record Management Systems

Part C: The Plant Collection – Linchpin of the Botanic Garden

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CHAPTER 5: COLLECTION RECORD MANAGEMENT SYSTEMS

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Nura Abdul Karim, Singapore Botanic Gardens

5.0 DEFINITIONS

Accession: Plant material (individual or group) of a single taxon and propagule type with identical or closely similar parentage acquired from one source at the same time.

Accession number: For tracking purposes, an accession is catalogued and assigned a unique identifier (number or code) associated with additional information.

Acquisition: Plant material prior to being accepted into the plant collection and catalogued as an accession. The term can also denote the process of gathering plant material before its incorporation into the plant holdings of the botanic garden.

Asset codes: Codes in the form of barcodes or Quick Respond (QR) codes which link electronically an item (asset) to a master record that provides further information about the item (for ease of tracking, reporting and data selection throughout a record system).

Batch number: A sequential reference number assigned to a group of samples of the same or a different taxon, received from one source at the same time.

Collection number: A unique sequential reference number that is assigned to a plant specimen/sample by the plant collector for the purpose of cross-referencing source information.

De-accessioning: The process of removal of all or part of the accession from the botanic garden, while related plant information is retained in the database.

Plant records: A suite of collection policies, databases, maps and other related files that document the plant holdings of the botanic garden.

Provenance: The original source of the plant material. The term is used both to denote a location (wild population or nursery-grown) and a concept (wild-collected or cultivated stock).

Qualifier: Qualifier in the form of a digit, letter or other data symbol is used as an extension of the accession number to distinguish a batch of the same taxon from the same source.

Serial number: A sequential series of numbers given to a batch of plants received at the same time.

Taxon (pl. taxa): A group of plants that form a botanically named unit, including all their components, e.g. *Fagus sylvatica, F. sylvatica* 'Aspleniifolia', *F. sylvatica* Atropurpurea Group, *F. sylvatica* f. *purpurea, F. sylvatica* var. *purpurea* and *F. sylvatica* 'Purpurea Tricolor' are six taxa of the same species.

5.1 INTRODUCTION

The historical significance of an object in the collection lies not in itself alone but also in the information relating to it.
Carl E. Guthe (1964)

> **KEY MESSAGE**
> Documentation should be systematised and structured to be useful since data that are randomly organised and stored – as accurate and noteworthy they may be – are of limited value if the information cannot be traced, extracted and updated.

The defining feature of a botanic garden is the management of its documented collections of living plants. The documentation process normally involves a record system whereby each acquisition of a taxon that enters the botanic garden is provided with a unique identification, i.e. an accession number (Section 5.4.1). This number links the plant material to various data and information. Each botanic garden has documentation needs that are specific to its vision and mission (Chapter 1, Section 1.2.4) and collection policy (Chapter 3), upon which the plant holdings and programmes of the institution are built. The development of a documentation process that captures all required data is a challenging task as there is no one model that fits every botanic garden's needs and resources. However, whatever the individual information needs, there is a basic structure that is useful for most institutions.

This chapter presents generic guidance for the establishment of standardised documentation systems and related methods and technology in use in botanic gardens. Each acquisition of a taxon should come with relevant information which should be kept securely for future reference and use. Gathering and documenting the important and vital details pertaining to the acquisitions that will become part of the collections, should never be done retrospectively as information may prove irretrievable at a later stage. As the collections grow in size and scope, so too do the related volume and detail of information.

Management decisions for tracking, analysing, planning and assessing the significance and quality of the collections are dependent on the available, documented information. Randomly organised and stored data, no matter how accurate and noteworthy, is ineffective unless the documentation is systematised, i.e. it should have a structure to be useful. Keeping information on collections is not a random exercise and requires well-thought-out prioritisation and foresight, as well as an in-depth understanding of the workings of the institution.

Regular and rigorous data collection, tracking, updating and maintenance are also needed to ensure that documented information is current. It cannot be overemphasised that well-documented collections give added value and distinguish botanic gardens from institutions such as public parks or display gardens.

5.2 THE COLLECTION RECORD MANAGEMENT SYSTEM: THE BOTANIC GARDEN'S WORKING MEMORY

KEY MESSAGE

A botanic garden's collection record management system is closely linked to the collection policy of the institution, and is a fundamental tool for the development, management and review of the plant holdings.

A collection record management system comprises the mechanisms and processes of collecting, recording, tracking and producing relevant information or data for the effective and efficient curation and utilisation of the botanic garden collections (Box 5.1). This system is an important and evolving resource, and, built over time, becomes the institution's working memory. This is a legacy that will outlast any staff member, team or project, and is an essential element of an institution's future strategic decisions.

The development of a suitable collection record management system is closely linked to the botanic garden's collection policy, which is the common thread that informs and guides the development, management and review of the plant holdings (Chapter 3). Usually a subset of the collection policy, the plant records management procedure prescribes acquisition and documentation standards to ensure core data are captured and retained (Section 5.4). It will also detail de-accessioning and disposal standards, as well as the requirement of regular inventory checks to ensure that the living collection information is updated and current.

With the establishment of international, multilateral agreements including CITES, CBD or the Nagoya Protocol (Chapter 4), a growing number of botanic gardens ensure that their collections are properly documented and tracked. This includes obtaining all relevant legal agreements and permits on the acquisition and use of the plant material, as well as their entry and maintenance in the collection record management system. Although it is best-practice to devise a collection policy at the inception of a new botanic garden (Chapter 1, Section 1.7), this is often not the case. Such an instance is the Singapore Botanic Gardens which had procedures for managing its plant records in place since 1996, prior to drafting its collection policy in 2010.

Box 5.1 Key values of a collection record management system

- **Care and control of collections** by providing information that helps locate plants, manage internal movements, undertake inventories and respond to audits. This improves security and reduces the risk of loss or possible invasiveness of collections, assists in maintaining details of conservation, and ensures that uses are in accordance with any agreements attached to the collection. Documented data will enhance the management of *ex situ* collections as well as of *in situ* conservation/restoration projects over time, and forms a basis for evaluating conservation success or failure.

- **Facilitating the use of collections** by supporting publications, collection interpretations, educational programmes, material for research, and display development. The collection records will therefore need to be accessible to staff, researchers and visitors for specific uses. Exchange of records among botanic gardens and with other interested organisations can be facilitated with a good collection record management system. Botanic gardens with documented data of their collections and facilities, may utilise this information in future management decisions, for instance to address climate change. Collections' records can be of added value for conservation and restoration work if propagation protocols are recorded for the species grown.

- **Preserving information** about plants in the collections for future planning. Long-term availability of information is an overarching aim of a collection record management system.

5.3 CORE COMPONENTS OF A COLLECTION RECORD MANAGEMENT SYSTEM

To be effective, a system does not have to be complex. In fact, the system should be as simple as the complexity of the collection allows. Karol A. Schmiegel (1988)

Two main elements are essential to a collection record management system: Defining what is required versus what is optional information, and identifying what file management system (be it manual or digital) is appropriate to hold and process an institution's information needs within its available means.

It is critical that all required core information of the collections is available and complete (Chapter 3), and that optional but relevant data is also accessible when necessary. The collection record management system requires an in-depth analysis pertaining to the scope of the plant holdings against the number of staff and resources available. These elements will affect the amount of detail selected for the system to handle, which must contain standards for format, terminology and continuity (Hohn, 2004).

The file management platform is the building block of the record system. The scope of the system will require comprehensive documentation including registration, cataloguing, indexing, information retrieval and collections' control data. The documentation system is driven by inputs and therefore it should facilitate organising these in a way that supports the botanic garden's objectives and provide meaningful outputs. This is best accomplished by involving botanic garden staff in the design, development, implementation and maintenance of the system using manual and/or automated means. A system's success depends upon the accurate and efficient recording and retrieval of information that has been reliably keyed and connected to the plants in the collections (Sawyers, 1989). The information must be easily retrievable, interpreted, sorted, and reorganized. In short, a curator should be able to find information on the plant holdings simply and easily, and feel confident that they are all documented and that all documentation also includes records of collections that no longer exist at the botanic garden.

Some botanic gardens may be well-advised to start with the fundamentals of a record management system, and begin documentation at a general level of detail to become more specific and extended over time as their capacity increases. Others may find it more practical and suitable to build a comprehensive system from the outset (Hohn, 2004). While striving to capture as much detail as possible may be desirable, this can lead to incomplete documentation, for instance due to inconsistency in providing information or lack of time to follow-through in collecting and documenting the data for each accession in the collection.

Figure 5.1 Screenshot of a section of the accession register in BG-BASE software from Singapore Botanic Gardens (Section 5.5.2)

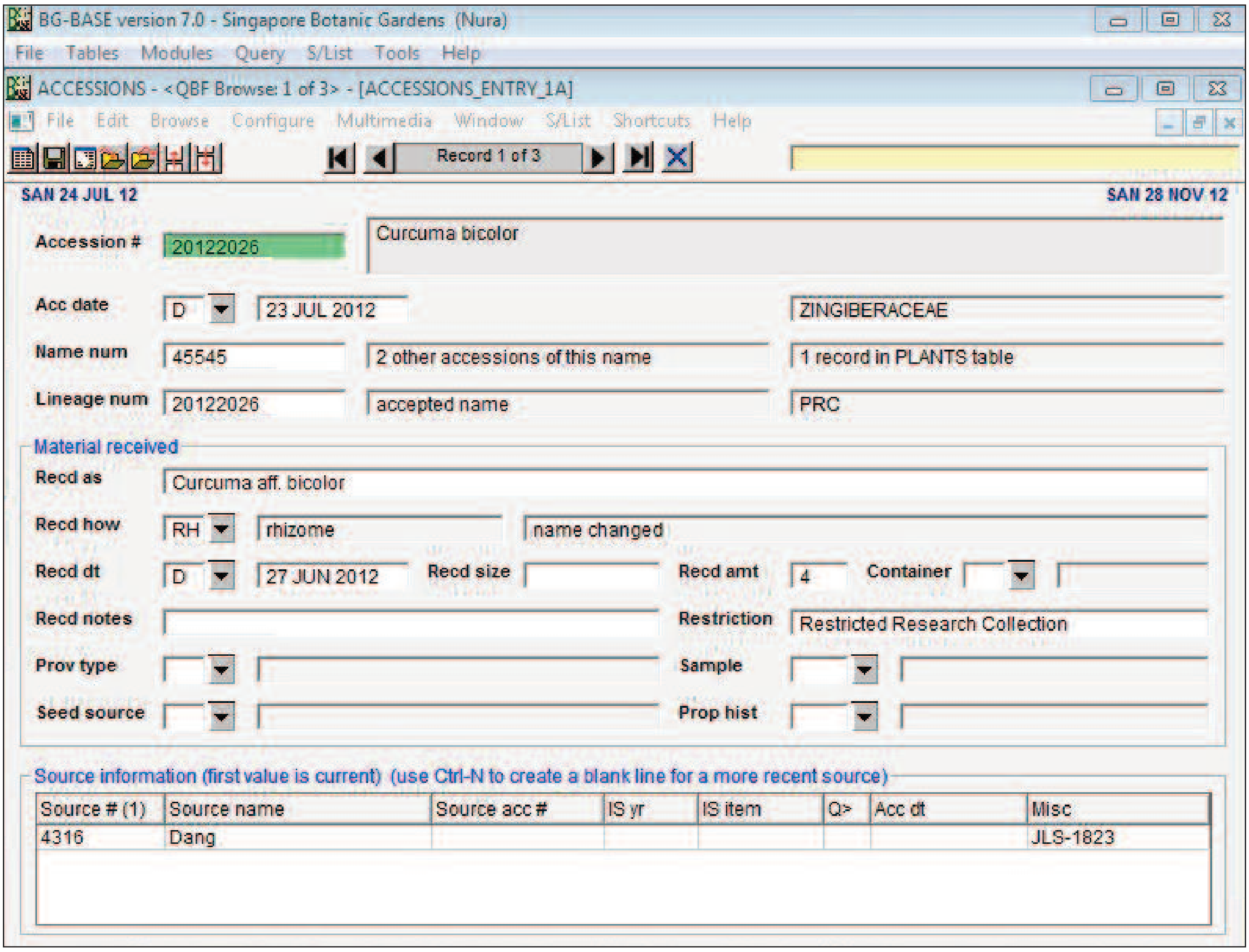
5.4 PROCEDURES AND DOCUMENTATION REQUIREMENTS OF A COLLECTION RECORD MANAGEMENT SYSTEM

It is important to monitor the plants from the moment they arrive in the botanic garden and to maintain the records even after the plant has died, been lost, given away or discarded. The curatorial staff should structure entry procedures and protocols. These need to take into account the background decisions which must be made to serve the documentation requirements of new and existing plant material. This is achieved through accessioning, de-accessioning, labelling and mapping and continuous monitoring. To keep consistent records and maintain the link between the records and plants, accessioning, labelling and mapping procedures should be streamlined and integrated with clear procedures.

5.4.1 Accessioning

KEY MESSAGE

An accession entering the collection is assigned a unique number for tracking. This reference will stay with the plant material and its supporting documentation, and is never deleted, transferred or reassigned to another plant.



Accessioning is the registration process by which a plant acquisition (Chapter 3, Section 3.4) becomes a permanent part of the collection, and more precisely a part of the records, i.e. an 'accession'. An accession is defined as 'plant material (individual or group) of a single taxon and propagule type with identical or closely similar parentage acquired from one source at the same time'. It will be assigned a unique number for tracking purposes. The accessioning process is the beginning of an inventory of the botanic garden collection. Many botanic gardens will simply enter all acquisitions in an accession register regardless of the plant's status, intended use, or the predicted length of stay within the collections. This approach creates a more consistent and simplified documentation process and reduces the chances of samples not being captured in the record system. It also means that every accession will have some documented history within the institution however brief its stay in the collection.

The accession register is a permanent, official record of all the plant holdings of the botanic garden, documented in sequential order by accession number (Figure 5.1). Additional documents and information, such as propagation and cultivation data, phenological observations, Material Transfer Agreements (Chapter 3, Section 3.6.1), permits, etc. are also part of the register.

Primary data usually captured for plant material entering into the botanic garden includes:

- **Accession number**

At the accession stage, all the information about the origin of the plant material is recorded. Each individual or group of identical-parentage will have to be assigned a unique accession or inventory number. This reference will stay with the plant material and its supporting documentation once it enters into the collection and is never deleted, transferred or reassigned to another plant (Box 5.2).

It should be noted that for wild-collected taxa, a single accession will be regarded as one that had been collected from one site by the same collector on the same date. Subsequent collections of the same taxon from the same collection site should be regarded as a new accession (Leadlay and Greene, 1998).

A botanic garden should never practise giving all plant material in the one incoming batch (which may contain several species) the same accession number (effectively becoming a batch number). Occasionally, an accession does consist of a mixed collection in which case it should be re-accessioned as soon as this has been recognised, while the individual taxa contained within the accession will need to be assigned different numbers.

The accession number should not be re-used if the plants die or are given away. Similarly, it should not be changed intentionally during the life-time of the plant. Generally, it is however advisable to assign a new reference number to a plant that has been propagated from the original accession. This is particularly true for propagation using seeds. They may be the product of hybridisation and a new accession number will help to monitor whether hybridization has occurred. In particular, individual specimens of trees and other long-lived plants raised from one accession (e.g. seed collection or cuttings) should be given separate accession numbers for ease of monitoring and documenting.

Botanic gardens will encounter plants in their collections that have lost their accession labels. Data from the last inventory check should help to relink the unlabelled plants to their earlier records, provided the plant species and location are matching, as well as the physical plant size and related records in the database are reasonably congruent. In situations where any unlabelled plants remain unaccounted for ensuing the inventory check as well as following interviews with staff on the site's planting history, the process of 're-accessioning' will follow. This means that plant material without a label that can no longer be linked to available database records is provided with a new accession number.

Box 5.2 Accession number types

Botanic gardens use varying forms of accession numbers with digits and letters. The simplest is a running serial number (e.g. 1,2,3,4...), but this is not widely employed as its management may become challenging if there are a great many accessions, in addition to conveying very little information. The longer a number, the easier errors can occur in transcription, etc.

A more common system is to incorporate the last two digits of the year when the accession was received, followed by a 4- or 5-character running number, e.g. 982460, i.e. the 2460th accession added to the collection during 1998. This system is simple, but is tricky for older botanic gardens as, for instance, there is no distinction possible for collections received in 1898 and 1998. Institutions that initiate an accessioning system are well-advised to include the full 4-digit year. Botanic gardens currently using only 2-digits to indicate the year, should consider switching to a 4-digit as of January 1st of any particular year. For example, if the institution used the 4-digit year followed by a sequential number increment, the accession number 20140100 will read as the plant material recorded in 2014 and received as the 100th accession in that year.

Some botanic gardens use more complex systems usually involving up to 12 characters including letters and signs as well as numbers, e.g. 107 2014 2460 (107=batch number, 2014=year, 2460=serial number) or 2014 W 2460 (2014=year, W=origin of material, 2460=serial number). If a botanic garden has decided to use signs for accession numbers in its written ledgers/accession reports, a decision must be made early to include these or otherwise in the computerised version. Consistency will be vital for retrieval purposes.

Further, it should be noted, that a group of clones or members of a line may be given the same accession number indicative of their genetic similarity. Propagules of a taxon are most often assigned and share a single accession number as a batch. Each successfully grown propagule from the respective batch may then be distinguished with qualifiers such as a digit, letter or other data symbol extension of the accession number. For instance, a batch of ten seeds of *Dipterocarpus tempehes* collected in August 2005 in the MacRitchie Reservoir, Singapore, was given the accession number 20050717, representing the seven hundred and seventeenth (717th) accession added to the garden in that year. Whenever individual plants are raised from this seed batch, they are given the same accession number but different alphabet qualifiers to distinguish them: 20050717*A / 20050717*B / 20050717*C / 20050717*D, etc. The addition of such qualifiers to each progeny resulting from this seed collection allows their tracking as part of the same accession number.

In instances where the database records show that the unlabelled plant material of the same taxon could originate from different sources, a new accession number should be assigned, labelling the source as 'mixed' with indication of the old accession numbers that may be involved. Latter should be noted as inactive with reference to the new, mixed-source accession thereby keeping the inventory process up-to-date. Often, unlabelled plants may be an indication of either lapses in following protocols to properly update records, or unauthorised additions by staff or the public.

- **Identification and verification of the name**

If the accession does not have a name, it should be identified as soon as possible. At a practical level, a temporary name may be assigned giving its family and/or generic affinities, for example, Myrtaceae (family) aff. (related to (affine)) *Eugenia* (genus). This will help to distinguish the plant or accession in the botanic garden and help communication.

Not all plant material that comes into the botanic garden is correctly named or identified, even after it has been accessioned and studied. Verification is a procedure for checking that a previous identification is correct, or for assigning a name to an unnamed accession (Box 5.3).

The information relating to the identity of a plant requires agreement amongst botanic garden staff on what taxonomic system of classification is followed within the institution. It should be decided by all staff in the horticulture and research branches what system is to be adopted consistently throughout the record process. This determines questions such as which plant families are to be recognised and which genera belong to which family, as well as which genera are to be accepted. Any ambiguity in the use of the names must be resolved to prevent the plants of the same taxon being recorded in the same system under two or more different names. Taxonomic classification systems have evolved over time. Earlier systems such as those by Bentham and Hooker, Engler, Cronquist, Dahlgren, etc. have been superseded by the Angiosperm Phylogeny Group (APG) Classification System which employs molecular technology. APG I was the first version of a modern, mostly molecular-based system of plant taxonomy published in 1998. It has been superseded by revisions in 2003, 2009 and 2016 – APG II, APG III and APG IV, respectively.

There are online databases that try to resolve the dilemma of accepted names of the world's flora and utilise the APG classification system. For instance, these include The Plant List and the World Checklist of Selected Plant Families for verification of current names and spelling.

- **Source of the plant material**

An essential part of accessioning is recording the source of the plant material received. This should be elaborated with information on the origin or provenance of the material (Chapter 3, Section 3.4.3). The more information available about the origin and history of the accession, the more value the accession will have for research and conservation. Equally, information obtained on material of wild or cultivated origin is useful for reference and other purposes. Source information on plant material which had been collected directly from the wild will help users assess the variability of the taxon in the natural environment, and is vitally important for conservation purposes.

Box 5.3 Verification of names

Checking and verifying names involves two separate procedures:

(i) Identification – which is the determination of a plant as being identical with or similar to a particular taxon. This procedure uses taxonomic experts, taxonomic reference books such as floras and monographs and other scientific materials such as accurately named herbarium voucher specimens or living plants that had previously been correctly determined by the taxonomist.

(ii) Nomenclature – which is concerned with the determination of the correct scientific name of a known plant according to a nomenclature system. This naming is regulated by internationally accepted rules laid down in the International Code of Nomenclature for algae, fungi, and plants and the International Code of Nomenclature for Cultivated Plants.

Thus this procedure establishes that the name is:

(i) the current and preferred one (and correctly spelt) under the rules of nomenclature and;
(ii) the appropriate one to be assigned under the system of classification used in the botanic garden.

Source: Leadlay and Greene (1998)

An accessioned specimen with inadequate source or provenance information can be considered for de-accessioning should related plant material with more comprehensive documentation on its origin become available. An exception to this is when a botanic garden is maintaining a special collection of cultivars, or when limited or no wild material remains, as in the case of very rare or highly threatened taxa.

Source information should include (see also Chapter 3, Section 3.4.3):

- From whom it was obtained: information on wild collected plant material should include collector's name, collection number and date of collection. Likewise, for cultivated plant material, information should be provided as to the nursery's or donor's name, date of receipt and address;
- Whether it is of wild source or not: if from the wild, where it was collected from (i.e. locality, habitat and collection details); similar information for cultivated plants, would help to track the original source of the parent material (e.g. country), but this may not be available from many nurseries;
- Details of compliance with international treaties and Material Transfer Agreements (Chapter 3, Section 3.6.1; Chapter 4, Sections 4.5.2 and 4.6.1): such agreements must be recorded and linked to the accession as part of the source for future reference and utilisation of the plant material and its progenies.

It is essential that the details of the source of the material be added and stored in the plant collection record system at the time of accessioning as this information will be challenging to retrieve at a later stage.

- **Propagation, cultivation and other biological data**

It is very valuable to record the propagation and cultivation methods used and results obtained including the conditions under which plant material has been established in the botanic garden (Figure 5.2). These details are vital for conservation and for restoration purposes *in situ*.

Information about plant growth development, flowering and fruiting, i.e. plant phenology, etc. derived from regular observations of the plants in cultivation should be recorded as well. It is also important to register pests and diseases (Chapter 6, Sections 6.4 and 6.8) during cultivation and the response to adverse environmental factors such as extreme climatic conditions. These data are critical to ensure due maintenance and monitoring of each accession.

Staff of the Ethiopian Biodiversity Institute discussing the importance of maintaining accurate propagation records. (Image: BGCI)

Figure 5.2 Screenshot of a propagation report generated by a bespoke record management system tailored to the institutional needs of Jardín Botánico Carlos Thays, Buenos Aires, Argentina

Tareas de Propagación

Id. : 000603 Técnicos: 018_König, Maximiano
015_Barreiro, Graciela

Guardar
Nuevo
Copia y Nuevo

Ing. Principal: 000006283
Prosopis caldenia
Legado : 09/12/2015 - Banco Nacional de Germoplasma de Pros / Rec.:Comandante Granville San Luis Argentina
Semilla
Cantidad en Origen:20

Ing. Complementario:

[7]

Objetivo : Proyecto Klorane
Fecha Inicio : 01/12/2015
Borrar

Ver Ejemplares
Método : Semilla
Impresión Etiqueta
Renglón para Imprimir Fecha : 0
Obs:
0 Fin

Reng	Fecha	Item	Descripción
001	10/12/2015	Sustrato	Bertinat
002	10/12/2015	Posición	Tunel plastico
003	10/12/2015	Trat. Pre-Siembra	Escarificación con papel de lija
004	10/12/2015	Siembra	20 semillas a 1 semilla por celda
005	14/12/2015	Germinación	11 semillas germinadas
006	28/12/2015	Germinación	14 germinadas
007	11/01/2016	Observación	16 semillas germinadas, 10 con hojas verdaderas. Sin caer los cotiledones.
008	20/01/2016	Observación	Se ubicaron fuera del tunel
009	02/02/2016	Manejo	fumigados con glacoxan Dsist. 4cm3 x litro.
010	05/02/2016	Trasplante	6 a maceta nº 12, con perlita.
011	26/02/2016	Observación	2 ind vivos
012	15/03/2016	Observación	1 ind vivo con hojas verdaderas de h 6 cm
013	05/04/2016	Observación	sin novedad
014	10/05/2016	Observación	Individuo de 7 cm con hojas verdaderas creciendo con normalidad
015	06/06/2016	Observación	sin novedad
016	06/07/2016	Observación	El ind presenta caida de casi todas lus hojas, no se encuentra en buen estado.

Des. : 255 máximo de caracteres
Fecha : 30/12/1899
Item :
Última Impresión : 18/07/2016 14:53:23
Salir

Jardín Botánico Carlos Thays | Usuario:[fc] | Creado:24/08/2016 10:05:29 - fc | Modif:24/08/2016 10:05:29 - fc

- **Use of the plant material**

Information may be stored regarding an accession's use in research projects, pharmaceutical screening, DNA typification, plant breeding, etc. or whether the plant material had been provided to and or received by other botanic gardens and institutions. In this context, it is important to note and record whether plant material held is subject to any legally binding international, regional or national regulations, laws and agreements (Chapters 3 and 4).

- **Integration of different collection types**

As part of each living accession's documentation, herbarium vouchers (Chapter 7, Section 7.1.3) should be prepared whenever possible. These can be important to verify the identification at a later date or if name changes occur as the result of a revised taxonomy; this highlights the value of integration of different collection types. Besides herbarium specimens, a botanic garden may also assemble seed, pollen, carpological, DNA or spirit collections. These should be recorded and documented in the database in accordance with the institution's plant collection record system.

The record system a botanic garden creates or purchases off-the-shelf (Section 5.5.2), can either be specific to the living plant collection or have a wider recording capability to include non-living collections and further accessory collections such as herbarium specimens, photographs, botanical artworks, publications and artefacts.

5.4.2 Labelling

Having accessioned the material, it is very important to keep the link between accession record and the plant in the collection by means of labels. Each plant or batch of plants should have a label at all times on which the accession number and name are clearly shown. The accession number and name are the key to unlock the information about the plant.

The basic standard information displayed on a permanent plant label would normally include the following information about the accession:

1. Plant family name;
2. Accepted scientific name of the species;
3. Common name(s);
4. Distribution range or origin;
5. Accession number as recorded in the institution's database.

If a plant's identity remains to be botanically verified, this should be indicated on the label. Before fabrication of accession labels, the following should be considered:

- The label must contain the accession number in readable form.
- The label material is reasonably durable and does not deteriorate rapidly.
- Labels are adjustable and/or removable and do not harm the plant.
- The placement of the label is consistent, for example, placing the labels on trees at eye-level.
- The method of attachment and placement deters as much as possible label-plant separation.

In collections where there are many plants together or on public display, it is good practice to include a second label either buried in the ground or at the bottom of the pot (inside), so that if a label is stolen, lost or switched, the plants' data are nevertheless securely linked to the accession.

Plant labels may be made from laminated paper, engraved plastics and metals, laser-engraved metals, embossed metals, photo-sensitive metal coatings and other types of materials (see also Chapter 7, Section 7.3.8).

Plant label categories

a. **Temporary label:** This is the first label attached to the plant material when it arrives at the botanic garden to ensure the sample can be located once the accession is assigned and the primary label (see below) is fabricated. This label is also utilised during a general inventory check on the collection, and any plant material missing any form of label is tentatively identified and tagged temporarily, while awaiting accessioning and fabrication of primary and/or permanent labels.

Examples of temporary labels. Singapore Botanic Gardens. (Images: Nura Abdul Karim)

b. **Primary label:** This label is usually fabricated immediately after the plant material received has been reported and accessioned. It is normally used in the nursery. This type of label will include the accession number as a bare minimum, or may include the scientific name and family of the material or even barcodes if the institution utilises such asset codes (see below).

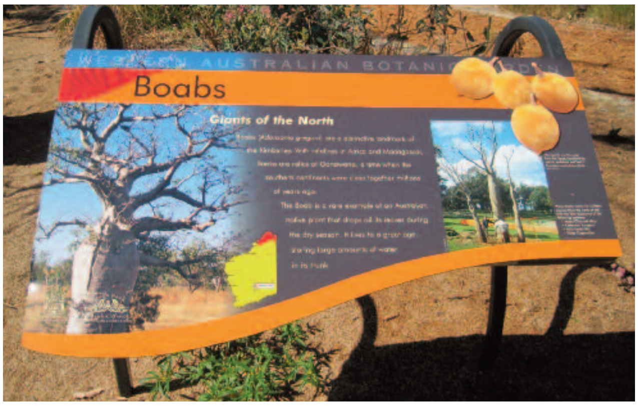
Examples of primary labels. Bali Botanic Gardens, Indonesia (top) and Singapore Botanic Gardens (above). (Images: Nura Abdul Karim)

c. **Secondary/Permanent label:** This label is fabricated for permanence when the material is planted out in the botanic garden. Secondary/permanent labels also serve as a brief informative feature to identify the plant material on display to visitors.

Examples of permanent labels. Bali Botanic Gardens, Indonesia (top); Bonn Botanic Garden, Germany (left); and Singapore Botanic Gardens (right). (Images: BGCI and Nura Abdul Karim)

Examples of permanent labels used over the last century in Stellenbosch University Botanical Garden, South Africa. The printed, brown labels with barcodes incorporated (far left) are the labels currently in use, followed by older, engraved plastic, porcelain and aluminium labels. (Image: Martin Smit)

d. **Interpretative label:** An interpretative sign or label generally serves as an educational tool. It is designed to inform the visitors by providing and highlighting interesting facts about the plant species or the whole thematic collection.



Interpretive sign. Kings Park & Botanic Garden, Australia (Image: Annette Patzelt)

Interpretive sign. Yachay Botanic Garden, Ecuador. (Image: Joachim Gratzfeld)

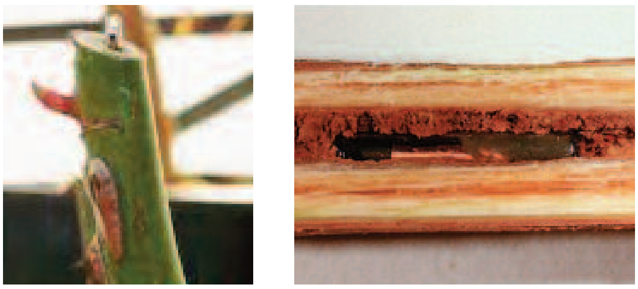
e. **Labels with bar code and QR code:** In addition to the standard information as described above, botanic gardens are increasingly placing asset tracking features, i.e. asset codes, on their accession labels, such as bar codes and Quick Response (QR) codes to augment and facilitate their automated documentation processes. These asset codes are linked to the institution's central database. Bar codes and QR codes allow for rapid, more accurate, consistent and direct collection of inventory, evaluation and other types of field data. These coded features can be read with handheld data loggers/scanners or even portable computers such as iPads and tablets that utilise downloadable scanning applications connected to the computerised database software. Transcription and other types of manual data recording errors are reduced with the utilisation of such new technology. Bar codes or QR codes can be fixed or engraved to accession labels if the fabric is weatherproof and UV resistant.

This asset code system is commonly in use in herbaria, such as the Western Australia Herbarium, the Royal Botanic Gardens Kew Herbarium, the Royal Botanic Garden Edinburgh Herbarium and the Singapore Herbarium. Equally, various botanic gardens have incorporated barcodes in to their nursery plant labels linked to their database systems, allowing rapid inventory checks and updates by staff and/or volunteers.

Extensive plant data can be linked to these asset codes thus serving as a new form of information collection and dissemination. Labels incorporated with such asset tracking features are increasingly employed by botanic gardens, and visitors can download suitable apps with appropriate scanning software to their personal mobile devices such as smartphones, tablets and iPads to read this special label information. This technology is fast evolving and is revolutionising the style of collection interpretation for educational outreach to the botanic garden visitor.

Label with QR code. Chadwick Arboretum & Learning Gardens, United States. (Image: Chadwick Arboretum & Learning Gardens)

f. **Radio Frequency Identification chips:** Building on the growing popularity of asset tracking systems, methods for the potential use of Radio Frequency Identification (RFID) microchips are being developed to find ways to streamline and improve the permanent collections' inventory and labelling process. RFID electronic chips used for instance in tracking live animals, is one of the technological advances with the promise of application for outdoor plant inventory checks. If RFID chips could be successfully imbedded into the plant tissue, the need to tie accession labels to the plant would belong to the past. However, besides the high cost of microchip production, there are numerous technological hurdles for application of RFID to plant-life, including detecting and reading these microchips inside plant tissues with high water content. What is more, the lifespan of microchips may be limited if they are not designed with an internal power source and/or are not recharged before depletion of the energy.



RFID chip implanted in a rose (left) and grapevine (right) and used in trials for certifying stock, monitoring pests and mapping. (Images: Associazione Toscana Costitutori Viticoli)

5.4.3 Mapping

Maps are visual representations of records and spatial information (Rakow and Lee, 2011). They include points, lines and shapes with possible enhancement such as colours, pop-ups, or animated graphics. As such, maps are a simple and clear communication tool. They are only effective and meaningful once the basic inventory needs of the collection are met. Accurate inventories are therefore critical to the mapping process. Mapping should either be carried out concurrently with or following on from the inventory process, but should never be undertaken in place of the inventory process. Increasingly, mapping is becoming an important aspect of collection management. Maps document the exact locations of accessioned plants in the botanic garden, and serve as an important safety net and backup when display labels and accession tags are inadvertently or deliberately removed or vandalised (Box 5.4).

A map of the botanic garden allows the collections' locations to be coded and mapped with coordinates to specify the position of each plant. Such maps presenting the location of individual or groups of plants are often prepared as part of the development of a new botanic garden, but are also useful if they are created once in operation. Maps are digitised for future manipulation and use such as updating and monitoring of mapped items over time.

If the preparation of a proper base map is not possible in the early stages of the development of a botanic garden, the institution may wish to divide its grounds into manageable sized areas or create a grid system. Each area/grid may be given codes which are linked to the accessions located in that particular area (Figure 5.3). This list of accessions at each coded location should be maintained if a map with coordinates of the plant position is unavailable. Once a suitable digital mapping programme has been established, the digital maps linked to the core records of the collection will become very useful to internal and external users.

Box 5.4 Main roles of a good map

- Maps provide clarity and ease of comprehension for the user. A plant location point or shape on a scaled map is unambiguous. In comparison, representing a location accurately with words is impractical.
- Maps can show change over time. Text and tables cannot capture and display changes very well over time and related charts may therefore have to be created.
- Maps can raise questions and encourage thorough analysis regarding the development and management of the collections. For example, patterns where plants thrive or fail can be discerned easily, and planning or designing landscapes and facilities can be carried out efficiently based on topography and hydrology maps, etc.
- Maps can be visually attractive. People enjoy looking at and contemplating information that is presented in an interesting and attractive manner. Maps can connect the collection to new audiences and their needs. They can raise the use of the institution and its collections and allow new correlations and links.
- Maps can also display useful non-plant information such as the location of utilities (e.g. water and gas pipes), artworks, interpretation signs and memorial seating.

Source: Adapted from Rakow and Lee (2011)

Figure 5.3 Map of Singapore Botanic Gardens showing coded areas linked to accessions

5.4.4 Stocktaking and Monitoring

Regular stocktaking or inventory checks should be undertaken to ensure that the accessioned collections are traceable and tracked particularly for audit purposes (Chapter 3, Section 3.7). Stocktaking is a check that the plant and its label are still present. It will encourage staff to look for and check every accession on a regular basis, and may lead to recording of additional data such as flowering and fruiting times. This can be achieved by using special index cards or specified forms, which are supplied to those responsible for the day-to-day care of the plants for annotating as necessary. Cards or forms are returned to the records office and used for updating the database. In this way botanic garden staff can help with stocktaking and updating without necessarily needing special knowledge of the software system utilised. However, if direct collating via a digital format is preferred and staff or volunteers who are computer-savvy are available, then such records can be captured digitally via handheld devices linked to the database. The curator should oversee the amount and quality of feedback from the collections. All records should be dated and initialled, i.e. the reference of the responsible staff is indicated (Leadlay and Greene, 1998).

5.4.5 De-accessioning

In the strictest sense, de-accessioning is the process of amending the records of plants removed from the botanic garden, but not the actual disposal of the record (Chapter 3, Section 3.6.3). Accessions may be removed if, for example, research or conservation priorities change, or for aesthetic or health reasons. Other grounds for de-accessioning may include the availability of new plant material with greater vigour or if current accessions are proving to be invasive. The related plant record should note the specific reason why the material was felt to be inappropriate or is no longer required by the botanic garden.

In summary, a plant is de-accessioned if it is:

- Dead, and no seed or clone is remaining;
- No longer relevant to the objectives of the botanic garden;
- Missing;
- Very toxic or dangerous in other ways, for instance a diseased plant that is likely to infect other accessions;
- A potential weed or an invasive.

However, it is critical to maintain the record on a de-accessioned plant, as this information may prove relevant in the future and could answer questions such as:

- Why it died;
- Whether it was given away or stolen;
- Who the recipient organisation was;
- Where more stock can be obtained if needed;
- Whether it had been propagated in the botanic garden.

It is worth mentioning cases where plants which were thought to be dead or missing from the collection were in fact overlooked, dormant or mislabelled. Following through with a proper process of de-accessioning will allow this to be rectified by restoring the accession along with its linked information, as the record as such had not been removed or deleted.

All potential de-accessions other than truly dead samples should be reviewed by the relevant botanic garden staff before the actual de-accessioning. Dead or diseased plants are normally de-accessioned at the discretion of the curator or collection manager. When adequate provenance information is not available for a particular taxon, de-accessioning is usually recommended; however, it is again at the discretion of the collection manager to make the final decision as some rare and endangered species which are not known to be cultivated elsewhere, may need to be retained regardless of the lack of information on the plants' origin to prevent potential extinction.

5.5 RECORD SYSTEM TOOLS AND SOFTWARE

5.5.1 Tools for Recording Collections

There are three alternative/complementary methods of holding accession data:

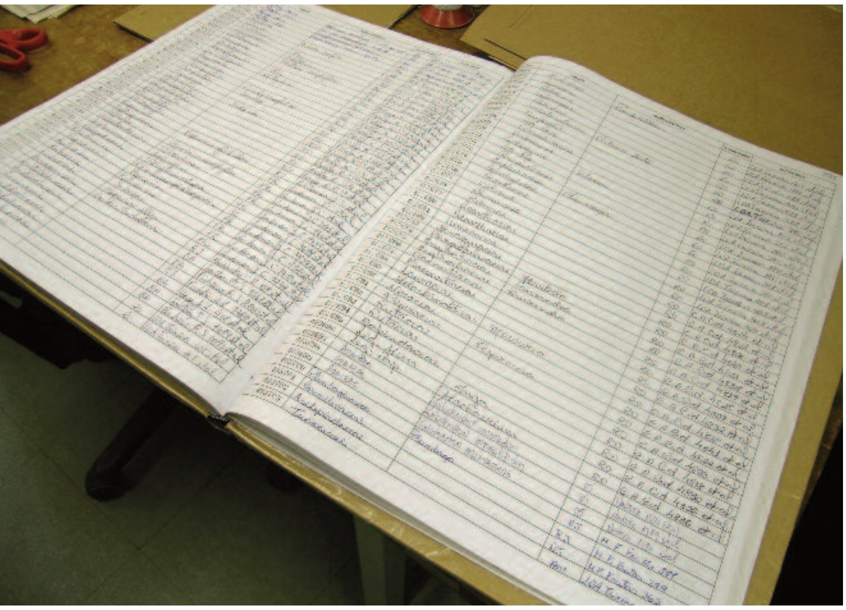
- Ledger/notebook;
- Index card or sheets kept in a loose-leaf folder;
- Computerisation (e.g. computer database).

While ledger, notebooks and index cards are earlier forms of archiving information, the digitisation of botanic garden collection data has seen major developments in recent years. Contemporary computerised record database systems are interconnected with mapping capabilities, and can be accessed via the internet or as internal standalone systems of the botanic garden. Ultimately though, it is the specific needs and available resources of the institution that influence the selection of a particular data recording system. The importance of collection management lies not so much in the method of storage but in capturing and recording all pertinent data required for the curation and use of the plant material.

Essential accession information, including accession number, name, date of accession, propagule type, source and location can be recorded in a ledger/notebook. However, the space for adding more information about the accession is usually very limited. Further, if a botanic garden has many taxa, searching through the ledger manually for a specific plant will take time and sorting this information can turn out to be very difficult. As such, it is recommended that the ledger is used to store only the initial information known about an accession when it was received. Further notes, such as transfer history, disease and pest problems etc. can be recorded on a card. An alternative is to record each accession on a card which can be indexed and filed under the plant name and accession number, or on paper forms which can be filed in ring binders or filing cabinets instead of using ledgers.

The design of an index card depends on its intended use, for instance for:

- Accessioning new material (in the absence of a computerized system);
- Collecting data from existing collections/labels/ledgers etc. for input to an existing or projected computerized system;
- Collecting data from the various departments of the botanic garden for updating a central database;
- Processing taxonomic reference data for labelling, etc.



Ledger book of Rio de Janeiro Botanic Garden. (Image: Kate Davis)

In a smaller botanic garden with less than 1,000 living plant holdings, records could be kept and maintained using paper or index cards. However, if the collection size increases, maintaining and managing records becomes much more complex and difficult to master with index cards. Nevertheless, this method will always remain a cheap and convenient way of compiling and consulting records – and can always be used as the input source for a computer database.

Computerisation provides many advantages in the management of the records. Data may be held in the following ways:

- Word processing documents;
- Spread sheets;
- Relational databases.

Opting for relational databases to store and process collection data in computers is highly advisable. If records are held in this way, specific fields may be linked with each other, which will enhance the sorting of the information in an almost infinite variety of ways. Holding data in Word processing documents and in spread sheets limits the sorting capacity of the computer system. However, the use of Word processing and spreadsheet software to store collection data is still acceptable for smaller scale botanic gardens with few staff trained in database management.

Making the transition from a card- or paper-based system to a computerized system, or upgrading from one computer system to another, can be costly. This includes not only the initial capital costs of the equipment and software but expenditure for continued maintenance and staff training. Ultimately, the advantages generally outweigh the disadvantages by a considerable margin.

Once digitised, the information can be used not only for the curation of the collections, but to provide fast access to all parts of the data, to re-sort entries and/or automatically produce reports or labels. In this way, a multitude of forms of information can be produced, such as catalogues of plants in cultivation, seed lists and inventories of plants belonging to a taxonomic group or growing in a particular area of the botanic garden. Further, links to computerized mapping systems can be established, and serve as an educational and interpretative tool by means of public-access terminals or websites to the database.

5.5.2 Software Types

KEY MESSAGE

Given the often substantial investment needed to purchase, maintain and update a collection record management system, the selection of the appropriate software packages requires both diligence and foresight, let alone long-term commitment by the botanic garden to support the system.

Many commercial database software packages are available at a reasonable cost. In addition, commercially provided systems generally include an initial and annual technical support package and staff training, installation assistance, availability of upgrades and compatibility with other devices such as handheld scanners, tablets, iPads or notebooks. Some may have a high initial purchase cost but in the long run the benefits of an appropriately selected system will outweigh the expenditure.

Computer mapping for botanic gardens is becoming rapidly and readily available, and is expected to evolve into a standard part of collection record systems in the future. Botanic gardens should therefore consider the advantages of linking the database with maps in terms of added value and more efficiency in managing collections. Botanic gardens with good map and database links are able to develop customised online search engines for plants of interest, including their location and images, and monitor the horti- and arboricultural management of the collections. Examples of such customised online search engines developed by botanic gardens are the Longwood Gardens Plant Explorer and the Purdue Arboretum Explorer. These allow the plant collection and facilities information to be shared with ease, as well as assist staff and visitors to navigate and locate plants or places of interest without difficulty (Case study 5.1).

CASE STUDY 5.1

Living Collections Data Management at Longwood Gardens, United States

Kristina Aguilar, Kennett Square, Pennsylvania

The original plant records system at Longwood Gardens, Pennsylvania, USA, dated back to 1955. As with all early systems, it relied on card files and accession log books, but as technology evolved, so did the plant records system. It grew from an early off-site mainframe system, to an in-house, custom-made Microsoft Access database, to the current server-based commercial databases, BG-BASE and BG-Map.

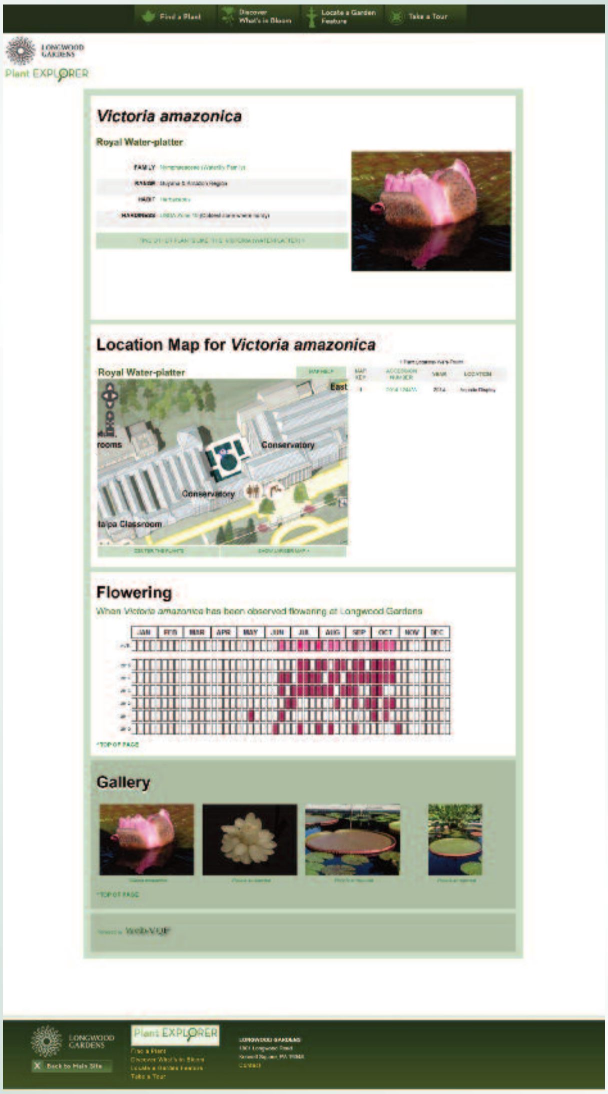
When BG-BASE was acquired in 2006, the database had little descriptive plant information and no images. A team of trained volunteers was assembled to research and enter such data and take digital images. Students doing a one-month rotation in the Plant Records office would also gather cultural and inventory information while learning about plant records management and databases. Early electronic field data collection was accomplished using personal digital assistants or pocket PCs to record bloom dates and inventory information. As technology evolved and mobile devices and wireless networks became more sophisticated, Longwood Gardens commissioned the development of an app in 2011. This app allows staff, students and volunteers to record data from the living collections, which are then sent through the wireless network to the plant records database server and uploaded into BG-BASE. Thousands of bloom dates are captured each year using this app.

Electronic plant mapping began with the implementation of BG-Map in 2005, building on Longwood Gardens existing early-1960s grid system for manually locating outdoor accessions on a map. Today, the precise location of trees and shrubs in the living collections, as well as the location of herbarium specimens, is recorded using a centimetre-level accurate GPS system. As a part of the Plant Records Management intern's yearly project, students learn to map new woody plant accessions coming into Longwood Gardens each year. These GPS coordinates are uploaded into BG-Map and can be searched, queried and displayed on an AutoCAD base map of the property.

As early as the 1980s, Longwood Gardens sought to utilize the plant records system to share horticultural information with visitors by disseminating accessioning, cultural and plant characteristic data. This idea of making plant records available to the public was behind the development of the Longwood Gardens Plant Explorer online plant collection database, launched in 2010. It combines data, maps and images from BG-BASE, BG-Map and Longwood Gardens' digital asset management system through both a public and a staff interface. The latter allows staff to print inventories, review accession records, and report changes to the Plant Records office via e-mail. Plant Explorer also links the information in the plant records system with Longwood Gardens' Continuing Education Program and the Garden Highlights section of the main website, unifying plant nomenclature across the organisation.

As a way of further connecting the public with Longwood Gardens' varied collections, Staff Recommended Tours were written to supplement plant records data in Plant Explorer. Each tour has a theme and introduction, followed by a list of plants that support the theme. For one of the most popular tours, Longwood Gardens' Champion Trees, QR codes linking directly to Plant Explorer were developed and placed outdoors next to each plant for visitors to scan.

Longwood Gardens will continue to utilize technology to make plant records a centralized part of its working culture. The convenience and flexibility of a web-based plant records system that can be viewed from any computer, tablet or smart phone has enabled staff to capture types of information never before recorded in a plant records database at Longwood Gardens, including tree health assessments, disaster priority codes, soil and tissue test results, integrated pest management records and seasonal plant display locations. The result is a knowledge-rich database that allows staff to make informed decisions regarding the plant collection and facilitates the sharing of our intellectual capital with the world.



Screenshot of Longwood Gardens Plant Explorer online search engine.

Botanic gardens may choose to purchase off-the-shelf software or create their own bespoke relational databases with programmes such as MySQL or Microsoft Access. Development of bespoke systems, however, is a time consuming exercise and will require specialist programmers and financial resources. The ease and high standards of commercial software have persuaded many botanic gardens to purchase 'ready to use' database software packages and customise these for their own use.

Examples of some of the most widely used (but by no means limited to these) commercial database software packages include:

- **BG-RECORDER**

BG-RECORDER counts among the earliest plant record management software packages. Developed by Botanic Gardens Conservation International (BGCI) at the beginning of the 1990s, it provides a Microsoft Access template to help botanic gardens manage their botanical collections. Compatible with the International Transfer Format (Box 5.5), BG-RECORDER 2000, is offered free of charge to BGCI members.

- **BG-BASE (bg-base.com)**

BG-BASE is a database application written primarily to handle the information management needs of institutions and individuals holding living and/or preserved collections of biological material. The system was first developed at the Arnold Arboretum of Harvard University in 1985 and has since been installed in over 200 institutions around the world. The application facilitates basic inventory control, but also enables users to fully document, label and curate their collections in six broad categories, while following all relevant international data standards:

1. Collection management (living collections, herbarium and museum collections, seed banks, DNA repositories, etc.);

2. Taxonomy/nomenclature (any level from kingdom to sub-form, cultivar, cultivar group, etc.);

3. Distribution (from global to exact latitude/longitude);

4. Bibliography (books, journals, unpublished references, images);

5. Conservation (threats, conservation status, protected areas, laws and conventions, etc.);

6. Management and administration (addresses, institutional affiliations, education programmes, etc.).

The modular design of the system provides a seamless interface to all data, instead of having to use separate database systems for each area. The modules include:

- Living Collections module (includes image, propagation, and seed bank management;
- Preserved Collections module (herbaria management);
- Conservation module;
- Web / HTML Export module;
- SQL / ArcGIS Connector module;
- BG-Capture module (mobile data collection).

Each module is further customizable, with the user having the ability to (amongst others):

- Turn fields on and off;
- Make fields required or skipped;
- Provide default values for commonly entered data;
- Configure user defined, institution specific fields;
- Create language specific help files;
- Generate bespoke drop-down lists.

Web module users form part of a 'virtual collection' shared with other BG-BASE sites around the world. End users can then search for help in multiple locations through a single Web search form.

Extensive reporting capabilities exist via canned reports, a menu driven Report Wizard, or via a direct command line interface.

For linkage of digital maps to BG-BASE data, BG-Map and Esri ArcGIS are available to meet the mapping needs of the botanic garden. These software programmes also allow the recording of botanic garden ground data via handheld equipment to be uploaded to the central BG-BASE database (Case study 5.2):

- **BG-Map (bg-map.com):** Mapping of accessions from BG-BASE (via AutoCAD software) and updating of inventory via handheld portable devices e.g. ipads or Android mobiles, can be carried out in conjunction with BG-Map. BG-Map is a mapping software that links directly to BG-BASE without the need for exporting or importing, and with the optional Web interface, users can access a wealth of information about a botanic garden and its collections, including maps and images.

- **Esri ArcGIS (esri.com/software/arcgis):** Mapping can also be carried out via ArcGIS. The ArcGIS Connector Module of BG-BASE facilitates the synchronization of relevant BG-BASE data with the high-end mapping software ArcGIS.

The software is neither open source nor free of charge, and includes an annual technical support fee.

Morris Arboretum, United States, map display showing tree location and canopy sizes created by BG-Map software that utilises the data recorded in BG-BASE. (Image: BG-Map)

CASE STUDY 5.2

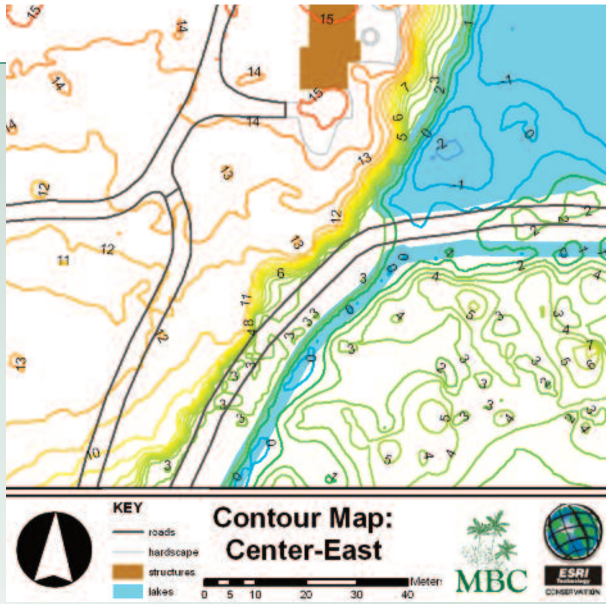
Living Collections Data Management at Montgomery Botanical Center, United States

Erica Witcher, Miami, Florida

Montgomery Botanical Center (MBC) is a non-profit botanic garden established in 1959 in Coral Gables, Florida, USA. With more than 26,000 plants in the nursery and grounds representing more than 1,300 taxa, the majority of which are from wild-collected seed, accurate and meticulously-maintained records and maps are an integral part of MBC's mission of 'advancing research, conservation, and education through scientific plant collections.'

The population-based, documented collections emphasize palms, cycads and tropical conifers, which together comprise 85% of the total holdings. The plants' habits allow them to be planted out, mapped, numbered, and labelled as individual specimens, an ideal situation for conducting research. To achieve this, MBC uses BG-BASE for its plant records in tandem with Esri's ArcGIS software platform for maps and analysis. As seeds arrive from expeditions, they are accessioned into the nursery with relevant collection and habitat information added to the database. All data pertinent to their germination and initial growth are recorded in separate tables. As they reach a more mature stage and are planted out, data related to their planting is likewise recorded and entered into another table. The latter contains years of additional notes relating to the phenology and life events (and death, if it occurs) of the plant. Each plant's record is accessed by its unique 8-digit accession number with letter qualifier (e.g. 20110123*A). This accession number is listed on the label attached to the plant, along with species name, family name, provenance and sex (in the case of cycads); all plants in the grounds collection have a permanent label. Because each plant is a separate entity with a unique identifier, each label is likewise unique.

MBC's maps were originally in CAD format oriented on a local coordinate system. This served the needs of staff for many years, but in 2008 a software grant from Esri and a monetary grant from the Stanley Smith Horticultural Trust allowed for the purchase of a Trimble GeoXH professional-grade GPS unit and the creation of georeferenced maps. Known points from within the CAD layers were marked in the field with the GPS unit as precisely as possible. The CAD layers were then imported into the ArcGIS ArcMap program and georeferenced one at a time based on these points, including utilities and annotation layers (digital notes and labels corresponding to layer features). Once georeferenced, the MBC property could be viewed as part of the surrounding landscape, with a definite location. Publicly available and free remote-sensing data, such as aerial ortho-photographs and lidar-derived digital elevation models, were easily downloaded and added to maps, adding new methods of analysis and ways to view the property. Staff were able to identify the tallest and broadest trees, create an elevation map with delineated contours to highlight key low spots on the property, and project phenology and experiment data on to maps for research, all in highly customized displays. Volunteers and interns without intimate knowledge of the collections and plant locations could assist with routine field actions such as label replacement and the annual inventory, while visitors and



Contour map portion of Montgomery Botanical Center created with Esri ArcGIS by utilising data from BG-BASE.

researchers could be quickly directed to plants of interest, because such information could be easily shown in printed maps designed for their particular use.

An ArcGIS connector module provides a linkage between BG-BASE and ArcGIS mapping software. SQL and XML are used to facilitate the synchronization of geo-referenced data between the two systems. Synchronization intervals are controlled by a user-defined scheduler, which may be configured to run every few minutes or longer.

MBC maintains its mapping work within the ArcMap environment without the use of BG-BASE ArcGIS connector module. To project data stored in the database, the database is first queried, then exported into an Excel spreadsheet. The accession numbers associated with each record serve as unique identifiers to link the information to the map table coordinates, and thus onto the map. This same linking can be done for virtually any data, as long as it is tabulated in a spreadsheet. The process, however, is unidirectional. Map location information (such as area code, quadrant number, or date of GPS survey) must be entered manually into the database. Similarly, when plants die or are transplanted or have a change in epithet, their information must be updated in both the database and the map table.

It is worth noting that, in addition to the digital linking of data between database and maps via Excel spreadsheets, the conveyance of all other information between nursery and grounds staff to the database and map staff is done with color-coded paper forms, so data entry and editing remains controlled by limiting write-access to only a few people. This not only ensures consistency in coding, querying, and terminology within the database records and map files, but also provides an instinctive visual organisation of handwritten data, accessible to all staff regardless of technological literacy, as well as a hardcopy backup in case of input errors.

How data is organized and accessed directly impacts how it is used and gathered by staff in the grounds and nursery, and the reverse is also true. Technology that facilitates this relationship has a very influential role to play in any botanic garden.

- **IrisBG (irisbg.com)**

IrisBG is a relational database application able to handle the information management needs of institutions and individuals holding living and/or preserved botanical collections. The software has been in development since 1996 and is regularly improved and updated based on feedback from the user community. IrisBG offers complete information management and covers these main areas:

1. Collection management (living and herbarium collections, seed banks, plant history, tasks, plant inspections, botanic garden tours, assets, botanic garden maps, etc.);
2. Taxonomy and nomenclature (formalized recording of all taxonomic levels, hybrids, synonyms, authors, references, etc.);
3. Localities and collectors (origin of plant material, coordinates and map support, etc.);
4. Literature and web references (books, journals, electronic documents, web links, etc.);
5. Maps (multiple map types, internet and custom map providers, plant origin and botanic garden location);
6. Images (integrated image handling with support for external image libraries);
7. Contacts (institutions, donors, nurseries, etc.);
8. Reports and labels (flexible report and label production, multiple file formats);
9. Data exports and imports (BGCI PlantSearch and Darwin Core export, import from spreadsheets, etc.);
10. Multi-lingual support (data entry in several languages, all writing systems supported);
11. Internet publishing (share collection information with visitors, web solution for smartphones, tablets and PC with multi-lingual support);
12. Seed exchange (seed store, *Index seminum* web solution, International Plant Exchange Network (IPEN)).

IrisBG is compatible with international data standards and the data can either be hosted on a local SQL database or used with a cloud database service. Data quality is ensured through data validation, referential integrity and access control. In addition to using PC and laptops, data can also be recorded on a portable device or be loaded onto the system via spreadsheets using the data import feature. Software licences can be purchased in a wide range of combinations, including a configuration where multiple gardens can share one database installation. The software is not open source and therefore not free of charge, and includes an annual technical support fee. The system is regularly updated and enhanced, based on user input.

- **BRAHMS (herbaria.plants.ox.ac.uk/bol)**

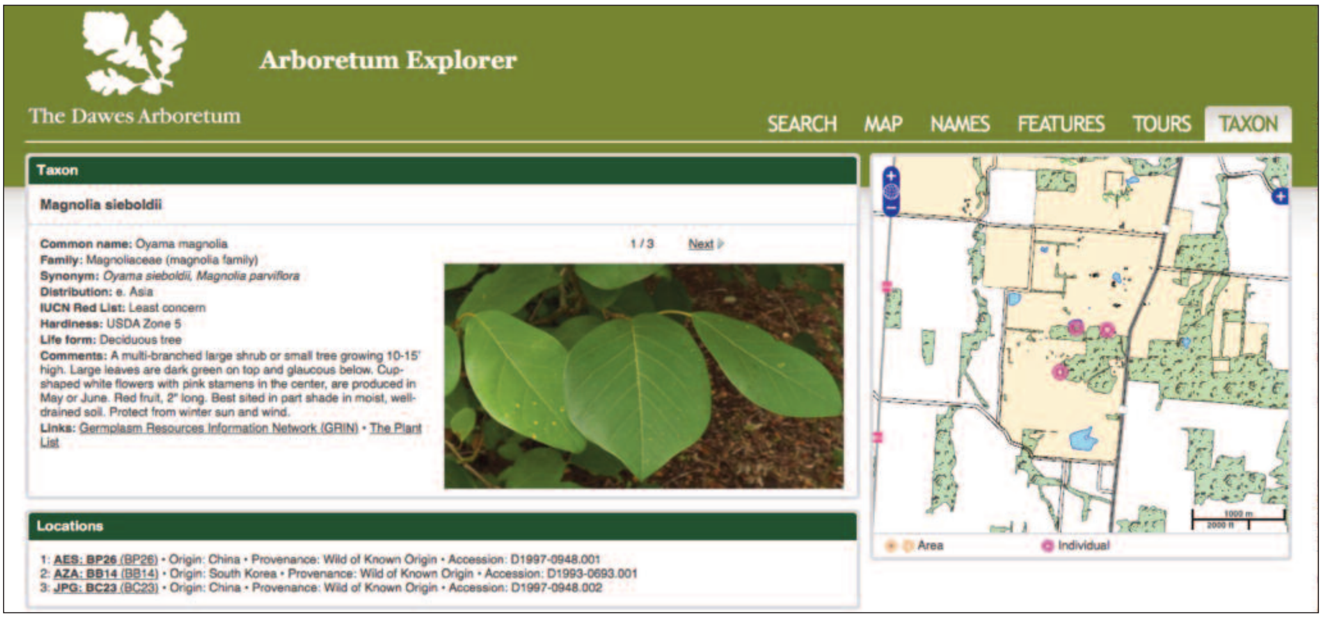
BRAHMS was originally designed and developed for use in herbaria. However, in 2010, a Living Collection module was added to cater for demands of managing data of both living and preserved collections. The living collection module is linked through to the main BRAHMS taxonomic framework. BRAHMS is a relational database application able to handle information management needs of institutions and individuals holding collections of biological material. It is compatible with international data standards. The system is regularly updated and enhanced based on user input. It is not open source and not free of charge. With BRAHMS, collection localities can be described in detail with the pinpoint location map of the botanic garden's areas and thematic zones linked to the data. BRAHMS also covers the six broad categories mentioned above (see BG-BASE).

- **Atlantis BG (botgard.bio.uu.nl/index.php?name=Atlantis%20BG&topic=Introduction)**

Atlantis BG is a relational database for botanic gardens created by Utrecht Botanic Gardens. It is able to handle the information management needs of institutions and individuals holding living and/or preserved collections of biological material. It covers the general needs of collection data storage and allows searches for plant information in the database from the Web interface. It is compatible with relevant international data standards, but is not open access.

- **KE EMu (kesoftware.com)**

This database is a collections management system mainly for museums but can be customised for use by botanical institutions. It was developed to manage collection types of various fields and topics such as culture, anthropology, archaeology, science and technology, paintings, sculpture, photographs, textiles and digital objects. It can also record natural history collections relating to zoology, earth sciences, palaeobiology, botany, horticulture and physical anthropology. It has a Web interface and also allows access to data via mobile devices. The software is not open source and not free of charge.



Accession information of The Dawes Arboretum generated by IrisBG software. (Image: IrisBG)

- **Ghini (ghini.github.io)**

Ghini is a desktop application for managing plant collections, primarily designed for botanic gardens and arboreta. A GPL (free and collaborative open source) project, Ghini started as Bauble in 2004 at the Belize Botanic Gardens. Institutions can choose to use Ghini as it is, or can contribute to its development by proposing and sponsoring features. A geographic web interface to the database is planned for early 2017.

- **Customised databases**

Customised databases for collection management are mainly established by institutions that are IT-competent and require independence to manipulate and link data to other computer applications based on individual needs. In-house database systems are usually relational with specific, customized fields. Smaller institutions may utilize flat and non-relational databases such as MS Excel, MS Word or a general database such as MS Access to create their own data management systems.

Box 5.5 Use of the International Transfer Format (ITF) for Botanic Garden Plant Records

The International Transfer Format for Botanic Garden Plant Records (ITF) is a standard format by which information about living plants, as held by botanical institutions, particularly botanic gardens, may be exchanged between organisations. It is a means for structuring the transfer of data or recorded knowledge about a single plant accession from an originating (sending) institution to a receiving institution.

Building on the earlier system published in 1987, the International Transfer Format for Botanic Garden Plant Records, Version 2 (ITF2) was launched in 1998, in response to requests from botanic gardens to incorporate additional data fields for transfer within botanic gardens and to allow for a more flexible format. ITF2 incorporates a procedure allowing for further data fields to be identified and exchanged between institutions. The system provides a convenient guide to the kinds of information (i.e. set of fields or information categories for a database) that could and should be recorded. The basis and purpose of the ITF is to pass on and share information with other institutions about individual accessions, such as where and when the plant was collected, and by whom. These fields are accession-based. This information can be elaborated with additional data from other sources, for example taxonomic information (plant family, synonyms); geographical distribution of the taxon in the wild; conservation status assessments; economic uses of the plant; bibliographic information about the taxon; or details about the place of origin (country, province or region, latitude and longitude). This latter information applies to the species and is applicable to all accessions of that species. The data from other sources can always be added at a later date.

The ITF was designed by botanists and horticulturists who have learnt from experience which accession information is necessary when undertaking plant research. Although intended to assist electronic exchange of plant information primarily between botanic gardens, it has been used by many institutions in the design of their collections databases, and is believed to remain relevant despite the rapid development of information system technology.

Source: Leadlay and Greene (1998)

Box 5.6 Sharing botanic garden data via BGCI's databases

BGCI maintains two globally unique and publicly accessible databases: GardenSearch and PlantSearch.

GardenSearch

BGCI's GardenSearch database is effectively an on-line, searchable directory of the world's botanical institutions. In addition to thousands of botanic gardens and arboreta, GardenSearch also includes gene and seed banks, network organizations, and zoos. Each GardenSearch profile includes nearly 150 fields providing information on garden location and staff contacts, as well as presence or absence of expertise, facilities and programmes aimed at supporting plant conservation and research. Data contained in GardenSearch is primarily provided and managed by individual institutions.

The database is freely available to all online users via the BGCI website. The database can be searched by country or keyword and an advanced search facility allows combinations of data fields and geographical location to be searched and the results mapped. All botanic gardens are encouraged to keep their GardenSearch profile up-to-date.

PlantSearch

PlantSearch provides a list of the plant taxa being cultivated and conserved by botanic gardens and related institutions around the world. PlantSearch includes over one million records representing over 400,000 taxa, with data uploaded by more than 1,000 contributing institutions. It is the only comprehensive global database of plant species in *ex situ* collections and through its linkages to the global IUCN Red List, allows threatened species to be identified in *ex situ* collections. Additional onward links from PlantSearch provide a vast array of species level data to be easily accessed. While all plant name records in PlantSearch are linked to the provider's record in the GardenSearch database, this link is not visible, thus all records in PlantSearch remain anonymous to public users.

PlantSearch is used to measure progress toward Target 8 of the Global Strategy for Plant Conservation by tracking which threatened species are in botanical collections throughout the world. Managers of living botanical collections (plants, seeds, or explants) are encouraged to upload plant lists to the PlantSearch database on an annual basis to demonstrate and enhance the conservation value of living collections, and connect living collections to the global botanical community of conservationists, educators, horticulturists, and researchers.

For institutions that contribute data to PlantSearch, the database provides a useful collections management tool and connects individual collections to the global botanical community. PlantSearch allows data contributors to easily identify threatened taxa in their own collections and also find out how many other collections maintain the same taxa.

Full instructions on how to contribute data to Plantsearch are provided on the BGCI website: bgci.org/plant_search.php

CASE STUDY 5.3

Botalista, an open source tool to manage botanic garden collections – Conservatoire et Jardin botaniques de la Ville de Genève (CJBG), Switzerland

Raoul Palese, Cyril Boillat and Pierre-André Loizeau, Geneva, Switzerland

In 1994, a staff member of the Conservatoire et Jardin botaniques de la Ville de Genève (CJBG) published her highly innovative thesis 'Un système d'information botanique : contribution au désenclavement de l'information'* on the subject of the use of relational databases for the integration of various research and collection management projects in one system, with the aim of sharing approaches, data, methods and applications. Since then, the CJBG has continued to develop this database management system known as 'Système d'information botanique de Genève' (SIGB).

SIBG allows users to manage:

- Herbarium collections;
- Living collections; and
- Information linked to research projects such as plant check lists, floras, taxonomy (nomenclature, synonymy, locality information, etc.).

These different components share the same basic information such as stakeholders, authorities, collectors, localities, etc. Initially, SIBG used proprietary technology including Oracle databases and Oracle Forms applications. In 2008, the component of the SIBG relevant to the management of the living collections ('SIBG-JIC for Jardin', 'Index Seminum' and 'Conservation'), was migrated to an open source, client server (JAVA) but still uses the Oracle engine.

*Zellweger, C. (1994): *Un système d'information botanique : contribution au désenclavement de l'information.* Thesis No. 400. Faculty of Economic and Social Sciences, University of Geneva.

A partnership agreement between the cities of Geneva and Paris

A study carried out to update the collection management system of the Jardin botanique de la Ville de Paris (JBVP) revealed that existing tools were inadequate and that the SIBG-JIC would encompass most of the functional needs of JBVP. This gave rise to the establishment of a partnership agreement between the two cities to jointly further develop the information management system. On the one hand, this has enabled the city of Paris to promptly access SIBG-JIC (in use by JBVP staff since 2014) and avoid a costly investment for a new development. On the other hand, this partnership between the two cities has facilitated the joint use of resources needed to realise further functional developments including an open source portal for the benefit of all botanic gardens and institutions.

***Botalista*: A management tool available to all**

To further facilitate the use of this open source database, SIBG will ultimately be offered to all botanical institutions free of charge. This software, called 'Botalista' will be based on the following technologies:

- Open source database (MySQL, MariaDB or PostgreSQL);
- Three-tier application with JAVA as the main engine and the Web interface in AngularJS;
- Communication with other available platforms with RESTful Web Services.

The software will be made available via interdependent modules (management of nomenclature, acquisitions, etc.) allowing interested institutions to install these based on their individual needs.

***Botalista*: A partnership project**

This ambitious project is led by the cities of Geneva and Paris. However, other parties and institutions are invited to join this collaborative venture, to capitalise on additional expertise, address further needs, improve existing modules and devise additional functionalities.

5.6 DATA SHARING

Increasingly, botanic gardens are making their collection information available online. Web-accessible records assist external enquirers and potential research or conservation partners to view collection information such as the availability or existence of a particular taxon. This creates the potential for better coordination of regional and international collections exchange and joint conservation programmes, for instance for the management of threatened or potentially invasive taxa. On the other hand, it is also important to note that the data sharing platform has the ability to create different levels of accessibility to sensitive information. At the discretion of the curator or collection manager, this information can be restricted or suppressed from the general users' view in the shared platform, for instance, exact information on the location of a rare, highly sought-after plant, to prevent the data from falling into the wrong hands.

Certain standard formats must be created for uploading data held by different institutions into an agreed central database before sharing in order to facilitate reading of the data by the various software involved. Systems such as the International Transfer Format (ITF) (Box 5.5), simple Comma-Separated Values (CSV) format or Extensible Markup Language (XML) format offer ways in which data can be filed for uploading into a central database.

Examples of shared collection database sites are the BG-BASE Multisite Searches webpage, the open source application *Botalista* (Case study 5.3) and the BGCI GardenSearch and PlantSearch databases (Box 5.6).

Sharing of botanical information at all levels is vital to rationalise and coordinate collection priorities and promote a more comprehensive approach to multi-institutional collection management. More widely practised, it may also encourage individual institutions to improve the accuracy level of their plant records as well as increase awareness by the staff of the value of the collections. In turn, this may invoke a shared responsibility for collection management and instil the importance of maintaining standards and accuracy of data.

5.7 CONTINUED STAFF TRAINING

Assigning staff or volunteer(s) to be in charge of the maintenance of the collection record management system is a prerequisite. Such responsibility also implies continued training in the management of records and record-keeping in general. Staff must be familiar with the institution's plant data management procedures and policies, and regularly track plant holdings to ensure that plant material is not lost and that the record system provides an accurate representation of the actual plants in the collection.

It is vital for all members of staff (and volunteers) to understand the need for thorough record-keeping, for example:

- The importance of accurate records for effective management and curation of the collections, or to accurately respond to queries;
- To ensure that information is not lost when staff leave if it is not written down or documented;
- The procedures for transferring information from the botanic garden to the record system, e.g. the germination protocols of an accession, the movement of plants to another institution, the death of the last plant of an accession, etc.;
- The need for correct labelling of plant material, for instance to minimise errors during propagation such as loss or switching of labels;
- To facilitate regular audits of the collections (Chapter 3, Section 3.7) and ascertain that the accessions in the database are still present and living, as well as to ensure that information is updated.

Efforts should be made to train staff in record-keeping, hard- and software tools, methods and use. Cross-training, in terms of providing briefings to botanic garden staff from various departments on the importance and procedures of the collection record management, may help improve the functioning of the botanic garden, as well as overcome the loss of information if there are changes in staff (Leadlay and Greene, 1998).

Training of Pha Tad Ke Botanic Garden staff on collections' record management. (Image: Rik Gadella)

5.8 SECURING THE RECORDS

KEY MESSAGE

A duplicate of the plant records should always be established. Backup copies can be regularly and quickly generated by a computerized system. As an insurance policy, these backup copies are best kept at a separate site from the botanic garden's main collection record management system.

However well records are maintained (either in hard copy or on the computer), they must be protected from accidental loss. This is generally achieved by generating backup copies in a safe location away from the main centre. If paper records are maintained, they should be stored in a secure and safe location protected from damage by fire, floods, hurricanes and other hazards. A duplicate copy of the records should always be established. While this is challenging for card-held records, duplicate copies are easily generated with a computerized system which can produce backup copies regularly and quickly on media of small physical size (compact discs and detachable hard drives). Backup copies are best kept at a separate site from which the original system can be fully restored, should this become necessary.

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Part C: The Plant Collection – Linchpin of the Botanic Garden

Chapter 6: Horticultural Management

Part C: The Plant Collection – Linchpin of the Botanic Garden

Contents

CHAPTER 6: HORTICULTURAL MANAGEMENT

Chapter 6:
Horticultural Management

Kate Hughes and Leigh Morris, Royal Botanic Garden Edinburgh

6.0 DEFINITIONS

Biosecurity: The protection of plants from any type of infectious agent whether viral, bacterial, fungal, or parasitic. People, other organisms, the wind and water can spread these as they move within a facility and from one facility, or plant to another.

Fertigation: Application of fertilisers and soil conditioners into irrigation systems in order to provide nutrients to growing plants along with water.

Growing media: The material used to support the growth of a plant, particularly in containers and pots. Commonly in botanic gardens this can include soil, organic matter and compost, bark, sand, coconut fibre, peat, rice husks, vermiculite and perlite amongst other materials.

Isolation: Keeping plants separate from the main collections in order to monitor for and treat pests and diseases thereby protecting the site from unwanted infections (see also Quarantine).

Organic matter: The remains of dead and decomposing organisms. A good source of nutrients and soil conditioner for growing plants.

Pesticide: A chemical or biological agent used to control pests, diseases and weeds.

Provenance: The original source of the plant material. The term is used both to denote a location (wild population or nursery-grown) and a concept (wild-collected or cultivated stock).

Quarantine: Measures put in place to isolate and screen plant material as a potential pest or disease carrier (see also Isolation). Moreover, the term is used to denote the legal requirement for organisms to be inspected and cleared for health on entry to an area.

Stratification: To subject seeds to temperature change in order to stimulate germination. This usually involves lowering the ambient temperature for a period of time.

Viability: The capability of a seed or spore to germinate.

6.1 INTRODUCTION

Without living plants there is no botanic garden. While the collection policy (Chapter 3) determines the species to be grown, cultivated plants need horticultural care and management. This chapter describes the core elements of conservation horticulture in botanic gardens and key considerations for horticultural operations.

6.2 PLANTS AND HABITATS

KEY MESSAGE

For successful growth and display of plants the correct environment needs to be provided. This may mean adapting the prevailing on-site conditions. These should be assessed first before deciding on the adaptations required.

This section discusses the considerations that should be made with respect to the plants and habitats to be represented in the botanic garden, governed by the collection policy (Chapter 3), and the climatic modifications and horticultural environments that will need to be provided. The requirements of the plants that will be cultivated as well as the climate and other environmental features of the site and how this may affect the plants, will have to be well understood. Determining how the environment can be manipulated, and how to do this with the resources available for the plants selected, is an important part of growing plants successfully:

Key questions

- What plants will be grown?
- What habitats do they come from?
- What is the climate of the site?
- What habitats and ecosystems will be represented?
- What environmental conditions are needed to cultivate them?
- What possible changes can be anticipated?
- What are the options for creating the habitats sought?

6.2.1 Habitats and Plant Types

A key decision with any planning for a botanic garden is the choice of plant groups and habitats to be represented within the collections. Once a conclusion has been reached, the suitability of the climate and soil of the site, as well as the level of environmental modifications needed, should be examined.

- Habitats

Habitats commonly represented in botanic gardens that fall under various ecosystem categories such as aquatic, woodland, rainforest, cloud forest, savannah, steppe, desert, etc. have variable characteristics, including soil type, precipitation and water regime, temperature, light level, wind and air flow, altitude and biodiversity at large. An understanding of these features in relation to the prevailing conditions in the botanic garden site is important

A planting bed has been adapted with the addition of drainage and a gravel mulch for alpine plants in a low altitude location at the Royal Botanic Garden Edinburgh. (Image: Kate Hughes)

for successful plant cultivation. It is recommended that, whenever possible, this habitat information is obtained from secondary sources such as climate and soil maps, but it may be necessary to collect data from the habitats the plants originate from as well as the site of the botanic garden. For instance, this can be done by collecting and analysing soils and using data loggers for temperature information.

- Plant types

Plants within botanic garden collections are typically grouped into broad categories, such as alpines, trees and shrubs, aquatics, herbaceous perennials, ferns, xerophytes, food plants, herbs and epiphytes. The prevailing site conditions will determine the types of plant that can be grown easily, but for those that will not establish well, conditions will need to be modified and permanently maintained. Examples include modifying water supply, temperature and soil pH.

- Natives or exotics?

It is important to consider whether mostly native species will be grown (which may require little site manipulation) or exotics (which may entail changing the natural site conditions considerably). Whatever is decided, the most important information for successful cultivation is consideration of the plants' requirements, and this will be informed by detailed habitat analysis, not simply by replicating the general climate in the country of origin. Decisions over whether to grow exotics or natives will always require referring back to the collection policy (Chapter 3) which in turn is derived from the botanic garden's vision and mission (Chapter 1, Section 1.2.4). Consideration should be given to the user groups who will interact with the living collections. For example, a botanic garden in a temperate climate may wish to display and use tropical plants as part of its education strategy or to attract more paying visitors.

6.2.2 Climate and Environment

It is fundamentally important to know and understand the climate of the botanic garden site and how this compares to the adaptations of the plants to be grown. This will enable botanic garden managers and horticulturists to understand what changes are to be made for successful cultivation. Information on climate and environment from existing external sources, as well as data collected from the botanic garden should be carefully studied, especially pertaining to microclimatic conditions on the site. It is particularly important to have access to local information if the species to be grown are at the edge of their tolerance or have a reputation for requiring very specific environmental conditions.

- **External sources of information**

- Airports: All major airports have weather recording stations.
- Governments: Meteorological data for longer term weather patterns and soil data.
- Local growers, parks and reserves: Soils and local climate information.
- Local societies, agencies and environmental organisations: Any other insights to an area that may be relevant.
- Data loggers: Placed into the habitats that are planned to be represented within the botanic garden which measure maximum and minimum temperatures over a number of months.

- **Collecting data on-site**

- Soil analysis: Soil type influences plant growth and this should in turn inform plant selection and horticultural practices in a number of ways. It is fundamental that a good understanding of the soil type(s) on-site at the botanic garden is achieved, including its physical, chemical and biological properties.

  Soil samples can be taken from across the site and tested for acidity (pH) and texture quite simply and cheaply. Soil profile pits can be dug to determine soil depth and structure. For more detailed analyses of nutrient levels and organic matter content, more specialist equipment is required and soil samples may have to be sent for testing externally for instance to a university, agricultural research station or private company. Likewise, information on bedrock type, watercourses and topographical features needs to be gathered as these may affect the establishment and growth of the plants on-site.

  It is important to compare the soil(s) of the botanic garden with those of the habitats from where the plants intended for cultivation are originating. This will be particularly important in propagation and nursery growing media for any young plants.

- Weather data: It is advisable to collect weather data on-site to gain a comprehensive understanding of the overall local climate and within-site microclimate. Weather monitoring equipment can range from a simple maximum / minimum thermometer and a plastic rain gauge, to a weather monitoring station containing more complex electronic devices that measure a range of factors including air and soil temperature, sunlight level, wind speed, humidity, rainfall and air pressure.

Table 6.1 Natural habitat factors that can be manipulated and how these relate to the horticultural requirements

Natural habitat factors	Horticultural considerations and applications
Soil type: texture, structure, pH, nutrient levels and organic matter content.	Choice of propagation and growing media, and choice of substrate in final planting; soils can be changed completely for some areas, particularly in containers or planting pits; soil additives can be incorporated such as grit, sand, organic matter and fertilisers.
Precipitation and water regime: quantity, quality (pH), seasonal changes, types.	Choice of irrigation or fogging system(s) and frequency of application; drainage systems can be installed if required.
Temperature: maximum and minimum, diurnal fluctuation.	Use of greenhouses (glass, polythene, netting, etc.) and heating or cooling systems within them.
Light levels: full sun or shade, sunshine hours per year.	Use of supplementary lighting or shading.
Wind and air flow: plants from exposed sites, requirement for high humidity.	Use of ventilation (open or closed) and/or fans to increase or reduce air circulation; wind break mesh material to reduce wind speed.

6.2.3 Manipulating the Environment

Most botanic gardens are manipulations of the environment to a greater or lesser degree. It is possible to adjust the growing conditions for plants in a number of ways, and an understanding is needed of the options available with the resources at hand. The more deviation from the prevailing conditions on-site, the more complex and expensive manipulating the environment becomes. This has a direct impact on plant and habitat selection for the botanic garden (Table 6.1).

Some species or individual plants are extremely adaptable and can survive or thrive in a range of different conditions. Others are much less adaptable and need specific conditions with small margins of change. It is important to know these features for the plants intended for cultivation before expending resources on sourcing, transportation and propagation. The more energy required to create the conditions that the plants need, the greater the cost. Consideration must also be given to the purpose of the collection, such as whether the plants are aimed at *ex situ* conservation or display. Maintaining plants for a stunning exhibit is likely to require more resources overall and possibly more environmental manipulation, dependent on the groups of plants selected.

Pot culture and polytunnels are both examples of manipulating the environment to create conditions which are more suitable for plant growth in the prevailing climate. (Image: Kate Hughes)

Impacts of climate change should be taken into account when planning long-term plantings. These include drainage, irrigation and hard landscaping as well as the materials and the design used. Climate change trends in the area should be examined regularly, including the occurrence of extreme weather events. This may also be a time to look at the tolerance levels of the plants, whether their requirements are within very narrow parameters or whether they will tolerate a range of conditions or extremes.

6.3 SOURCING PLANTS

KEY MESSAGE

Plants can be acquired from a number of sources. The sourcing of plants should be compatible with the mission and collection policy of the botanic garden. There are regulations governing the movement of plants, and ensuring legal compliance is essential to this. At the sourcing stage, comprehensive plant information needs to be recorded as this is the starting point for the part that the plant will play in the future of the botanic garden.

This section discusses the methods by which plants can be obtained by the botanic garden. Acquisition of plants for conservation, display or any other purposes should be driven by the institution's collection policy (Chapter 3). Once key decisions regarding landscape design and species selection have been made, various aspects of sourcing the plant material need to be considered:

Key questions

- What living collections are planned?
- What provenance information is required for the living collection?
- Do they need to be grown on-site or can they be procured externally?
- Can seeds or plants be obtained from other botanic gardens?
- Do seeds or plants need to be collected from the wild?
- What propagation and production facilities are required for the initial plantings?
- How will these fit with the long-term requirements of the botanic garden?

6.3.1 Provenance Information

Detailed provenance information is the ideal for any botanic garden collection. The more information, the greater the flexibility for display, research or conservation in the future. Standard provenance information (Chapter 3 and Section 6.3.3) for plant material should include name, type of material collected (such as seed, herbarium specimen, tuber), date, locality, altitude, habitat, associated species, descriptive information such as flower colour or other features which may be lost once a specimen has dried out (Barber and Galloway, 2014). Gathering additional information and details on the locality may prove beneficial for other purposes. For example, if a collection has been made from an arid habitat but the plant material was found in a damp and shady overhang with different conditions from the prevailing environment, this information could be valuable for future cultivation of the species as it could provide particular indications on how to grow the plant well. Soil types and conditions should also be noted (Section 6.2.2) because they could affect cultivation of the plant. Other features may be worth noting. For instance, if a plant is locally abundant and in flower with a range of colours, this could have implications for the flower colour from any seed collected. Other features of the habitat, such as evidence of seasonal changes in the environment, are important to record as well. An example of these could be waterlines which demonstrate levels of inundation in monsoon seasons but which change through the seasons. These offer clues regarding environmental changes of a habitat which may have to be considered for successful cultivation.

6.3.2 Seeds or Plants?

Plant material for propagation can be brought in as seed, spores or as vegetative material. Clonal and non-clonal material both have benefits and constraints as a starting point for the living collection. The selection will be informed by the types of collections, growth forms and displays which the botanic garden is aiming to create.

- **Benefits of material sourced from seed:**

- Can be easier to collect from the parent plant as they already come in their own biological 'package';
- Generally light and easy to transport in bags and envelopes as well as relatively small containers;
- Large quantities can be gathered and stored for potentially long periods;
- Flowers, fruits and seeds are key identifying features and therefore immediate verification is more likely if seeds are present;
- The genetic variation of seed collections may be more suitable for species of conservation concern and for botanical and conservation collections.

- **Disadvantages of material sourced from seed:**

- Genetic variation in seed means that desirable features, such as flower colour, particularly for display, may not be guaranteed;
- Seed-grown plants can take longer to reach maturity than vegetatively propagated plants;
- Species may have dormancy and germination requirements which may not be fully understood or be difficult to replicate in the botanic garden;
- Seed production may be very limited or absent as some species may not produce seed, or not abundantly, or not every year, or it may be rapidly predated;
- Some seeds have very low viability, are difficult to store and may be found to have been contaminated by pests or disease on sowing.

- **Benefits of material sourced from plants:**

- Lack of genetic variation in the propagules means predictability in the features;
- If identifying features are present, species can be immediately verified;
- Propagules may grow and reach maturity more quickly than seed-grown plants;
- Plants which are easily propagated can make large numbers of plants and expand collections relatively rapidly;
- The time period for collecting vegetative material during the year is longer than the seed season;
- Mature plants allow the creation of an 'instant garden';
- Mature plants can be rescued from habitats being destroyed;
- Highly specific germination requirements can be avoided.

- **Disadvantages of material sourced from plants:**

- Lack of genetic variation may mean that a collection has limited conservation value;
- Biosecurity issues and regulations may restrict the transportation of rooted plants across state boundaries;
- If whole plants are to be transported, the removal of soil may be required to cross state boundaries which can cause stress, thereby compromising the plant's health;
- Plant material can be more difficult to transport and establish in a new location as it may resent transplantation, and requires more coordination, space and resources;
- More horticultural resources and skills may be required, such as heated propagation equipment and daily checking by staff to process plant material and generate rooting.

Gathering plants from a government nursery in Tistung, Nepal, for planting at the National Botanic Garden Nepal. (Image: Kate Hughes)

6.3.3 Sources of Seeds or Plants

• Commercial nurseries and seed suppliers

A number of questions need to be considered before purchasing seeds or plants from commercial nurseries or seed suppliers. These include: Are taxa reliably verified? Is plant health assured? Is provenance information sufficient and accurate? Were the plants legally sourced? Based on the collection policy, decisions concerning the extent and accuracy of provenance and collection information need to be made when exploring sources of plants, as the amount of data available from different suppliers will vary. Plants can be procured within a country or imported.

- **Local in-country suppliers:**
  Local nurseries may be able to supply the plants required. These facilities could also be used to grow larger numbers of plants under contract (Case study 6.1). It is recommended that time is spent visiting local nurseries during the initial planning phase for the botanic garden, to gauge plant availability, local capacity and expertise.

- **Importation:**
  A far wider range of plant material is available internationally, but the issues of verification, plant health, legal acquisition and provenance are amplified. It is important to adhere to the country's plant health and phytosanitary regulations, which need to be abided by before purchase of any plant material (Sections 6.4 and 6.8).

CASE STUDY 6.1

Sourcing plants from local nurseries – Sulaimani Botanic Garden, Kurdistan

Sophie Neale, Edinburgh, United Kingdom

Briefing on the planting strategy at the Sulaimani Botanic Garden, Kurdistan. (Image: Saman Ahmad)

The Sulaimani Botanic Garden (SBG) is located in the south of Iraqi Kurdistan. It is part of the Kurdistan Regional Government Ministry of Agriculture and Water Resources. In late 2013, the SBG planning committee approached the Centre for Middle Eastern Plants (CMEP) based at the Royal Botanic Garden Edinburgh, to provide consultancy skills for the master planning and establishment stages of this botanic garden including a habitat restoration project. In December 2013, a brainstorming and planning workshop was held in Sulaimani in order to define the aims and remit of the institution and to guide initial stages of the establishment of the botanic garden. In February 2014, CMEP submitted a master plan document providing information on the plans, requirements and next steps for the botanic garden. Construction began mid-2014 and the first specimens were planted in October 2014.

The master plan of SBG contains a section dedicated to the spatial, structural and staffing requirements for a nursery. The mission statement, collection policy and aims of the institution were examined carefully to establish that a nursery facility was in fact essential to create and maintain the planting plans which the SBG wished to realise. In the consultancy process CMEP discovered that there were government-run nurseries, growing thousands of native oaks and other native trees, the very species which would be required for the restoration element. Due to the fact that the nurseries and this project are run by the same government institution, it was easily agreed that the nurseries could provide an initial supply of the appropriate native oak species. In October 2014, planting of some 5,000 one- to two-year seedlings began, thus initiating the landscape development and the plant collections. The plants did not come with the provenance information which the botanic garden would have ideally liked. However, they were the appropriate species, plants were of the right size and they were immediately available. This enabled the project to start swiftly and without delay caused by collecting and cultivating slow-growing woody species.

Prior to planting, service and access roads had to be constructed, and irrigation points had to be installed. A plan of service roads, irrigation points and channels were made in the initial consultation process as an essential part of the planning. In contrast, the nursery facilities had not yet been designed or constructed and were not needed in this case to make these initial plantings, although they are planned for the future.

Primary issues for the establishment of plants at Sulaimani Botanic Garden:

1. Water availability is extremely limited in the local environment and therefore water needs have an important influence on the landscape design. Water conservation was covered in extensive detail in the master plan. The irrigation points and possible systems were provided on a separate map. Water conservation was, and will continue to be, strongly considered in the landscape and planting design. For example, native species tolerant of dry conditions will be selected, which also fits with the mission of the botanic garden, and areas of lawn requiring much irrigation will be avoided altogether.

2. Native plants tolerant of the environmental conditions will be planted. As many of these species have not been grown in botanic gardens before, experience of their cultivation is limited. This means that it is essential to document propagation and cultivation requirements and develop a core, skilled horticultural team right from the initial stages of the botanic garden's establishment.

• Botanic gardens

Sharing plant material among botanic gardens is a common practice. Guidance and resources on mechanisms, issues and international standards related to the exchange of plant material among botanic gardens are provided in Chapters 3, 4 and 5.

There have always been professional and informal relationships between staff working in different botanic gardens, which greatly facilitates the exchange of plant material as, for instance, is illustrated in Case study 6.2. However, it is essential to ensure that such exchanges fulfil national and international conventions and standards such as the Nagoya Protocol on Access and Benefit-sharing (Chapter 4, Section 4.5) and phytosanitary regulations (Sections 6.4 and 6.8).

• Wild collection

Wild collected material is considered to be the best source of plant material because the full range of habitat and location data can be recorded. This makes such plant samples most useful for research and conservation. The collection of plant material from the wild must abide by national and international conventions and standards such as the Nagoya Protocol on Access and Benefit-sharing, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Chapter 4, Sections 4.3 and 4.5) and phytosanitary regulations (Section 6.4 and 6.8). Plant collection methods by botanic gardens should serve as a model in terms of legal compliance, habitat and biodiversity conservation, access and benefit sharing, working in partnership and applying scrupulous recording methods. For botanic garden displays it can be equally useful to have material from the wider

CASE STUDY 6.2

Well-documented plants from partner botanic gardens and other botanical institutions for the Muséum national d'Histoire naturelle, Paris

Denis Larpin, Paris, France

The public display glasshouses (Les Grandes Serres) of the Muséum national d'Histoire naturelle (MNHN) in the Jardin des Plantes, Paris were reopened to the public in June 2010 after five years of renovation. Once the structures were ready for planting, plants were supplied from a number of sources. One of the most difficult aspects of the project was the acquisition of living plant specimens with reliable names and good provenance data. A request was made to colleagues in the botanic garden community. In all cases the plants were obtained on the condition that distribution outside the MNHN was restricted.

In this way plants of wild collected origin with detailed accession data and horticultural knowledge of their cultivation were obtained from various botanic gardens in France, the United Kingdom, the United States and New Caledonia. For instance, the Royal Botanic Garden Edinburgh offered conservation plant material from their fern and tropical conifer living collections, including *Acmopyle pancheri, Araucaria schmidii, Falcatifolium taxoides, Podocarpus lucienii, P. sylvestris, Retrophyllum comptonii* and *R. minus* to complement the New Caledonian endemics collection already existing at the MNHN. The Jardin des Serres d'Auteuil, Paris provided a large palm, *Chambeyronia macrocarpa,* amongst other species. Additional plant material was made available by the Conservatoire botanique national de Brest and the Montgomery Botanical Center, Florida.

Specimens directly sourced from New Caledonia were offered by different organisations. Species in Myrtaceae, Cunoniaceae, Proteaceae and Euphorbiaceae were supplied by SIRAS Pacifique, a company specialised in ecosystem restoration, while Apocynaceae, Arecaceae, Casuarinaceae, Fabaceae, Lamiaceae, Moraceae, Pittosporaceae, Rubiaceae, Sapindaceae, Sapotaceae and Sterculiaceae specimens were provided by nurseries in Eriaxis, Mango, La Nea, Tipinga and Tuaiva. Additionally, unique species from the dry and mangrove forests were generously offered by the 'Programme de Conservation des Forêts Sèches' and the 'Point Zéro Baseline' environmental association.

This type of sharing is useful in reducing the resources required to obtain wild collected plants, and decreases pressure on natural populations. Well-documented provenance information assures the relevance of the material both for display as well as for research and conservation.

New Caledonian Glasshouse of the Muséum national d'Histoire naturelle, Paris, with wild-origin specimens sourced from botanic gardens. (Image: Manuel Cohen) natural range of the species to rejuvenate a particular collection. In many cases, specimens in cultivation originate from one or a few clones introduced many years ago. These can lack genetic vigour and be susceptible to pests and diseases, or can succumb to climatic conditions if they are at the edge of their distributional range.

For horticultural purposes, detailed provenance data including date of collection, location, altitude, habitat, associated species, growth habit and any other features regarding the way in which the plant is growing, may prove vital information for successful *ex situ* cultivation. The abundance of the species should also be noted, as well as the number of individuals from which the collection was made, and whether other mature plants or seedlings were present. Ideally accompanied by a herbarium specimen, which provides the opportunity to name the species accurately, information of this type will help horticultural staff at the botanic garden to better appreciate the plant and its growth behaviour in the wild, in turn informing appropriate cultivation techniques (Rae, 2011), for instance:

- Some species may be widely cultivated in the botanic garden, but all the specimens may originate from the same clone from one collection made a long time ago. Vegetative propagules of a clone may weaken over time. The 'garden population' of such a species can be augmented and invigorated by introducing additional genetic material. Increased genetic variety is also essential for the conservation of a species.

- If collections from wild populations are made by horticultural staff, the specific propagation and cultivation needs and conditions of the species may be more adequately described. To know it better is to grow it better and this will have great benefits for the long-term health of the species and the collection.

It is generally acknowledged by botanic garden managers that the health and successful cultivation of plants are improved by continued personnel development (Section 6.9). Particularly valuable is the active involvement of botanic garden staff in field work, leading to a greater familiarity with, and knowledge of the species and its habitat.

Examining propagation challenges in the field with staff from the Oman Botanic Garden. (Image: Peter Brownless)

6.4 PLANT HEALTH – QUARANTINE AND ISOLATION

There are potential long-term plant health hazards associated with the introduction of plant material, growing media and soil. It is strongly recommended that biosecurity facilities and procedures are developed and implemented before any material is outplanted. 'Quarantine' is used here to describe the practices as well as the legal requirements for organisms to be inspected and cleared for health on entry to an area. Some quarantine facilities may need to be regulated by national government agencies. 'Isolation' refers to what an organisation may do for its own benefit to protect the plants and the site.

To further address the hazards associated with the introduction and spread of new and damaging plant pests and pathogens, the International Plant Sentinel Network (IPSN) has been set up. A network of botanic gardens and arboreta, national plant protection agencies and plant health institutions, the aim of this global alliance is to provide an early warning system for new and emerging pest and pathogen risks (Box 6.4).

Further information on plant health and biosecurity management is given in Section 6.8 on page 129 cont.

Mist unit for epiphytic species in the quarantine area of the Royal Botanic Garden Edinburgh. (Image: Fiona Inches)

Plant material arriving in quarantine at the Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

6.5 PLANT PROPAGATION AND PRODUCTION – THE NURSERY

KEY MESSAGE

All botanic gardens will need plant production facilities. These do not have to be large, complex or expensive but should be compatible with the collection policy, budget and staff resources. Planning prior to construction and regular review once established will assist in the creation of effective facilities. Equally important is to have a functional plant records management system in place at propagation and production stages.

Nursery facilities at the Oman Botanic Garden (shade house) (top) and Pha Tad Ke Botanic Garden respectively. (Images: Leigh Morris)

CASE STUDY 6.3

A comparison of nursery requirements for two different botanic gardens

Leigh Morris, Edinburgh, United Kingdom

This case study compares and illustrates the nursery requirements and facilities at two distinctly different, new botanic gardens, in terms of their scale, ambition and finances. The Oman Botanic Garden, in the Sultanate of Oman, involves major government funding and a large team of Omanis and international experts, consultants and contractors. It aspires to provide world-class facilities, collections and other visitor attractions with high impact on native plant and biodiversity conservation at large. Pha Tad Ke, conversely, is a small, privately owned botanic garden situated on the bank of the Mekong River near Luang Prabang in northern Laos. Both botanic gardens require nursery and propagation facilities, however, their needs, specifications, resources and budgets are very different.

The Oman Botanic Garden aims to represent all of the diverse habitats of Oman and grow the majority of the approximately 1,407 Omani flowering plant species based on wild-sourced material. The target production of some 250,000 plants (excluding plant material directly sown in the botanic garden's ground) required a large, state-of-the-art nursery, with the capability of producing plants from different habitats, ranging from high mountains to sand deserts in climate-controlled environments (Patzelt *et al*., 2008 and 2009; Morris, 2011). The nursery contains environmentally controlled and zoned areas including a propagation and two large production glasshouses, a number of large polythene greenhouses, a large expanse of shade houses and an outdoor growing space as well as a nursery building with offices, potting, propagation, seed bank and storage facilities. The nursery was built by an international firm and the majority of the materials, tools and equipment were imported from overseas.

Far smaller in size, Pha Tad Ke Botanic Garden aims to grow and showcase only plants from similar climatic regions in Laos and southeast Asia. Plant propagation and production is carried out at a small scale and nursery facilities consist of benches and shade-houses constructed with local bamboo. Equally, the tools, equipment and materials are locally sourced, including the potting medium which is made from Mekong River sand, elephant dung, coconut bark and rice husk.

In conclusion, the propagation and production facilities of both botanic gardens are very different. The Oman Botanic Garden has an expansive and appropriately 'hi-tech' nursery capable of efficiently growing very large numbers of plants. It is working towards a clearly defined production list and targets and is comparable with a large scale commercial grower. Pha Tad Ke Botanic Garden, on the other hand, has a suitably 'low-tech', small scale nursery, using locally sourced materials and built to support the horticulture operations of the botanic garden, without fully prescriptive production targets. Importantly however, the respective facilities fulfil their functions very well whilst their differences highlight the diversity of nurseries based on the mission and objectives of the botanic garden.

Once plant material has been sourced, it may need to be propagated or grown-on in a nursery before planting out. Not all botanic gardens need nursery facilities, but the majority do have at least a small propagation facility. The specific requirement for plant cultivation and production facilities will depend on the type and scale of the planned plantings, and the overall ambitions for the botanic garden. 'Nursery' can refer to a diverse range of facilities from large, state-of-the-art production nurseries to small, low cost areas growing a small number of plants (Case study 6.3). To identify the appropriate features of the facility, various aspects need to be considered:

Key questions

- Is a nursery required or can propagation and production be carried out elsewhere?
- What scale of production is needed in the short-term for growing the initial plantings and in the long-term for maintaining the collections?
- How much propagation is planned in the short, medium and long-term?
- What types of propagation methods will be used?
- How much water will be required and where will this be obtained?
- Will any production be done off-site?
- Which habitat types are the plants from?
- How many and what sizes of plants will be grown in the nursery?
- What human and financial resources can be allocated to production facilities?
- Will production be containerised or field-grown?
- Is it planned to grow plants for sale or planting in conservation programmes off-site?

6.5.1 Production Planning

It is recommended that a production plan is produced prior to nursery construction (Chapter 1, Section 1.7.5). This plan should include the type and number of plants required, and the environmental conditions necessary to grow them. It may also be possible to spread plant production out over a longer period of time to save nursery space. Once these decisions have been made, it will be possible to calculate the size of the nursery and constructions needed, such as greenhouses and equipment facilities.

6.5.2 Site Considerations

As far as possible, the location of the nursery should consider the following aspects:

- Within the botanic garden area or as close to it as possible;
- In shade or full sun, depending on the material to be grown, preferably with the provision of both conditions;
- On level ground with the same soil as in the botanic garden;
- Provide shelter structures for plants and staff – either planted or constructed;
- Vehicle access;
- Have access to services including clean water, electricity, gas, an alternative energy source, sewage and data connection;
- Security and controlled access.

6.5.3 Nursery Design

The layout and design of the nursery should aim to reduce labour and transport distances for plants and materials. A huge amount of time and money is spent in moving plants and materials around a nursery and the design must aim to minimise the resources required to do this.

Careful consideration must be given to the handling and transport systems that will be used in the long-term, as this directly influences the size and surfaces of paths and roadways. For example, if small trollies are to be used then a good/smooth path surface is required. The unloading and subsequent handling of bulky materials such as growing media, pots, trays and fertilisers may require mechanisation, such as a tractor or forklift truck, and a yard and storage area.

Ergonomic principles should be applied throughout the design process in order to have a production system that allows propagules (seeds, cuttings and plants) to start at one end and established, grown plants at the other end. The ideal nursery layout has the buildings and propagation facilities in the centre and production beds and greenhouses surrounding them, which facilitates shorter paths.

6.5.4 Specific Structures and Facilities

Secure buildings and covered structures are required for most nurseries to operate efficiently. These are dependent on the purpose and staffing of the nursery, but most medium-sized nurseries will require the structures listed here.

- **Potting and propagation shed**

These can be separate facilities, however in all but the largest nurseries, the same building will serve both functions. The potting shed is the central work area for many nurseries and, along with pesticide storage, is one of the most important structures. For a potting shed to function well it should comprise of:

- Benches to work on which can be easily kept clean;
- Ventilation;
- Clean water;
- Space to store pots, compost and other equipment;
- Knife storage and sharpening;
- Space to carry out seed and vegetative propagation;
- Access to cool storage such as a refrigerator for biological controls and chemicals or seed and spore storage.

Above: Potting shed area in a nursery in Kathmandu Nepal with benches which are easy to clean as well as space for storing potting mixes and other equipment. (Image: Kate Hughes)

Left: Potting bench, Pha Tad Ke Botanic Garden, Laos. (Image: Leigh Morris)

- **Office and staff amenities**

These facilities are typically adjacent, connected to, or within the potting shed. Provisions for computers and data management, and cloakrooms, kitchen and toilets should be made. These buildings will require heating/cooling and a consistent supply of mains water and power.

- **Equipment and materials store**

This includes facilities for storing gardening appliances and machinery, pots, trays, growing media, fertilisers, etc. These should be located close to the potting shed.

- **Compost storage and mixing area**

A large outdoor covered, or partially covered area, for storing and mixing bulky organic materials. This area needs to have adequate drainage, run-off and hygiene systems to ensure that materials are safely stored.

- **Pesticide store**

Local legislation with regard to storage and application of chemicals will need to be considered. Related buildings should be constructed and managed with awareness of health and safety for users, other botanic garden staff, visitors and the environment at large.

- **Irrigation house and water storage**

These facilities, including the pump house, can also facilitate the application of liquid fertilisers.

- **Greenhouses and growing rooms**

A wide range of types and sizes of growing structures are available for plant production. Greenhouses can be glass houses, polythene tunnels or shade houses. It is fundamental that these are chosen carefully to suit the plants to be produced. In addition, heating and cooling systems, ventilation, supplementary lighting, irrigation and fertigation systems need to be considered.

- **Other facilities**

Depending on the requirements by the botanic garden, additional facilities may include:

- Heated benches;
- Cold frames;
- Outdoor seedbeds;
- Vermin-free areas;
- Closed cases;
- Mist or fog units;
- Weaning unit for gradual acclimatisation of propagated material from heated propagation equipment to ambient conditions;
- Refrigerators for stratification;
- Micro-propagation facilities;
- Quarantine and inspection area for suspected or diseased material.

If horticultural education is one of the aims of the institution, a practical classroom and other areas kept for educational purposes will be useful within the nursery. Additional and separately maintained equipment and facilities as well as space for teaching is likely to be needed to enable educational activities even on a small scale.

Compost needs to be turned regularly in order to maintain the temperature and ensure an even breakdown of the constituents. (Image: Royal Botanic Garden Edinburgh)

Compost from leaf mould. Leaves will break down quickly in warm conditions, especially if dug down below ground level. ICIMOD Knowledge Park, Godavari, Nepal. (Image: Kate Hughes)

Propagation tunnel at Pha Tad Ke Botanic Garden, Laos. (Image: Leigh Morris)

The nursery as a classroom, Jardín Botánico Francisco Javier Clavijero, Jalapa, Veracruz, Mexico. (Image: Laura Cohen)

6.5.5 Propagation Protocols

To standardise propagation and plant production systems it is useful to establish propagation protocols. Examples of these are the protocols developed by the UK Overseas Territories Programme based at the Royal Botanic Gardens, Kew for the propagation of endangered species (Boxes 6.1 and 6.2).

6.5.6 Management of Nursery Records

Nursery propagation and cultivation methods form an important pool of knowledge useful for replication elsewhere or for further development of a plant collection. Related data should therefore be carefully recorded in the botanic garden's collection record management system (Chapter 5).

Box 6.1 Quick Reference Sheet 1 for the germination of *Acacia anegadensis* developed from propagation trials (Corcoran *et al.*, 2014)

- **Seed Compost Ingredients**
- 50% loam: sterilised, particle size < 3 mm
- 50% sharp sand, fine grit or a mixture of the two: washed or
- 70% coir: screened to < 3 mm
- 30% sharp sand: washed

- **Container**

Pot or similar: 70-90mm in depth, 60-80 mm diameter, with drainage holes

- **Environment**
- Sterile growing conditions (pots, bench etc.)
- Bright filtered light but not direct sunlight (provide shading if necessary)
- Ambient temperature/humidity (in the tropics)

Day 1

a) 'Nick' the hard seed coats with a sharp blade (at the opposite end of the seed to the seed-stalk) to expose a small area of the seed's food-reserve (endosperm): **NICKING IS ESSENTIAL FOR GERMINATION**.
b) Sow the seeds on the firmed compost surface, leaving no less than 15 mm between seeds.
c) Carefully cover the seeds to a depth of approx. 4-5 mm, or a little more, with the seed compost.
d) Water the compost from above with a fine rose or stand the container in shallow water until moisture can be felt at the surface (1-2 minutes).
e) Place the newly sown seeds in a propagation case (see notes) or place on a bench out of direct sunlight.
f) The soil must be kept moist, but not waterlogged.

Day 14 (approx.)

a) Seeds germinate.
b) The soil must be kept moist, but not waterlogged.

Day 42 (approx.)

Prick-out the seedlings into individual pots when the first true leaves can be seen (approx. 5-6 weeks after sowing).

Box 6.2 Quick Reference Sheet 2 for potting up of *Acacia anegadensis* developed from propagation trials (Corcoran *et al.*, 2014)

- **Growing Compost Ingredients**
- 50% loam: pasteurised, screened to < 9mm
- 20% home-made compost: pasteurised, screened to < 9mm
- 30% grit/sand: washed, < 3-5 mm

- **Container**

Any sterile plastic pot or similar container with drainage holes

- **Environment**
- Sterile growing conditions (pots, bench etc.)
- Bright filtered light but not direct sunlight (provide shading if necessary)
- Ambient temperature/humidity (in the tropics)

1. Prick-out the seedlings into individual pots when the first true leaves can be seen.
2. Water well.
3. The compost will provide adequate nutrients for the first 2-3 weeks.
4. After 2-3 weeks and as the plants increase in size, a soluble feed with a low nitrogen fertiliser can be applied.
5. Water as needed, make sure compost is moist but not waterlogged and do not allow to fully dry-out.
6. If plants become 'leggy', prune back shoots by a third of their length, this will encourage them to bush out.
7. Check the bottom of the plant pots regularly to see if roots are visible.
8. If roots can be seen at the drainage holes, gently 'knock' the plant out of its pot and check the extent of the root system.
9. If the roots are spreading around the 'ball' of compost it is time for them to be re-potted.

Note: Subsequent re-potting should follow the above instructions.

6.6 PLANTING AND ESTABLISHMENT

Following successful propagation, a number of aspects should be considered prior to outplanting in the grounds of the botanic garden:

Key questions

- Do the institution's development or review plans, including master plan, detailed design, construction plans and the collection policy, inform detailed planting plans?
- How should the landscape be prepared for the plantings?
- How should the plants be prepared for transplanting?
- How many staff are required for preparation and planting?
- Are there any training requirements for staff?
- What tools, equipment and materials are required for planting and establishment?
- What immediate and medium term aftercare measures are required to ensure successful establishment?

6.6.1 Preparation for Planting

A good start to a plant's life in the final planting position makes an enormous difference to the future success of plant establishment and the planting scheme. There are many cases where much effort has been put into the acquisition and propagation of planting material, and where plants have been subsequently placed in the ground with no further consideration for their establishment needs, only for the plantings to fail, causing wastage of the efforts made up to that point.

Preparing beds for planting at the National Botanic Garden Nepal. First, weeds are removed, then soil is dug over. (Image: Kate Hughes)

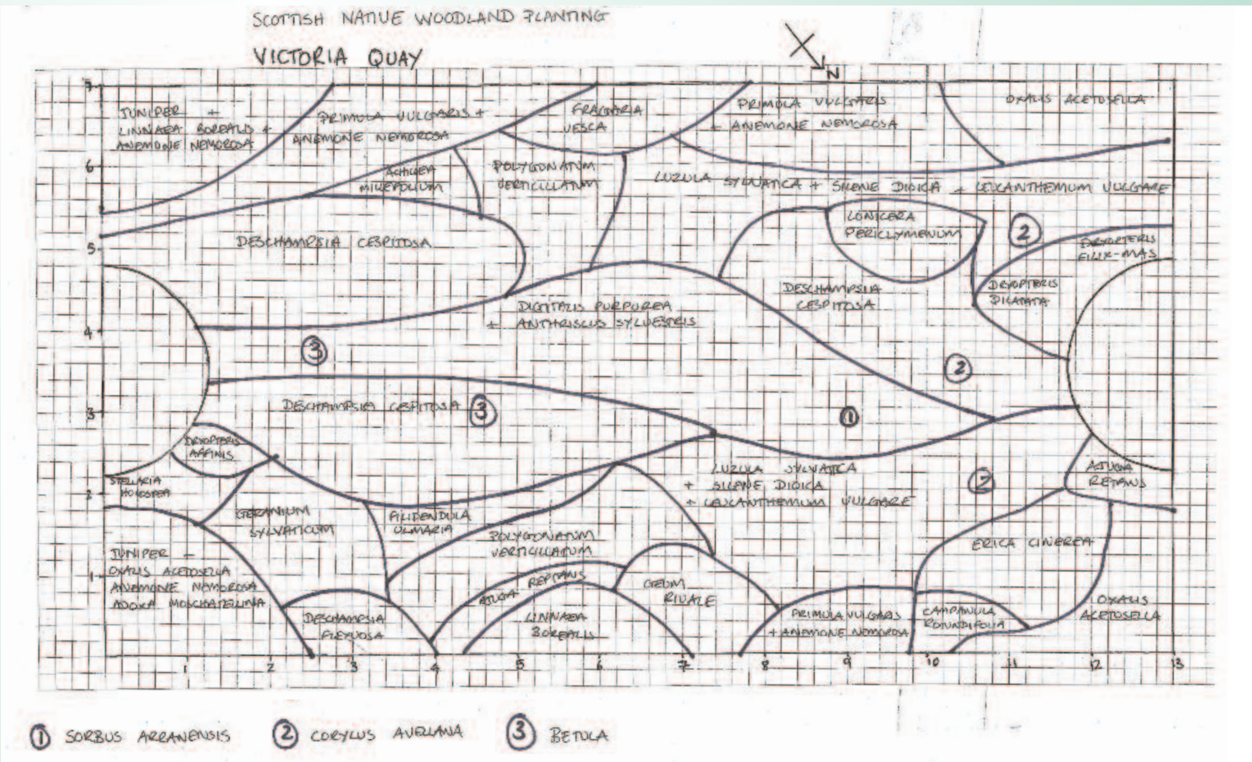
Plants need to be sited according to their growing requirements and this should be part of the planning process. Many species will grow well in conditions and positions which are different from those in which they are found in the wild. However, certain key conditions must be provided for most species. Therefore, prior to establishment, the site should be assessed for suitability for the planned plantings as informed by the institution's collection policy (Chapter 3). The prevailing environmental conditions such as maximum and minimum temperatures, soil type, soil pH, wind and rainfall levels should all be assessed before initiating the groundworks. The establishment process must consider many factors, some of which may need to be carried out well before planting is planned. This could include the preparation of planting material, such as hardening off propagated material over a period of weeks or months, potting on to build up a root system, and root pruning large woody plants over a period of 1-2 years in advance of transplanting.

- **Preparation of the site**

This will include:

- Preparation of the soil and substrate, the addition of organic matter, minerals or drainage; the creation of shelterbelts or microclimates, installation of irrigation.
- Drawing up a planting plan (Figure 6.1), bed numbers and records for material to be planted out.
- Provision of appropriate hand or mechanical tools and materials for each process at each stage, such as tractors, pallet lifters, mechanical diggers, trolleys, wheelbarrows, hand tools, buckets, hoses, watering cans, bags and hessian cloth, additional compost and substrate, organic matter, stakes and ties, granular fertiliser, mulching materials and labels.

Figure 6.1 Planting plan at the Royal Botanic Garden Edinburgh



6.6.2 Planting

Protocols and methods for planting out should be produced and followed for each site as these may vary according to the species and types of plants. General considerations which should be observed for all species and situations include:

- **Care during the time of planting** – plants will establish better if they are not exposed to stress during the moving process. Before planting, they may need to be watered and protected from excessively low or high temperatures and with the roots shaded.
- **Planting at the appropriate point in the plant's lifecycle** – while for some species this is likely to be when the plant is not in active growth and when temperatures are least extreme, others may prefer to be transplanted when in a state of growing rather than resting. It is also important to observe the correct planting sequence, that is, large plants which provide structure to the scheme first, followed by plants of decreasing size.
- **Records and data management** – records should be made and the overall database updated as planting is carried out with data kept for each species and numbers planted (Chapter 5). This information should be stored securely for reference during maintenance. Bed numbers should be marked on the Planting Plan and plants provided with temporary, or, if available, permanent labels. One person should have ultimate responsibility for, and control of, this element of the planting operation.
- **Team engagement** – ensure the availability of appropriate numbers of staff for each process at each stage. Taking the time to dig the right holes for the plant can help quick establishment, the benefits of which will be reaped after planting. This is important in areas which may have never been dug before or exhibit stony soils which are notoriously difficult to permeate with hand or mechanical tools. It is a task which can take a surprisingly long time.

Planting up a herbaceous bed. Fertiliser is added to the planting hole to provide nutrients for the establishing plant. (Image: Neil Davidson)

Planting up a rock garden bed at a cool and shady time of day at the National Botanic Garden Nepal to ensure that plants do not dry out too much in the planting process. (Image: Neil Davidson)

6.6.3 Establishment

Immediate and subsequent care at appropriate points post-planting is essential for successful establishment of new plantings. In the short-term aftercare should include application of water and mulches, protection from unusual weather conditions and pests, and provision of support. Examples of these could be fleece, shading, mulching mats, wire cages and stakes. In the weeks and months after planting they should be regularly and thoroughly inspected, especially regarding the appearance of pests or diseases and adjustment of stakes and ties.

To increase success, a planting plan (Section 6.6.1) including positioning of plantings plus a written work programme noting all the tasks, procedures and important dates starting up to a year in advance is useful. This can help to ensure that these considerations are made early and therefore a smooth transition is made from nursery to the final planting position. Efficient aftercare procedures also reduce any remedial work which can be required if plantings do not establish well, thereby saving time and resources and increasing the chances of successful plantings in the long-term.

Newly planted beds have been watered thoroughly and mulched with leaves to maintain moisture levels. All the plants should be watered regularly in dry conditions until they show signs of establishment. (Image: Kate Hughes)

6.6.4 Maintenance – Establishing a Horticultural Management Plan

Once outplanted and established, ongoing maintenance is required to sustain the plants and planting schemes so that they fulfil their purpose. Appropriate horticultural standards and maintenance regimes are crucial to a successful botanic garden, but the level of maintenance varies depending on the objectives and size of the institution:

Key questions

- What specific aftercare measures are required in the short and long-term?
- What are the seasonal maintenance requirements?
- What are the likely pest, disease and disorder issues?
- Is irrigation required in the long-term, post establishment?
- How will a long-term maintenance regime be implemented – are specific staff skills and training required such as arboriculture operations or pesticide application?
- Is specialist equipment required?
- Are there structures housing living collections which require maintenance?
- What type of plant records and level of detail should be documented for the collection(s)?

A horticultural management plan either for specific groups of plants (Case study 6.4) or the plantings as a whole will ensure that the main horticultural tasks are considered and resourced, and that any issues with these are more easily anticipated. Once plantings have established there will be a need to review them and consider the need for replacement, gapping-up or thinning out.

CASE STUDY 6.4

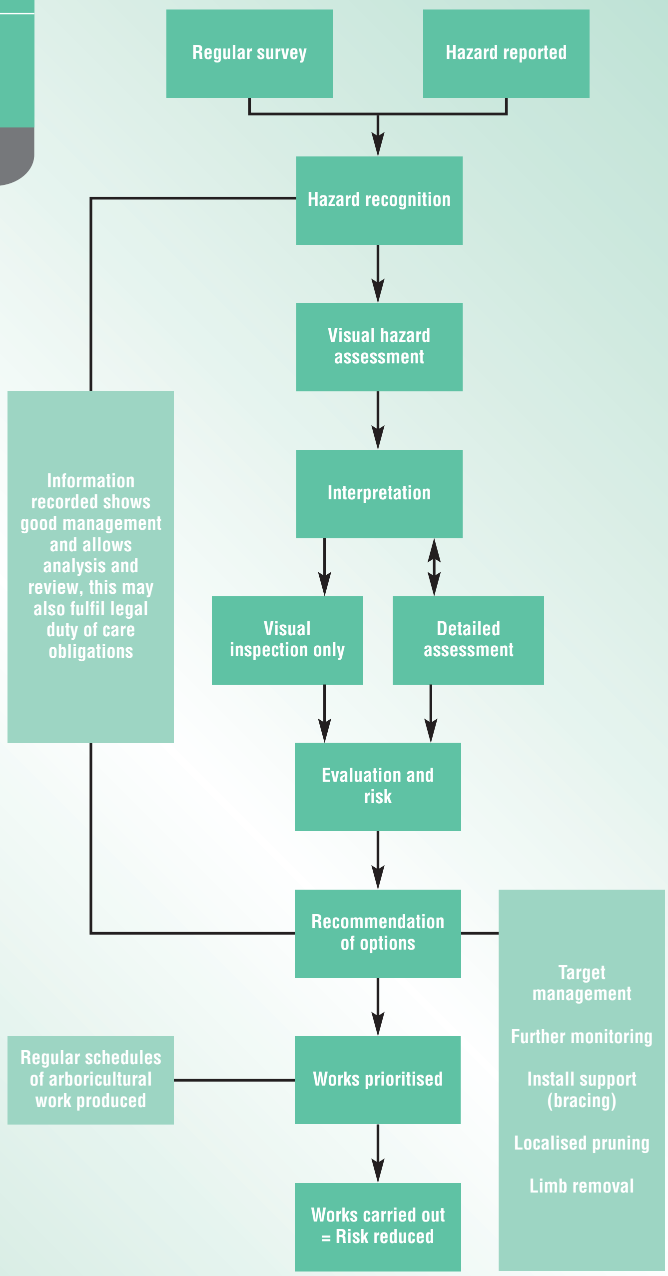
Tree Risk Management at the Royal Botanic Garden Edinburgh

William Hinchliffe, Edinburgh, United Kingdom

There is a clear professional responsibility for botanic gardens to give consideration to the risk of injury to staff or visitors from falling branches or trees. An effective system for managing risks from trees must identify trees and groups of trees by their position and degree of public access. A map with areas identified as either frequent or low public use is useful. This allows risks associated with tree stocks to be prioritised and helps identify any checks or inspections required.

At the Royal Botanic Garden Edinburgh, a Tree Risk Management Strategy has been prepared and is implemented by a team of trained arborists. They are responsible for reporting on, maintaining, developing and protecting the tree collection. In places where trees are not subject to frequent public access individual tree risk management records are unlikely to be necessary. Documentation may however be desirable for other reasons such as growth rate data collection and monitoring plant health.

For trees in frequently visited zones, a system of periodic checks is implemented. The flow chart on the right shows how tree works are generated and scheduled following periodic checks or reporting of a hazard. In this way the risks associated with the trees on-site are reduced.



Key components of the horticultural management plan:

• Labelling and record keeping

Accuracy of the plant records is a vital part of maintaining botanical collections (Chapter 5). Plants can move locations by themselves in the botanic garden by self-seeding, layering or suckering. They can also interbreed or be pollinated and then disperse seed. Horticulturists caring for the plants need to keep track of these events and treat them accordingly, whether this involves removal or re-naming and labelling. Regular checking and removal of labels of dead individuals is important to prevent errors in plant identification and record keeping.

Verifying that the recorded names are correct prior to planting, National Botanic Garden Nepal. (Image: Kate Hughes)

Drawing up the label order and verifying names involves computer and literature checks. National Botanic Garden Nepal. (Image: Kate Hughes)

• Irrigation and feeding

Almost all plants in all conditions require initial irrigation on transplantation to their final position. Some will require high levels of irrigation to establish, depending on the prevailing weather conditions and the requirements of the species. If required, fertiliser can be added in granular or liquid forms, the former in particular, can be incorporated in the planting hole. The latter is especially relevant for long-term maintenance of plants in pots. Liquid feed can also be applied through the irrigation system.

Liquid feeding at the Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

• Pruning (including arboriculture)

Regular pruning and training of plants is an essential part of the maintenance regime of all botanic gardens regardless of their size or plant collections. The purposes of pruning include regulating flowering and fruiting, removing dead and diseased branches, shaping shrubs if they are growing unevenly or removal of branches if they are in the way of paths or roads. Some species and cultivars display coloured stems more vividly if coppiced close to the ground each year.

• Pest, disease and weed control

Collections will at times develop pests and diseases. The acceptable threshold needs to be decided before control methods are implemented. Measures can either be preventative or eradicative. It is to the advantage of any botanic garden to keep the application of chemicals to a minimum and instead, where possible, employ cultural and physical measures. Application of chemicals should be the last resort or reserved for environments where there are no other options. This can be done by operating a system of Integrated Pest Management (IPM). This integrates a range of control methods to eradicate, or keep a pest/disease problem below the threshold of concern (Case study 6.5). Methods employed can include biological control agents, selective pesticides, cultural and physical control techniques (Helyer *et al*., 2003). In some areas, certain pesticides should not be used such as near fish ponds or other waterways where further spread of, and contamination with the chemicals, would be highly likely.

Above and below: protection from small pests and cold temperatures, Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

Weed control is one of the main occupations of the horticulturist as weeds compete with planted specimens for water and can be unsightly. Where optimum conditions are being created for the cultivation of desired plants, many other undesired ones also find the conditions that they need to thrive. The methods of weed control will vary widely dependent on the type of weed.

The most environmentally sustainable approach to weed control is through cultural methods and physical removal. However, this requires sustained activity by staff, possibly with machinery which increases the costs of this approach. Many institutions manage a balance of different methods on the basis of IPM principles to manage weed control (see Smyth *et al*., 2013).

- **Composting**

Recycling the plant waste material is a good way to recycle nutrients in the botanic garden, and has horticultural and sustainability benefits. All botanic gardens should aim to make and use compost from the plant waste generated on site, although additional organic matter may need to be purchased to address specific requirements. If the plant waste contains pests, a separate, insulated compost heap, or burning the material will have to be considered.

Weed control at the Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

- **Growing media**

Additional substrates and additives to the prevailing soil conditions may be required for some species, particularly for plants in containers under the protection of structures such as polytunnels or glasshouses. The types of growing media available are extremely variable, and the availability and use of these will vary according to local and international markets.

- **Managing climate change**

In addition to managing light availability, insolation, wind, etc. for instance through shading structures and selection of sheltered locations, botanic gardens should consider the possible impacts of climate change both for infrastructure and the collections. Where impacts are noted due to climate change, these should be incorporated into the horticultural management plan and changes in practices and resources accounted for.

Preparing soil mixes at the Royal Botanic Garden Edinburgh (Image: Royal Botanic Garden Edinburgh)

CASE STUDY 6.5

Integrated Pest Management of tropical water plants at the Royal Botanic Garden Edinburgh

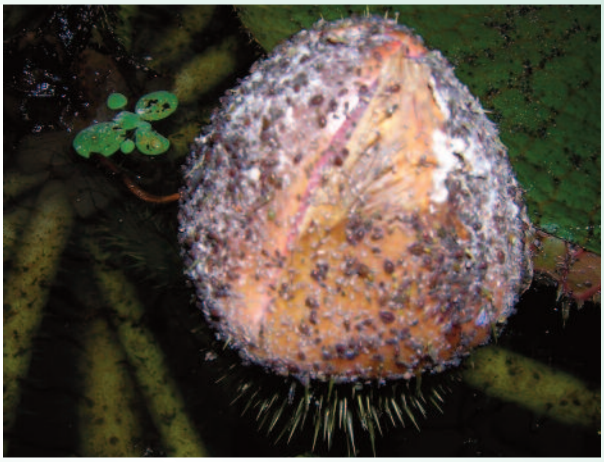
Pat Clifford, Edinburgh, United Kingdom

Despite the strictest acquisition and quarantine procedures, botanic gardens can host a wide range of pests. Decisions have to be made regarding acceptable levels of pests. In the past staff at the Royal Botanic Garden Edinburgh (RBGE) have discussed whether there might be an educational role for allowing a level of pest presence in some living collections. Currently, there is an expectation that there should be no pests accepted for plants of conservation concern, or into which many resources had been invested to source and raise the plants.

A system of Integrated Pest Management (IPM) is in operation at RBGE in order to keep chemical use to a minimum. For instance, the victoria water lily, *Victoria amazonica*, from the Amazon rainforest of Brazil, grown in the tropical glasshouses, produces enormous leaves with beautiful flowers much loved by visitors. Due to the high temperature, soft growth and lack of predators, the plants easily succumb to sap-sucking aphids preventing leaf growth and ruining the display if an infestation is allowed to take hold. Chemicals cannot be used because they would kill the fish in the pond. The following measures are taken to prevent this without the use of chemicals:

1. A cultivar is selected with faster and more vigorous growth.
2. The plant is completely free of any pests when it is moved from the propagation facilities where seed was germinated and grown on to the final planting position.
3. When the leaves are small and aphids are spotted, a hose is used to spray the insects into the water; the fish will feed on them.
4. When the leaves get bigger and produce the characteristic pronounced lip, it is no longer possible to wash the insects off the leaves. Biological controls are introduced at this point. This involves a parasitic wasp (*Aphidus colemanii*) and a predatory midge (*Aphidoletes aphidomyza*) (Clifford, 2005). It is important that biological control is introduced at the right time and at the correct dosage, both in the season and appropriate to the growth stage of the plant and pest.
5. It is fortunate that these insects are successful at keeping the aphid populations at a negligible level because chemicals cannot be used in the pond. However, the same steps and considerations are made for plantings where chemical control is an option.

If this solution had not been successful, the next step would have been to introduce 'soft chemicals' (i.e. chemicals with a physical mode of action), where there is no risk of developing pesticide resistance (e.g. with plant and fish oil-based preparations, urea-based products and horticultural soaps). The choice of the product will depend on national legislation and the context in which the chemical is being used. If this is ineffective, the use of 'hard chemicals', governed by strict guidelines, could be considered. When these chemicals are applied, areas should be spot-treated to keep the quantity used to a minimum. The mode of action should also be considered. A contact-action insecticide will be active for less time than a systemic one (i.e. it will be less persistent). A soft chemical can be used in conjunction with a hard chemical to increase the effectiveness of the latter. Cultural methods can also be used to minimise chemical use, for example by simply removing any heavily infested parts.



Aphid infestation of Victoria water lilies, Royal Botanic Garden Edinburgh. (Image: Pat Clifford)

Biological control application, Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

6.7 HUMAN RESOURCES FOR HORTICULTURE

At every stage of planning and establishing living collections, personnel are required. A number of aspects need to be considered to ensure appropriate skills and training to maintain the plants to a high standard:

Key questions

- What skills and type of work are required to maintain the collections?
- What are the legal, mandatory training or qualification requirements?
- Could or should any skills or operations be contracted out?
- How many plants under structures are maintained?
- Is machinery available to mechanise some tasks?
- Can volunteers be used for some tasks?

Training in the use and maintenance of horticultural tools, Jardín Botánico Francisco Javier Clavijero, Jalapa, Veracruz, Mexico. (Image: Kate Hughes)

Training in pruning techniques, Jardín Botánico Francisco Javier Clavijero, Jalapa, Veracruz, Mexico. (Image: Kate Hughes)

6.7.1 Factors Influencing Staff Requirements

The scale and size of the botanic garden, diversity of the collections and the funding structure will influence the staffing of the institution (Chapter 2, Sections 2.3.1 and 2.3.2). All botanic gardens will require a horticultural manager or senior horticulturist, or, as often referred to, a head gardener or curator. While roles and responsibilities overlap, generally the head gardener would manage the care of the collections while the curator would also review and maintain the species' content of the collections in accordance with the missions and strategies of the institution. The extent of the staff portfolios and functions required varies according to the nature of the institution but personnel will be required for the management of biosecurity and quarantine facilities (Section 6.8.3), pesticide and chemical treatment and record keeping and labels. In a large botanic garden, staff may focus on one particular area of specialisation, but generally, horticulture staff are multi-skilled and deliver a variety of roles.

- **Scale and size**
  The scale and size of the botanic garden will influence the number of staff required. Under almost all circumstances, the greater the size, the more staff are needed. However, staff complement will also depend on the diversity of the collections, planting style and corresponding intensity of labour required to manage and maintain these areas. Many botanic gardens of both medium and large sizes include a range of lower maintenance sections which tend to have a smaller number of species in greater quantities, such as meadows and arboreta, to areas with high numbers of species which are more maintenance-intensive, such as rock gardens and glasshouses.

- **Diversity of plants and habitats**
  The diversity of the species cultivated and the divergence of the botanic garden environment compared to their native habitats will have a great impact on the intensity of maintenance required and therefore the numbers of staff required. A botanic garden which maintains a number of different types of collections and species, for example alpine plants as well as tree collections, will require a greater range of skill sets, qualifications and therefore people to look after this diversity. It is common to find proportionally smaller areas which may house a greater diversity of species, or species which are not native to the local environment. As plants are moved further away from their native habitat and environmental conditions they require more intensive horticultural input.

- **Use and purpose**
  How the collection is used and what for (Chapter 7), including the audience for which it is maintained, will impact on the type of cultivation and input required. Collections maintained for education or research may involve more input because they have to be closely observed or cultivation conditions are varied, and require regular adjustment and monitoring. Collections used extensively by school groups will need high levels of maintenance to ensure that the necessary elements for educational use are present at the appropriate times and cater for large numbers. A botanic garden with a reputation as a dazzling tourist attraction will also have high inputs to maintain a formal gardening standard which corresponds to the reputation. A range of extremes and priorities exist across the spectrum of botanic gardens. An institution with a primary purpose of research and conservation may not prioritise high visual standards, whereas botanic gardens which rely heavily on income from visitors and tourists will need to prioritise the displays in their maintenance regime.

Ornamental beds of seasonal displays have higher maintenance requirements than mixed or native plantings which are not changed regularly. Here, protection of tender ornamentals from frosts at the National Botanic Garden Nepal has been installed. (Image: Kate Hughes)

- **Gardening style**
  The style of gardening and horticultural methods applied will impact on staff numbers required. For example, herbaceous border displays which are changed throughout the season, such as annual bedding plants, will tend to need greater management input.

- **Growing environment and changing the prevailing microclimate**
  Plants under structures generally require more management in order to maintain the intended conditions. The more a plant cultivation environment is adjusted from the prevailing climate, the greater the input by staff required. This is comparable with the incremental increase in resources required with every move away from the natural growing conditions (Section 6.2).

- **Use of machinery**
  In some cases, the maintenance of plants can be assisted effectively with the use of machinery. Automation, or more usually, semi-automation of tasks still requires significant human input and resources but machinery can reduce the amount of human effort required and therefore impacts on the levels of staffing required (Case study 6.6).

6.7.2 Engaging Volunteers

Many botanic gardens draw on volunteers to help with horticultural work (Chapter 2, Section 2.3.2). They can provide a welcome boost to manpower in a botanic garden. However, a number of considerations should be made when working with volunteers. There should be a formal application and interview process in which both the botanic garden staff and volunteer can find out whether they are suitable for the work which is required and that it is suitable to the individual. An agreement should be reached by both parties whereby a specified commitment is made by each. The botanic garden may also cover an agreed amount of expenses incurred by the volunteer while they are working for the institution (e.g. long-distance travel to the botanic garden). The volunteer should be given the same access to facilities, health and safety clothing and equipment as core staff while working on behalf of the botanic garden. Other stakeholder groups who may have a mutually beneficial role in working for the botanic garden are people in training, including students, interns and apprentices. Advantages and disadvantages of working with volunteers include:

Advantages:
- Free of charge (except for nominal expenses);
- Enthusiasm;
- Support the paid staff;
- Alternative experiences and ideas – often way beyond what botanic gardens can afford;
- 'One-off', short-term jobs.

Disadvantages:
- Variable skills;
- More supervision may be required than for paid staff;
- Induction time;
- No guarantee of their time commitment;
- Staff may feel uncomfortable working with unpaid volunteers.

CASE STUDY 6.6

A large garden with a small team – Using machinery to good effect at Benmore Botanic Garden

Kate Hughes, Edinburgh, United Kingdom

Benmore Botanic Garden (BBG) is a well-respected visitor attraction located on the west coast of Scotland, 56 km from Glasgow. It occupies 49 hectares of densely wooded rural land which rises from 15 m to 137 m above sea level. Approximately one third of the botanic garden is fairly flat land, some of which has high maintenance formal plantings; the remaining two thirds are gradual to steep slopes. 11,000 individual accessioned plants grow in these 49 hectares and many of the plants are large trees, hundreds of them over 50 m in height, growing on shallow soil over rock. There is an enormous diversity of plants and environments, including a historic building housing over 70 species of ferns, which has to be maintained safely to a high standard for over 40,000 visitors per year, while ensuring that the botanic garden retains its wild and natural feel.

11 full time horticultural staff carry out all the work including plant records management and labelling. This is a small team for a large and diverse area all of which is maintained to a high standard. This team would have to be much larger just to keep the botanic garden safe for visitors, if it was not for the long list of large and small machinery and hand-held equipment which is used on-site. This includes large tractors and trailers, winches, timber grabs, a chipper, a band saw for cutting large trees, chain saws of various sizes, ride-on mowers, power barrows (motorised large wheelbarrows), blowers, hedge trimmers and fertiliser spreaders; all make the routine horticultural tasks quicker and easier.

The BBG team has a broad range of skills ranging from arboricultural expertise, collection and database management to formal garden maintenance. All the staff are trained to use the equipment appropriate to their main area of work. This training starts with how to use the equipment effectively and safely, and crucially includes maintenance and upkeep. It is essential to maintain equipment to get the most out of it and to ensure operator and visitor safety. As a result, training absorbs a significant part of the budget for running the botanic garden. However, the curator believes that this is a worthwhile investment because the equipment enables staff time to be used so much more efficiently. There are several levels to this training. Basic training for effective use of commonplace equipment is provided by experienced botanic garden staff, while an external contractor delivers the initial training for new equipment, or statutory and legally required training for specialised and more complex tools and machinery. The curator has to ensure that staff knowledge is always within the legal requirements for health and safety and insurance purposes, and has to be aware that legislation can change. The curator also keeps up-to-date with this by communicating regularly with colleagues and peers in the industry, and consulting industry literature.

Peter Baxter, Curator at BGG is keen to point out that there are some tasks which cannot be fully mechanised such as pruning and weed control. *"Machinery is fantastic but without the people, you can't ensure that time and valuable equipment is put to the best use. While machinery fulfils a vital function, people are essential to observe and evaluate collections, attend to visitor needs and to run a successful botanic garden. Machinery can never fully replace the staff who really enable the botanic garden to fulfil its mission"*.

Benmore Botanic Garden. (Image: Royal Botanic Garden Edinburgh)

6.8 PLANT HEALTH AND BIOSECURITY MANAGEMENT

Ellie Barham, Botanic Gardens Conservation International
Sara Redstone, Royal Botanic Gardens Kew

Invasive alien species refer to plant pests and diseases and plant species which pose a significant environmental, social and economic threat to biodiversity. Their impacts may be exacerbated by human activity, trade, habitat disturbance, pollution and climate change, amongst others. Globally, the impact of invasive alien species is second only to habitat destruction in terms of the most important cause of biodiversity loss (CBD, 2001). In vulnerable island habitats, which often represent some of the world's most precious, biodiverse and unique habitats, they can be the primary cause of extinctions.

Due to the way in which many plant collections are organised and because of the mobility of plants, staff and visitors, botanic gardens and arboreta can be especially vulnerable to the impact of invasive alien species. Such organisms can arrive in botanic gardens naturally, for instance through range extension, but introduction through human activity, whether deliberate or accidental, is the most common pathway. Plant material, especially large specimen plants, are a significant pathway for introduction of plant pests and diseases, but many other vectors and pathways exist. Commercially sourced plant material poses as great a risk in terms of the introduction of invasive alien species, as material which has been wild collected.

However, risks are not restricted to horticultural material managed by horticultural staff. Managers need to consider the risks associated with the movement of other commodities in other departments – including plants for sale areas and herbarium specimens, artefacts for economic botany and museum collections, dried goods, flower arrangements, soil and growing media, chipped bark and woody packaging material, including pallets.

Outbreaks of new pests, diseases or invasive plant species can be difficult and costly to identify and eradicate, and control measures may impact non-target organisms, so prevention rather than 'cure' should always be the objective.

Whether botanic gardens are receiving or sharing plant material, it is vital to ensure that neither the plant itself nor any associated pests or diseases affect the collections of the botanic garden or of the wider environment. Careful planning, preparation and management of plant material, good record keeping and robust procedures can help safeguard biodiversity and avoid serious environmental and economic impact. Annually 35 million hectares of forest are damaged by forest pests alone, with the temperate and boreal zones being most severely affected (FAO, 2010).

6.8.1 Structure and Plant Health Governance

Since the late 19th century nations have recognised the need for international cooperation to try and minimise the impact of invasive alien species. This was a result of tragedies such as the Irish potato famine and the introduction of Grape Phylloxera to France in the 1860s which rapidly destroyed two thirds of European *Vitis vinifera* vineyards causing enormous economic and social damage (Skinkis *et al*., 2009).

There are several tiers of plant health legislation and controls (Box 6.3). A key driver in many countries is to maintain high levels of trade whilst also providing a measure of biosecurity. In most countries legislation focuses primarily on known risks – pests that have already been identified and listed. New threats are constantly emerging and consequently pose a significant challenge for legislators to keep policies current. For these reasons, it is important that botanic gardens understand and address related issues. Reliance on complying with legal obligations alone will not safeguard plant collections or the environment (Brasier, 2008).

Box 6.3 General overview of plant health governance worldwide

National

National Plant Protection Organisations (NPPOs)
Organisations designated by a country's government responsible for protecting natural plant systems against invasive alien species and preventing native organisms becoming invasive in other countries.

https://www.ippc.int/en/countries/all/nppo/

Regional

Regional Plant Protection Organisations (RPPOs)
Inter-governmental organisation representative of particular regions; NPPOs are often (but not always) coordinated by RPPOs.

https://www.ippc.int/en/partners/regional-plant-protection-organizations/

International

International Plant Protection Convention (IPPC) The IPPC is a multi-lateral treaty for global cooperation in plant protection; making provisions for governments to protect their plant resources (cultivated and wild plants) from harmful pests. It is overseen by the Food and Agriculture Organisation (FAO).

https://www.ippc.int/en/

Commission on Phytosanitary Measures (CPM)
Reviews the state of plant protection around the world, identifies actions to control the spread of pests into new areas, adopts guidelines for the recognition of RPPOs; and cooperates with international organisations on matters covered by the IPPC. The CPM adopts International Standards for Phytosanitary Measures (ISPMs) which aim to prevent pest introductions and spread whilst still facilitating trade.

The CPM is an annual meeting held at the FAO headquarters in Rome, Italy, which governs the IPPC. RPPOs and NPPOs are members of the commission and each is responsible for implementing work for standards development, information exchange and capacity building within their respective countries/regions.

https://www.ippc.int/en/core-activities/governance/cpm/

6.8.2 Plant Health Terminology

It is a common convention in plant health legislation that both pests and diseases are referred to as 'pests'. Plant material that may or may not pose a biosecurity risk is legally categorised as one of three types:

- **Prohibited:** Poses such a serious risk to horticulture, agriculture, forestry or the environment that import is only permitted under authority of a licence. In the UK and EU this category includes many species of rooted plants and trees, often of genera or species related to those of economic or environmental importance within Europe. Importing, keeping and using material which is prohibited usually requires a licensed containment facility.

- **Controlled:** Normally requires a phytosanitary certificate issued by the plant protection service of the exporting country; includes those cuttings, rooted plants and trees that are not prohibited, bulbs, most fruits, certain seeds and some cut flowers.

- **Unrestricted:** Considered to present little or no biosecurity risk and is not subject to routine plant health controls; includes nearly all flower seeds, some cut flowers and fruit and most vegetables for consumption (except potatoes).

Quarantine organisms are plant pests listed in legislation and are prohibited for import. They normally pose a significant threat to plants in horticulture, agriculture, forestry or the environment. Many quarantine organisms are not only damaging in their own right but can act as vectors for important plant pests or diseases.

Botanic gardens that import prohibited plants, soil and growing media and plant pests and diseases normally need to operate a containment laboratory or quarantine glasshouse, licensed by their National Plant Protection Organisation, to enable them to manage this material safely.

6.8.3 Biosecurity Management

KEY MESSAGE

Botanic gardens and arboreta that acquire, move and share plant material on a regular basis, need to implement biosecurity measures to protect plants from potentially introduced pests and diseases.

There are potential long-term plant and human health hazards associated with the introduction of plant material, growing media and soil. Botanic gardens and arboreta that acquire, move and share plant material on a regular basis, sometimes internationally, need to implement biosecurity measures to protect plants from such threats. It is strongly recommended that biosecurity facilities and procedures are developed and implemented before any plant material is brought on-site. There can be significant plant health threats from material which is not controlled, particularly from commercial sources.

- **Biosecurity measures**

Biosecurity measures are precautionary and are aimed at reducing the risk of introducing and/or spreading harmful organisms. Preventing the introduction of plant pests and diseases, rather than eradicating or controlling new introductions, should be the priority as it is simpler, cheaper and less disruptive to an institution. It may be decided that biosecurity is not an issue, for example if all plants are purchased from local nurseries. However, it must be realised that once established a pest problem can be extremely difficult to eradicate (Long *et al*., 2006) and can threaten not only live plant collections but also herbarium specimens, art and archives too, as well as the wider environment (particularly in the case of pests which are able to move large distances of their own accord). Botanic gardens also have a responsibility to stop the spread of pests and diseases. They should ensure any plants leaving their collections are clear of any potentially harmful organisms, whether this is to share plants and plant material with other institutes, sell plants to visitors or use specimens in recovery programmes in the wild (Table 6.2).

Similarly, botanic gardens have a responsibility to report any findings of damaging organisms (particularly quarantine organisms as above) to their National Plant Protection Organisation. Quick discovery and identification can drastically improve any eradication, containment or control management programmes; thus mitigating the impacts of an outbreak (Case study 6.7).

Pinus muricata showing dieback symptoms. (Image: Peter Symes)

CASE STUDY 6.7

Melbourne Gardens, Royal Botanic Gardens Victoria discover first case of *Diplodia africana* on pines

Peter Symes and Chris Cole, Melbourne, Australia

Royal Botanic Gardens Victoria (RBGV) has a beneficial relationship with agencies charged with plant protection and biosecurity across the State of Victoria. For example, RBGV has made significant contributions through the development of weed risk management procedures, involvement in industry reference committees, and fulfilling a role as a sentinel site for exotic pest incursions. In order to detect new pests in a timely manner, staff have a high level of awareness.

In June 2010, horticultural staff reported unusual dieback symptoms on branchlets of some *Pinus* spp. Subsequent samples of *Pinus muricata* (Bishops Pine) were submitted to Crop Health Services (CHS), Department of Primary Industries, Victoria. The symptoms included stem cankers, dieback, needle death and resin seepage from infected branches. An initial assessment from CHS reported *Botryosphaeria* sp. as the likely cause of the damage. However, due to the unusual nature of the dieback, and past experience of *Botryosphaeria* sp. which is usually more commonly found as a secondary disease in stressed plants, staff decided to investigate further. A DNA sequence analysis revealed that the primary pathogen was in fact *Diplodia africana*, a species which had been previously identified in South Africa, but only on *Prunus* sp. Further surveying and diagnostic analysis revealed that a *Pinus patula* in close proximity to the original host was also infected with *D. africana*. This finding of the pathogen was a new record for both Australia and for *Pinus* as a host.

Diplodia species are associated with symptoms such as dieback, shoot blights and cankers. Often *Diplodia* infections are initiated due to biotic or abiotic stresses (such as physical injury). In the case of Melbourne Gardens, the precursor damage was thought to result from a severe hail storm that had occurred in March 2010.

Biosecurity Victoria (BV) is the state agency responsible for domestic quarantine and plant protection of natural and cultivated plant assets in Victoria. One key risk to be mitigated was the damage *D. africana* might cause to the *Pinus radiata* plantation industry (wood, pulp, potting mixes). Experts from BV worked closely with management and staff from Melbourne Gardens to contain and seek to eradicate this pathogen. Some of the measures included barricading the infected areas, restricting arboricultural works on *Pinus* to emergency works only, and halting movement of plant materials (especially *Pinus* spp.) within and across the Gardens' boundaries. Further surveillance (and pathogenicity testing) continued for a few months, to ensure the pathogen had not spread further within the Gardens or into the local environment. Providing accurate, grid-based locations and maps of all *Pinus* spp. to BV staff also resulted in more efficient surveys. It was eventually determined that this pathogen had not spread beyond the infected *Pinus muricata* and *Pinus patula*. In October 2010, the more severely infected *Pinus muricata* was removed to minimise the excursion risk of this pathogen. The removal was a joint operation between the Gardens and Biosecurity Victoria and occurred under stringent quarantine conditions; meaning containment zones were setup, and rigorous sanitation and hygiene protocols were observed. All plant material (including sawdust) removed was placed into a large transportable bin, sealed with plastic, and transported for disposal as deep burial in a prescribed landfill location.

Ultimately, *D. africana* was not found to present any more pathogenicity than other *Diplodia* sp. diseases already present in Australia that afflict Pines. This example highlights the importance of promoting staff awareness and the complementary roles of diagnostic institutes and botanic gardens. In this case, Melbourne Gardens were integral in providing early warning, active surveillance, identification and management. The Gardens also provided key information which enabled policy makers to make a reliable judgement of the threat the pathogen posed; e.g. pathogen pathogenicity and host range. For particularly damaging organisms; quick identification, the establishment and initiation of viable management programmes, and robust surveillance and continual monitoring are all paramount in mitigating impact.

This example of best practice shows the important role that botanic garden staff can play in diagnosing a problem. Supporting staff's professional development is a powerful tool in establishing effective biosecurity within botanic gardens. Specifically, the development of staff's profound knowledge of a given plant's life-history, recall of previous management regimes, recognition of 'out of the ordinary' symptoms, and identification of common abiotic causes can all aid biosecurity best practice.

Containing and wrapping of all vegetative material on-site. (Image: Peter Symes)

Inspection of plant material in quarantine at Royal Botanic Garden Edinburgh. (Image: Royal Botanic Garden Edinburgh)

• Biosecurity staff

Botanic garden managers should identify staff responsible for biosecurity and ensure they have adequate support and resources. All botanic garden staff working in science, catering, shops, maintenance, etc. need to be aware of and engaged with the organisation's approach to biosecurity.

Staff directly involved in ensuring biosecurity at the botanic garden should receive appropriate training and support. They should develop procedures for the management of incoming and outgoing plant material and ideally establish a single point of entry where plants and other materials are received, inspected and (where necessary) held and treated or destroyed. A single point of entry for a botanic garden will also assist with compliance with international conventions such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora as well as the Convention on Biological Diversity (Chapter 4, Sections 4.3 and 4.4). Herbaria (Chapter 7, Section 7.1.3) will also benefit from using similar procedures.

• Quarantine and isolation facilities

On arrival, plants should be held in a 'quarantine area'. This can range from a bench or bay in a glasshouse or polytunnel to an enclosed area in the botanic garden or a purpose-built facility (Case study 6.8). Unless the plant material requires a statutory quarantine period (consultation with the National Plant Protection Organisation) it should be held for a minimum of six weeks where possible.

Recommended essential requirements for effective quarantine facilities include:

- Secure and separate location, with regulated access for staff (and visitors), locked doors, barriers and appropriately signs;
- Controlled drainage;
- Separate, dedicated tools and equipment;
- Plant inspection and diagnostic skills and equipment;
- Facilities for pesticide application;
- Facilities for cleaning and disinfection;
- Facilities for incineration and disposal of infected material;
- Regular monitoring for pests and diseases; use of traps such as sticky traps, pheromone traps, light traps, etc.

Whether working in a quarantine area or carrying out field work in sensitive locations such as in island habitats, staff should always operate from areas of low to high biosecurity risk. This will help minimise the risk of transferring plant pests to new areas.

CASE STUDY 6.8

Plant material quarantine procedure at Royal Botanic Garden Edinburgh

Fiona Inches, Edinburgh, United Kingdom

When living plant material is collected in the field, plants are packed carefully and checked every day and all decaying or unwanted material is disposed of; soil or growing media is only removed prior to inspection for export. Only whole plants or sections of stem for cuttings or rhizomes are required to go through phytosanitary procedures. Seed and spores can be carried through borders without inspection in Britain. This may not be the case in other countries. Local and country regulations governing the movement of organisms need to be consulted before crossing borders with plant material.

Plant material is transported to the Royal Botanic Garden Edinburgh (RBGE) following phytosanitary inspection at the airport. It is carried in sealed boxes which are only opened once inside the quarantine facility. The door to these facilities is kept locked at all times when not in use. Once the plants have been inspected and descriptions written, they are potted up and processed within the quarantine reception area. Cultivated there for a minimum of 3-6 months, horticulture staff then establish whether they are free of pests and diseases. Tubers, rhizomes and corms are kept longer in the quarantine facility for a minimum of six months. The plants are then inspected by the RBGE plant pathologist before leaving the quarantine unit for planting outside. Sometimes plants do not pass this inspection and, even though growing well, have to remain in the isolation facilities until a specific pest or disease has been removed. There is a policy of zero tolerance for organisms in the facility which means that biological controls cannot be used as pesticides.

The quarantine unit is inspected four times per year to ensure that it complies with isolation and other requirements by the Agriculture, Food and Rural Communities Directorate, the regulation body of the Scottish Government. The licence is renewed every three years, which requires an additional inspection.

The longest a plant has ever been cultivated in the quarantine unit at RBGE is five years for a slow growing xerophytic Saudi Arabian member in the family of the Asclepiadaceae. Many plants are given a clean bill of health and released from quarantine within six months of collection. Plants received from within the United Kingdom go through a similar isolation and inspection process, plants from European Union countries go through the quarantine process described here although there is no legal requirement for this, while plants from other parts of the world are legally required to go through this process.

Door of quarantine facility at RBGE. (Image: Fiona Inches)

Table 6.2 Plant material biosecurity hazards and risk mitigation measures

Type of material	Risk	Notes	Actions
Certified seed	Low	Under ISTA (International Seed Testing Association) regulations certified seed has certain tolerance levels for infection by fungal and bacterial diseases so is unlikely to be totally disease free. This may be important if such material is grown close to plant collections that are also susceptible. seedtest.org/en/home.html	Monitor seedlings and surrounding plants once planted out.
Non-certified seed	Medium to high	Seeds have the potential to carry infections by fungal and bacterial diseases so are unlikely to be totally disease free. Similarly, insects can store themselves in seed, both in larvae and egg form.	Quarantine for 4-6 weeks and monitor seedlings and surrounding plants once planted out.
Natural source seed	Medium to very high	May carry viruses and other diseases as well as insects internally and a range of pathogens externally. Seeds and fruits collected from the ground should be treated with particular care. If there is sufficient material, break open a few seeds to check for signs of insect pests (e.g. weevils). These may not necessarily pose a risk to plant collections themselves but could escape and threaten natural aphid populations by affecting their ability to reproduce (e.g. rose seed weevils).	Where suitable, a short soak in a surface sterilant such as a dilute solution of hydrogen peroxide may help reduce microbes carried on the seed coat. Peroxide can also be a useful way of triggering germination, but is only practical for robust seeds – excluding fine seed from plants such as begonias and orchids. Careful inspection and screening of seedlings and young plants can also help identify pest or disease issues.
Tissue cultures	Low to high	Generally considered relatively low risk but this depends very much on the source, motherstock and growing conditions. May carry latent infections and viruses.	Monitor for a number of weeks upon arrival, where possible, keep separate from living plant collections.
Cut flowers	Low to high	Dependent on type, source and cultural conditions e.g. tropical flowers such as *Phalaenopsis* have been found to be infested with *Thrips palmi*; cut flowers have been found to be infested with quarantine pests such as *Bemisia tabaci* and leaf miners (e.g. *Liriomyza* spp.).	Carefully inspect upon receiving.
Dried flowers	Low	Low risk to live plants but check for storage pests – e.g. weevils and beetles – as these may cause havoc in areas such as herbaria, libraries and galleries.	These will need to be treated appropriately (e.g. fumigation, heat treatment, rapid freezing) if entering sensitive areas such as herbaria, libraries and galleries.
Dried artefacts	Low to medium	Risk to plant collections low-medium but risk to preserved collections (e.g. herbarium) or art library collections can be high.	Will need to be appropriately treated (e.g. freezing) prior to being added to collections.
Reproductive material or storage organs (e.g. bulbs, fruits, etc.)	Medium to high	It is common for interceptions of non-native plant pests and diseases, including quarantine organisms, to be found on and in imported fruits and vegetables.	Monitor for a number of weeks upon arrival, where possible, keep separate from living plant collections.
Plants	High	Pose a threat whether from commercial sources or from other organisations, from in-country or further afield.	Plants should be carefully inspected and quarantined (for 4-6 weeks) before integration into plant collections.
Large specimen plants	Very high	These plants, especially if in leaf and with large rootballs, are a significant pathway for the introduction of plant pests and diseases and other non-native species.	It is crucial to know where plant material originated – it may originally have come from countries outside your region and could be accompanied by unwelcome biodiversity. Ideally this type of material should only be aquired after rigorous risk assessment. Quarantine for at least 6 weeks.
Wood, timber, bark samples	Medium to very high	Can carry nematodes, insect pests and diseases, as well as other non-native species. Wood with bark attached is considered particularly high risk.	Under International Standards for Phytosanitary Measures (ISPM) 15, woody packaging material (including pallets) should be marked to show it has been treated by chemicals or heat, ensuring it is not infested with live beetle larvae (e.g. Asian longhorn beetle), nematodes and other plant pests. ispm15.com/ISPM15_Revised_2009.pdf
Soil and growing media	Medium to very high	Can harbour a range of invertebrates, including flatworms, nematodes, insects and microorganisms such as fungi and bacteria.	Avoid importing/exporting plant material with soil and growing media. If unavoidable, quarantine for at least 6 weeks.

6.8.4 Biosecurity Best Practice

- **Field work**

  A large proportion of notifiable pest species not only cause damage in their own right but can be vectors for other pests and diseases, e.g. nematodes, viruses and fungi (for instance, *Ophiostoma ulmi*, the fungus responsible for Dutch elm disease, is vectored by the Scolytus beetle). Where botanic garden staff are involved in fieldwork, careful preparation, planning and good hygiene measures should be followed to avoid the introduction and/or spread of invasive alien species.

- **Sourcing**

- When sourcing plants from commercial sources, use reliable suppliers with a proven track record of providing healthy/pest-free plants – if possible, visit nurseries and look at how they manage their plants;
- Contact with suppliers, for example visiting storage sites;
- Specify exact requirements on purchase order forms;
- Seek to purchase plants propagated within country; avoiding large container-grown plants, where possible;
- Avoid plants which have been treated with pesticides, as these can mask symptoms of infection.

- **Plant arrival**

  Botanic gardens acquire material from many sources (Chapter 3, Sections 3.4.3 and 3.4.4; and Section 6.3) and it is recommended that all plant material is inspected and monitored, as cultivated material often presents as many issues as that from natural sources:

- Inspect all plants carefully on arrival;
- Only accept delivery if happy that plants are free from unwanted organisms;
- Check all necessary documentation where applicable (for instance, if in Europe or sourcing European plants, check the plant passport number – EC Plant Passport UK/EW 12345).

- **Export**

  Equally, plant material leaving *ex situ* collections, especially when intended for (re)introduction purposes and population reinforcement programmes *in situ*, needs to be carefully screened for any pests and diseases it might carry. Plants should only leave the nursery if they are healthy and pest free. Useful protocols have been developed for this by the Royal Botanic Garden Edinburgh with particular reference to plants used for reintroduction programmes (Frachon, 2013).

Tuberous plants ready for shipping. (Image: Royal Botanic Garden Edinburgh)

- **Disinfection**

  This is particularly important when entering or leaving infected sites or quarantine areas where all staff (and visitors) should disinfect/clean footwear, hands, equipment and vehicles. Make disinfecting kits available which could include; brush for scrubbing footwear, bucket, water container (and source of clean water), disinfectant (differs dependent on country), hand sanitizer and associated consumables including paper towels, gloves and safety glasses.

- **Reducing risk**

  General careful management of plants within collections will greatly reduce the risk of the establishment and spread of any pests and diseases. This includes:

- **Practice good husbandry** – a healthy plant is less likely to succumb to disease;
- **Not over-fertilising plants** – overuse of nitrogen results in 'soft' growth which may be more vulnerable to attack by pests and diseases;
- **Not overplanting, and pruning trees and shrubs carefully** – to ensure good airflow to reduce the likelihood of disease outbreaks;
- **Good infrastructure** – well-maintained paths, fences and signs can not only restrict visitor movement through the botanic garden (thus reducing spread of organisms), but also stop breeding grounds for harmful organisms (muddy paths, rotting wood etc.);
- **Good irrigation and drainage** – stops the spread of organisms and generally maintains the health of plants;
- **Careful waste disposal** – all known infected plant material should be burnt to stop spread; correct composting will kill most organisms though;
- **Continuous monitoring for pests and diseases** – helps the quick identification and subsequent treatment of any outbreaks, and increases the success rate of any management measures; special attention should be paid to nursery and production areas; staff should be encouraged to observe plants carefully while caring for them, noting any significant changes in health, and using tools such as sticky, pheromone and light traps to monitor what pests are present.

6.8.5 Preventing Future Introductions of Pests – Sentinel Research

Preventing the introduction or establishment of a pest is the most cost effective management tool available in the protection of plant species from invasive alien pests (MacLeod *et al*., 2002). A significant issue in safeguarding against the introduction of such organisms is that the majority of the most damaging pests introduced into temperate forests in recent years are not considered pests in their native regions or were unknown to science before widespread damage was recorded (Kenis *et al*., 2006).

Botanic gardens and arboreta are in a unique position to aid in the identification of such 'unknowns' (Case study 6.9). Within their collections they play host to plant species that are growing outside their natural ranges. These plants can be used as so-called sentinels, and can be monitored for damage by pests and diseases. Subsequent information recorded can be reported back to the plant's country of origin, and incorporated into efforts concerning plant protection. Sentinel plants within botanic gardens can not only help identify future threats, but also provide relevant information on a particular pest as illustrated in Case study 6.7. This information can be used to determine the risk a pest poses and potentially aid in the development of appropriate eradication and/or containment programmes. It also demonstrates the value of collaboration between different institutions – botanic gardens, research institutes and governmental regulatory organisations as in the case of the International Plant Sentinel Network (IPSN) (Box 6.4).

CASE STUDY 6.9

A role for botanic gardens in plant health – the example of Charles University Botanic Garden Prague, Czech Republic

Ellie Barham, York, United Kingdom

In recent years the Czech Republic has been plagued by a non-native sawfly, *Nematus lipovskyi*. The sawfly was first recorded in the Charles University Botanic Garden in Prague in 2010; before this, *N. lipovskyi* had only been recorded in the United States. The botanic garden not only played an important part in its identification in a new geographical range, but also aided research to increase knowledge of its general biology and potential implications for the local environment. This information was subsequently used in suggesting appropriate country-wide phytosanitary measures.

The presence *N. lipovskyi* in the botanic gardens was highlighted after larvae caused extensive defoliation to *Rhododendron molle*, the insect's major host. Samples of both adults and larvae were collected and sent to the Entomological Department of the National Museum in Prague for identification. Despite being found in 2010, problems with rearing the larvae meant that it was not formally identified until 2013 after further specimens were collected from the botanic garden. Morphological diagnosis of adult insects is essential in making a positive identification, though the use of molecular analysis is increasing. Similarly, often, even if adults are found within close proximity, only rearing larvae to adults will ensure they are one and the same. In the case of *N. lipovskyi*, the larvae had not been previously described.

Once identified, Charles University Faculty of Science set up a preliminary monitoring programme in collaboration with the State Phytosanitary Administration. Field observations were carried out in the botanic garden, monitoring particular behaviours including occurrence, damage on host plants, oviposition behaviour etc.

This work has greatly increased the knowledge of the hosts for the pest, and has allowed extensive study of the insect's biology and life cycle. This information is valuable in creating effective, integrated management programmes to prevent, control or eradicate outbreaks.

A larva of Nematus lipovskyi feeding on rhododendron leaves. (Image: Martina Juraskova)

Box 6.4 The International Plant Sentinel Network (IPSN) – a novel approach to combating invasive alien pests and diseases

The International Plant Sentinel Network (IPSN) is a novel approach contributing on a global scale to the protection of plant species from invasive alien pests and diseases by increasing capacity and capability within botanic gardens and arboreta. The network provides access to a host of IPSN resources through its 'members-only area', including in-depth guides to good biosecurity practise, diagnostic sampling and an introduction to the structure of plant health governance around the world. It also provides training on what could be causing particular types of damage and a form (the Plant Health Checker) to help record signs/symptoms in a standard format whilst familiarising users with key plant health terms. In addition, links to resources from around the world, discussion forums and information on current/new and emerging threats are provided. The IPSN also runs workshops and training sessions for contributing institutions around the world, bringing botanic garden staff together with representatives from government and institutes working on plant health. The IPSN is free to join, and gardens do not have to be BGCI members to do so.

Yorkshire Arboretum learning to use molecular diagnostic testing techniques for the needle blight fungus, Dothistroma septosporum. (Image: Ellie Barham)

6.9 ENHANCING HORTICULTURAL CAPACITY

Leigh Morris,
Royal Botanic Garden Edinburgh

For a botanic garden to deliver its mission, people with specific skills and knowledge are required in the horticultural team. Some skills and knowledge may be fundamental to the daily operation of the botanic garden, whereas others may only be required to meet targets or ambitions over a shorter period of time. This section is about the skills and training that need to be considered for the botanic garden team to ensure that the staff members have the capacity to deliver the mission.

It is important that the botanic garden management team recognises the importance of training and development of staff to keep the institution progressing and to maintain staff engagement. Therefore staff need to be given time to pursue training. In addition resources must be allocated to other forms of staff development such as travel to other botanic gardens, conferences or plant collecting. There are benefits to the botanic garden not only of increased knowledge of the team, but increased morale and engagement with the aims of the institution. A number of elements should be considered:

Key questions

- What skills and knowledge are required within the botanic garden for it to deliver its mission?
- What skills and knowledge exist in the staff team already?
- Is there potential to develop and build capacity within your existing team?
- Can the skills be sub-contracted (bought in) when required?
- Are staff with different skill sets required?
- How to ensure continued training for staff?

1. Training needs analysis

It is recommended that an objective appraisal of the capacity required within the botanic garden is carried out early in planning or review processes. This can be approached in different ways, but all can be termed a Training Needs Analysis (TNA). A TNA requires a critical analysis of the training needed and the best ways to get the required support and knowledge. In its simplest format, a TNA is simply writing down a list of the skills and knowledge required to operate the garden, appraising that of the current staff and identifying any gaps. A decision then needs to be made on whether the gaps are significant enough to justify employing new staff or to build up the capacity of the existing team using one or more of the approaches described below.

2. Capacity building options

A diverse range of training opportunities is offered by various botanic gardens (Box 6.5). However, it may be relevant for staff to attend courses or internships in other institutions such as commercial nurseries, forestry organisations and agricultural colleges. These operate many areas of activity which have cross overs with the horticultural activity of botanic gardens and are worth considering as sources of capacity building. Whether financial resources are well-allocated for training and travel or means are more limited (Case study 6.10), these numerous options enable tailor-made exchange programmes and staff development to ensure that the botanic garden is able to meet its aims within the context of the resources available.

CASE STUDY 6.10

Capacity building at the Oman Botanic Garden, Oman, and at the Nezahat Gökyiğit Botanik Bahçesi, Turkey

Leigh Morris, Edinburgh, United Kingdom

The Oman Botanic Garden (OBG) aims to be a showcase for Omani and Arabian flora and a model of sustainability in the Gulf region. Since the formation of the initial botanic garden team in 2006, the building of their collective capacity was identified as a key priority and a number of capacity building activities have been carried out to develop the team. OBG signed a Memorandum of Agreement with the Royal Botanic Garden Edinburgh (RBGE). This resulted in the following exchanges:

- A number of RBGE staff spent time in Oman delivering bespoke training and development for the OBG team in an extremely wide range of topics. These ranged from field collection and plant identification to horticultural skills, and from tractor driving to plant database set up and operation. RBGE staff were also in Oman to assist with, and work alongside Omanis, during key milestones early in the botanic garden's development. These included native habitats assessment and mapping, nursery construction, initial tree translocation operations and the planting of the first collections in the botanic garden.

- RBGE delivered their Certificate in Practical Horticulture (CPH) course in Oman to 16 members of the OBG team, including four senior botanists and horticulturists. Three of these senior staff then completed the RBGE Instructor Assessor programme at the Queen Sirikit Botanic Garden in Thailand. The CPH was further developed by staff of the Oman Botanic Garden and successfully taught in Arabic by adapting the course to local conditions and knowledge.

- A number of OBG staff have completed bespoke internships at RBGE alongside botanists and horticulturists to acquire in-depth knowledge of RBGE protocols, systems and techniques. In addition, many of the Omani interns joined the RBGE BSc study tour annually, to view horticulture in other areas of the UK.

- An Omani botanist successfully completed the MSc in Biodiversity & Taxonomy of plants, with their research dissertation focusing on an important Omani tree species.

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CASE STUDY 6.10 (CONT.)

In addition to the support of RBGE, OBG has acquired capacity building from a number of other partners including Botanic Gardens Conservation International (BGCI). OBG staff have attended international conferences, undertaken a number of study tours and carried out internships at other botanic gardens. Senior staff have completed Masters and PhD programmes at other UK universities. The vision for OBG is to become a 'world class' botanic garden and it was immediately recognised that building the capacity of their team in a number of ways was key to achieving this vision.

At the Nezahat Gökyiğit Botanik Bahçesi (NGBB) in Istanbul, Turkey, capacity building was aimed at a small number of personnel to enable them to deliver a practical horticultural course to other staff. This was carried out on-site, reducing the requirement for travel and ensuring that development was relevant to the local conditions:

- The RBGE Certificate in Practical Horticulture (CPH) programme was delivered in Istanbul to the NGBB horticulture team (Morris, 2010). Three of their horticulture team subsequently completed the Instructor Assessor course in Edinburgh. NGBB are now an RBGE Accredited Centre delivering the CPH to their own staff, and to members of the public.

- One of the NGBB staff completed the BSc in Horticulture with Plantsmanship at RBGE on a full-time basis over four years and has now returned to a senior post at NGBB.

- A number of NGBB staff completed bespoke internships within the horticulture team at RBGE.

- A number of RBGE staff spent time at NGBB delivering bespoke training and development for their team on an extremely wide range of topics.

Training in plants record management, Oman Botanic Garden. (Image: Leigh Morris)

Training module on soil texture for NGBB's horticulture team as part of the RBGE's Certificate in Practical Horticulture. (Image: Leigh Morris)

Box 6.5 Capacity building options

Training on-site: Trainers are contracted to come to the botanic garden to deliver tailored training in specific areas of operation. Such capacity building is typically un-certificated. However, as much time as necessary (or that can be afforded) can be devoted to specific areas and individuals. Such delivery of skills and knowledge can be extremely focused and make good use of external expertise. This can be useful for highly specific skills and knowledge, for example a herbarium expert or plant propagator from another botanic garden coming to work alongside your own to develop a curation system or propagation protocols. Bespoke training can often be delivered by external botanic garden consultants, or by staff of another established botanic garden with which a collaborative relationship has been established.

Training off-site: Staff visits to other botanic garden(s) for an internship period. This can be highly focused, or more general. Many large botanic gardens offer an internship programme. However, within the global botanic garden network, the vast majority of institutions host staff for training only if their expenses can be met by the employer. In such a relationship, the visiting staff will simply be placed in the appropriate team and will work alongside the staff of the host botanic garden, learning through experience. Such capacity building is not as focused and therefore a longer training period is required; however, the embedded learning gained by such an immersive placement can be highly significant and can expand the learning in other unexpected ways.

Formal training programmes: Some large botanic gardens offer training courses specifically aimed at building capacity for staff of botanic gardens in development. In this model, staff typically travel to the host botanic garden where they undertake a formal courses. In the 1980s, the Royal Botanic Gardens Kew recognised the need for specialised horticultural and botanical training, and began to establish a series of international diploma courses for people working in botanic gardens, herbaria, arboreta and other plant conservation organisations, including the International Diploma in Botanic Garden Education and the International Diploma in Botanic Garden Management delivered over a period of 5 weeks. A different model in formal education is offered by the Royal Botanic Garden Edinburgh (RBGE). Practical Horticulture and Field Botany are certificated programmes specifically aimed at delivering key practical skills. The RBGE certificates are delivered as a two-week block course in Edinburgh, or within the botanic garden where the skills are required. The advantage of these programmes is that they can be tailored specifically to the host botanic garden according to its resources. It can also be more economical for one or two trainers to travel to one botanic garden, than for several staff to travel to Edinburgh. The RBGE Certificate in Horticulture is endorsed by BGCI and has now been successfully delivered in a number of botanic gardens around the world (Morris and Cohen, 2010; 2013)

In-house training: For long-term success, a botanic garden needs knowledgeable staff who can pass on their skills to new and developing personnel. In order to communicate their knowledge to others effectively these individuals need to have capacity building and teaching skills.

It is recommended that key staff develop their teaching skills, and this is possible with specific training. There are a number of courses offered by colleges and training agencies to deliver this. RBGE developed a 4-day 'Train the Trainer', now known as the 'Instructor Assessor' programme, designed to teach botanists and horticulturists the key skills required to pass on their own knowledge and skills. The course is itself practical and requires participants to deliver and critique a number of micro-teach sessions, with the emphasis on improving communication techniques throughout. This course has been used to train staff at a number of botanic gardens and has also been adopted by the Royal Horticultural Society in the UK for the development of senior horticulturists.

Full-time professional courses: Professional Diplomas, Degrees and post-graduate qualifications on a full-time basis should be considered for long-term development of staff to acquire deeper knowledge and understanding in a specific area. Staff undertaking such a period of study, gain a far wider and deeper knowledge base, which then returns to their own botanic garden. While on the programme, they will usually have the opportunity to focus some of their studies and research on topics that are highly specific to their home garden needs and a strong link between the employer garden and the education provider is highly recommended. Some botanic gardens offer professional programmes in conjunction with colleges or universities, and these programmes can provide additional linkages, opportunities and benefits to the employees on the programmes. Examples of these programmes are:

- RBGE's Diploma and BSc (Hons) in Horticulture with Plantsmanship, offered with the University of Glasgow and the Scottish Rural College (SRUC); and
- RBGE's MSc in Biodiversity & Taxonomy of Plants, in partnership with University of Edinburgh.

Online learning support: The internet is becoming an increasingly important source of knowledge for botanic gardens and there is a number of on-line courses that could be highly relevant across a number of topics. The big advantage of such learning is that it can be widely accessed at a comparatively low cost to the garden. The main disadvantage is that there is no face-to-face contact with tutors, other institutions and colleagues on the programme.

A few online learning providers now offer 'blended learning', where there is some face-to-face contact with tutors and other learners, so that the studying continues beyond this via the on-line learning platform. The success of either completely on-line or blended learning hinges on several features: Learners need to be highly motivated and given the time to study remotely. The learning provider must be dynamic in their delivery methods and, most importantly, the on-line content needs to go beyond a long list of documents to be read. RBGE developed their own on-line virtual learning environment called 'PropagateLearning' which is used to support the courses and bespoke training offered (Morris, 2014).

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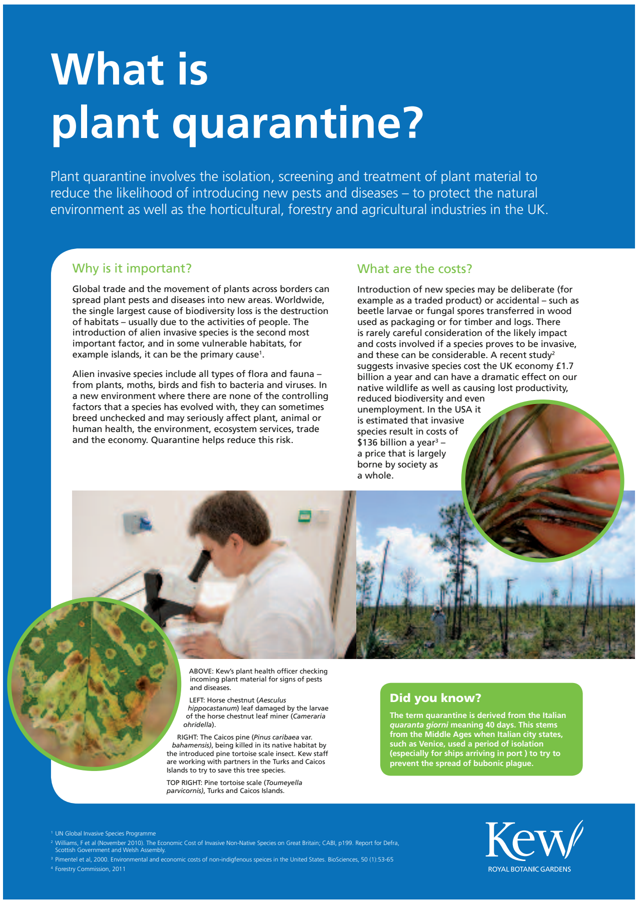

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Chapter 7: Using the Plant Collection – Research, Conservation, Public Engagement, Recreation and Tourism

Part C: The Plant Collection – Linchpin of the Botanic Garden

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CHAPTER 7: USING THE PLANT COLLECTION – RESEARCH, CONSERVATION, PUBLIC ENGAGEMENT, RECREATION AND TOURISM

Chapter 7:
Using the Plant Collection – Research, Conservation, Public Engagement, Recreation and Tourism

7.1 RESEARCH AND CONSERVATION

Joachim Gratzfeld, Malin Rivers and Katherine O'Donnell, Botanic Gardens Conservation International; Vanessa Sutcliffe, Royal Botanic Gardens, Kew; Raquel Folgado Casado, The Huntington

7.1.0 Definitions

Conservation assessment: The process to determine which species are at greatest risk of extinction. Conservation assessments are used to prioritise the most threatened species for conservation action, publicise their plight and provide information needed to plan the action needed to save them. Assessment of conservation status can also be referred to as 'red list assessments' based on the IUCN Red List of Threatened Species – the most widespread system used to evaluate the conservation status of species.

Cryopreservation: An *ex situ* conservation method for long-term storage using liquid nitrogen at -196°C. This technique may be used in particular for recalcitrant seeds which cannot be stored via standard seed banking (see definition) methods.

DNA bank: An *ex situ* conservation facility for long-term storage of genetic resources – e.g. plant genomic DNA conserved at -80°C.

Ecological restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. Ecological restoration seeks to 'assist recovery' of a natural or semi-natural ecosystem rather than impose a new direction or form upon it.

***Ex situ* conservation:** Conservation of components of biological diversity outside their natural habitats. This off-site storage of genetically representative samples of natural populations serves as a backup in the event of species extinction in the wild (see also *in situ* conservation).

Field gene bank: An *ex situ* conservation collection of 'live plants'. Field gene banks, often generally referred to as 'living collections' are especially important for long-lived perennials that reach sexual, reproductive maturity only after protracted periods of time, or for species with short-lived, desiccation-sensitive (recalcitrant) seeds, as well as for plants that only reproduce vegetatively in the wild.

Herbarium: An *ex situ* plant collection of dried voucher specimens mounted on paper along with collection information to act as a preserved and lasting record.

***In situ* conservation:** Conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in the wild.

***In vitro*, tissue culture:** A collection of techniques using test tubes, culture dishes, etc. to maintain or grow plant cells, tissues or organs under sterile conditions on a nutrient culture medium. Plant tissue culture is widely used to produce clones of a plant through a process referred to as micropropagation.

Pollen bank: An *ex situ* conservation facility for long-term storage of desiccation tolerant pollen following freeze- and vacuum drying.

Population introduction: The intentional movement and establishment of an individual or a group of individuals outside their natural range. The aim is to prevent extinction of populations of the target species by establishing new populations in suitable habitats with favourable environmental conditions in areas where they have not been recorded from in recent geological history.

Population reinforcement: Measures to assist the recovery of declining or degraded populations of species and enhance their viability, that without intervention would not regenerate in the wild. The aim is to enlarge the effective size of remaining populations by increasing genetic diversity or representation of specific demographic groups or stages and, where possible, re-establish their original connectivity in the wider landscape.

Population reintroduction: The intentional establishment of an individual or a group of individuals in their natural area of distribution from where they have disappeared. The aim is to re-establish a viable population of the target species in its original range. This can either concern the reintroduction of a particular population that is no longer present where it formerly occurred, or of the species at large if all of its populations have entirely ceased to exist in the wild.

Seed bank: An *ex situ* conservation facility to store seeds. Seed banking describes the entire process from seed collection in the wild to long-term storage at -20°C ± 3°C in the seed bank. This has many advantages such as ease of storage, economy of space to represent genetic diversity, relatively low labour demands and consequently, the capacity to maintain large samples at an economically viable cost.

Spore bank: An *ex situ* conservation facility for long-term storage of desiccation tolerant spores following freeze- and vacuum drying.

7.1.1 Introduction

As multidisciplinary institutions at the interface between people and plants, botanic gardens are prime centres for botanical research and plant conservation. With plant diversity continuing to decline worldwide, *ex situ* conservation at botanic gardens presents a major insurance policy for the safeguard of rare and threatened species. Plant material held in *ex situ* collections can be used in efforts to reinforce dwindling and degraded plant populations in the wild, let alone to reintroduce species and populations where they have entirely disappeared. Botanic gardens are also becoming increasingly visible as influential stakeholders and versed actors in the area of restoration ecology and practice. What is more, in times of unprecedented global transformations, climate change and changing ecosystems, botanic gardens may hold plants and genetic diversity relevant for the development and management of emerging ecosystems with new species assemblages.

KEY MESSAGE

Ex situ conservation of plant germplasm provides a vital backup in the event of species extinction in the wild.

Given the multiple facets of *ex situ* conservation, this section aims to provide guidance on selected key research and conservation undertaken by botanic gardens. This includes methods and standards for different types of *ex situ* conservation collections – living and non-living – and their relevance to and integration with *in situ* conservation endeavours (Figure 7.1.1). While the research component as presented in this section primarily considers efforts supporting practical conservation (Case study 7.1.1), it should not be overlooked that botanic gardens are, as a matter of course, major scientific institutions for the numerous study areas of botany, including plant taxonomy and classification, nomenclature, phylogeny, vegetation ecology, study of flora, horticultural research, physiology, phytopathology, phenology, economic botany, etc. Equally, botanic gardens are also centres of excellence to develop plant-based solutions to pressing global challenges such as food security, poverty, health and sustainable water and energy provision, thereby contributing to the Sustainable Development Goals (SDGs) and Aichi Biodiversity Targets (Chapter 4, Section 4.2). As institutions maintaining *ex situ* collections, botanic gardens are also the prime agents working towards achieving Target 8 of the Global Strategy for Plant Conservation (Chapter 4, Section 4.4.3) aimed at integrated *ex* and *in situ* conservation action of species at risk of extinction.

Figure 7.1.1 Overview of *ex situ* plant conservation strategies and links to *in situ* conservation

<table>
<tr><td colspan="8">EX SITU CONSERVATION</td></tr>
<tr><td colspan="6">'Hortus vivus' – Living collection</td><td colspan="2">'Hortus siccus' – Non-living* collection</td></tr>
<tr><td>Collection category</td><td>'Live plants'</td><td colspan="4">Germplasm / propagules</td><td>Dried, spirit-preserved, etc.</td><td>Derived, secondary resources</td></tr>
<tr><td>Collection type</td><td>Field gene bank</td><td>Seed bank</td><td>Tissue culture / cryopreservation</td><td>Pollen / spore bank</td><td>DNA bank</td><td>Herbarium and other collections incl. fruit, wood, fossil, etc.</td><td>Illustrations, images, plant data records, books, etc.</td></tr>
<tr><td colspan="8">IN SITU CONSERVATION</td></tr>
<tr><td rowspan="2">Species recovery</td><td colspan="7">Population reinforcement</td></tr>
<tr><td colspan="7">Population reintroduction</td></tr>
<tr><td>Ecosystem recovery</td><td colspan="7">Ecological restoration</td></tr>
<tr><td rowspan="2">Ecosystem design</td><td colspan="7">Population introduction</td></tr>
<tr><td colspan="7">Emerging, novel ecosystem conception and/or management</td></tr>
</table>

**Non-living collections may still contain viable plant material, such as seed or intact DNA.*

CASE STUDY 7.1.1

Research programmes at botanic gardens supporting practical plant conservation – three examples from Denver Botanic Gardens, Colorado, United States

Jennifer Ramp Neale, Sarada Krishnan and Rebecca Hufft, Denver Botanic Gardens

- **Phenology monitoring**

Phenology examines biological phenomena such as timing of germination, blooming in the spring or leaf colour changes in the fall. Understanding the timing of such events and their relationship to climate is critical to planning seasonal work like plant population monitoring and seed collection.

Since the 1950s, dedicated volunteers across the country have tracked the phenology of lilacs. Partnering with the USA National Phenology Network (USA-NPN), Denver Botanic Gardens (DBG) has been monitoring the phenology of *Syringa vulgaris* individuals, including 25 *S. vulgaris* varieties. Monitoring all of the varieties in one location provides the opportunity to determine how phenology varies among the varieties. In 2013, DBG also planted two cloned lilacs (*Syringa x chinensis* 'Red Rothomagnesis') received from USA-NPN. Data collected from these and other cloned lilacs allow phenological comparisons across the country without genetic variation contributing to differences in timing. The observations have been invaluable in documenting plant responses to changing spring conditions. This information has been used along with historical weather data across the country to capture the timing of spring indices, such as leaf-out and flowering that primarily vary with temperature.

Monitoring lilac phenology at Denver Botanic Gardens. (Image: Denver Botanic Gardens)

- **Long-term research into the life-history and demography of *Astragalus microcymbus* – a rare species endemic to Gunnison County, Colorado**

Since the mid-1990s, Denver Botanic Gardens has been partnering with the US Bureau of Land Management (Colorado State Office) to monitor population demographics of the rare skiff milkvetch, *Astragalus microcymbus* (Fabaceae). The study was initiated to learn about the species' life-history, determine population trends and examine management actions that will best support long-term survival. DBG has tracked thousands of individuals at six sites within a drainage outside of Gunnison, Colorado. The first nine years of research documented a statistically significant population decline in all monitoring plots, prolonged dormancy, episodic fruit production and herbivory. More recent results indicate that while *A. microcymbus* is stable in overall population size it is following a large time-scale cyclical pattern of growth and decline. The findings of this research conducted over a period of 25 years have contributed to formal assessments of the species by the US Fish and Wildlife Service, listing it as a candidate for protection under the Endangered Species Act.

Surveying Astragalus microcymbus (Fabaceae). (Images: Denver Botanic Gardens)

CASE STUDY 7.1.1 (CONT.)

- **Conservation management recommendations based on studies of population genetics for federally protected *Sclerocactus* species in the arid west of Colorado**

In collaboration with the US Fish and Wildlife Service and the US Bureau of Land Management, Denver Botanic Gardens has collected genetic data on three federally protected members of *Sclerocactus*. The Colorado hookless cactus (*Sclerocactus glaucus*) has a limited distribution in Western Colorado. It has been listed as Threatened under the Endangered Species Act (ESA) since 1979. Populations have been monitored throughout their range to better understand life-history traits of the species. Partnering with the University of Northern Colorado, DBG has conducted a population genetic study to identify diversity within and among populations as well as any populations showing hybridization with the widespread small flower fishhook cactus (*Sclerocactus parviflorus*).

Utilizing microsatellite markers, the genetic diversity in more than 800 individuals throughout the species' range was studied. Two genetically distinct regions of the Colorado hookless cactus were identified: a northern range occupying the Colorado River drainage and a southern distribution in the Gunnison River drainage. Few hybrid individuals were found during the study. As morphological traits used to identify species and potential hybrid populations did not correlate with genetic identity, it is recommended to manage populations in the future based on geography rather than morphological criteria.

Similar management recommendations were made for two other species of *Sclerocactus* found in Utah and protected under the ESA, the Pariette cactus (*Sclerocactus brevispinus*) and the Uinta Basin hookless cactus (*Sclerocactus wetlandicus*). Analyses of nearly 600 individuals across the species' ranges identified two genetic clusters which do not entirely correlate with the species as defined by morphological traits.

Sclerocactus glaucus in the wild. (Image: US Fish and Wildlife Service)

7.1.2 Conservation Prioritisation

While *ex situ* collections are established to serve many purposes, such as to represent species for their geographic, phylogenetic and ecological significance and/or cultural uses, securing threatened taxa of urgent conservation concern has become a major focus for botanic gardens in the last few decades. Determining the conservation status of plants is an important first step to identify species that are at risk of extinction in the near future. Species conservation assessments are essential to prioritise *ex* and *in situ* conservation action and make informed conservation decisions. The most widespread system used for conservation assessments is the IUCN Red List of Threatened Species (Box 7.1.1). Therefore the process of assessing the extinction risk of species is also referred to as 'red listing'.

Box 7.1.1 IUCN Red List Categories and Criteria

The IUCN Red List of Threatened Species has nine different categories:

Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE).

EX means a species has gone extinct, whereas species that are EW are extinct in the wild, but do persist *ex situ* (such as in botanic garden collections). CR, EN and VU are the three threatened categories used for species that face a high risk of extinction in the wild. Species that do not qualify for a threatened category, but are close to or likely to qualify for a threatened category in the near future, can be assigned to the category NT. LC is used for species that are assessed but are not considered threatened. The use of the category DD may be assigned to poorly known taxa. Species not yet evaluated are classified as NE.

To assign a species to a red list category different criteria are used to measure symptoms of extinction risk. Species are evaluated in relation to five criteria, based on a set of quantitative thresholds and several subcriteria, in order to assess whether a species qualifies for a threatened category (CR, EN, VU). The five criteria are: A) Population reduction; B) Geographic range; c) Small population size and decline; D) Very small or restricted population; and E) Quantitative analysis.

Botanic gardens play a vital role in red listing. They help analysing the impact of different threats on plant diversity and, in such a way, informing species level conservation assessments. Botanic gardens are ideally placed to support red listing as they have a wealth of expertise, information and experience for plant red listing. Botanic gardens are often centres for taxonomic expertise; and taxonomic experts not only tell us which species we should red list but they often have a wealth of relevant information on particular species groups. Botanic garden staff will have information on habitat requirements, propagation techniques, threats in the wild, etc. All this information is useful when red listing plants. In addition to scientific knowledge and expertise of the botanic garden staff, valuable information on distribution, population structure, habitat and ecology, threats and current conservation action may also be found in herbaria, libraries, living collection databases and other information sources housed at botanic gardens.

Both, existing and new information, are collated and a species is then listed to be of conservation concern (i.e. threatened) or not, based on a set of categories and criteria. Conservation assessments can be made on global, regional and national scales. BGCI's ThreatSearch database lists all known plant conservation assessments, including global and non-global assessments. It contains over 242,000 assessments which represent over 150,000 different taxa (Box 7.1.2). Although a threatened conservation status itself does not warrant conservation action, this information is useful to prioritise conservation action and make effective and informed conservation decisions.

Box 7.1.2 ThreatSearch database

ThreatSearch is the world's most comprehensive database of conservation assessments for plant species, including global, national and regional assessments. The database allows to search over 242,000 conservation assessments, representing over 150,000 taxa.

Together with BGCI's two main collaborators – the National Red List and the Royal Botanic Gardens, Kew – currently available conservation assessments have been assembled into a single list of conservation assessments for plants. New conservation assessments as well as older, non-digital sources are continuously being added.

It is possible to search for species of interest, and also filter on scope, threatened status and year of the assessments. Species names have been matched to The Plant List wherever possible. The source of the assessment is indicated, and, when available, a URL link will refer to the original source of the information.

ThreatSearch is directly relevant to conservationists, educators, horticulturists, collection managers, researchers, policy makers and many others who are working to save and understand plant diversity. ThreatSearch can be used to measure progress toward several targets of the Global Strategy for Plant Conservation.

Many botanic gardens are involved in national or regional red listing initiatives (Case study 7.1.2). They play a vital role in contributing information towards conservation assessments for plants. These evaluations will help the botanical community to prioritise *in situ* as well as *ex situ* conservation action.

CASE STUDY 7.1.2

Species conservation prioritisation – Red Listing at Jardim Botânico do Rio de Janeiro, Brazil

Malin Rivers, Botanic Gardens Conservation International, and Eline Martins, Centro Nacional de Conservação da Flora committee

An example of a botanic garden actively involved in producing national level conservation assessments (i.e. Red Lists) of plants is Jardim Botânico do Rio de Janeiro (Rio de Janeiro Botanic Garden) in Brazil. The botanic garden hosts the Centro Nacional de Conservação da Flora (CNCFlora) at their research institute.

Brazil's flora consists of over 46,000 species, and red lists (conservation assessments) are an important tool for prioritizing the limited resources in the conservation of species. CNCFlora is responsible, at the national level, for assessing the conservation status of the Brazilian flora, by the year 2020. CNCFlora adopts the standards and procedures recommended by the International Union for the Conservation of Nature (IUCN). The red listing of the Brazilian flora is performed by the CNCFlora Red List team, in collaboration with a network of experts from across botanic gardens in Brazil and the scientific community. This network helps to validate the information collated by the red list team and contribute to the consistency of the conservation assessments.

The workflow adopted by the team has an online information system developed specifically for the process of assessment of extinction risk and has three main steps:

1. The first step is data analysis, which is the compilation of data online to create a species profile. The information collated includes: population structure, ecology and distribution of each species, as well as information on threats and conservation actions.

2. The second step is validation. During this stage the data are passed on to the network of collaborating specialists who access and review the information entered.

3. With the knowledge generated and passed by the expert, the third step begins: the process of extinction risk assessment, following the IUCN categories and criteria (version 3.1). During this step, the species are categorized into one of the extinction risk categories.

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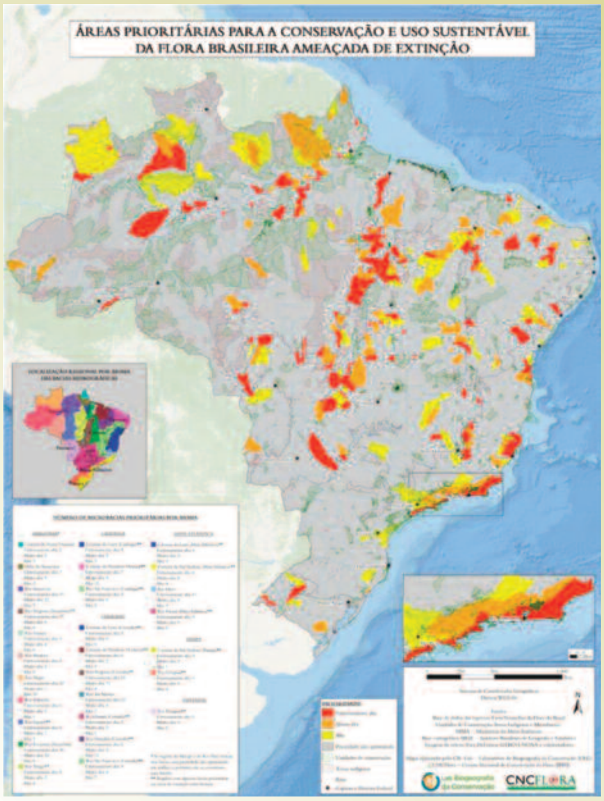
CASE STUDY 7.1.2 (CONT.)

When the assessments are complete they are available again to be reviewed by experts who can send comments and suggestions regarding the assessments. Subsequently, the ratings are published in the CNCFlora portal and sent to the Ministry of Environment (MMA), responsible for drafting the Official List of Threatened Plants in Brazil. In December 2014, the first results were officially recognized by the MMA. This allowed the publication of the updated official list of threatened flora in Brazil, an important tool for public policy and law enforcement for the conservation of threatened flora (MMA, 443/2014*).

Since 2010, CNCFlora has assessed the extinction risk of 6,046 species of the Brazilian flora (13,2% of the national flora), and nearly half of these are of species considered at risk of extinction (i.e. threatened). CNCFlora also works to develop recovery and action plans for many of the most threatened species and habitats.

Plant species	Evaluated	Threatened	Action plans
46223	6046	2953	332

*Ministry of Environment (MMA), 2014. Portaria no 443, de 17 de Dezembro de 2014. Diário Of. da União 110-121.



Priority conservation and sustainable use areas based on red listing. (Image: Centro Nacional de Conservação da Flora committee)

Orthophytum humile (Bromeliaceae), endemic to Brazil, assessed as Critically Endangered. (Image: Rafael Louzada)

7.1.3 From Species Prioritisation and Collection Policy to Plant Collection

Ultimately, our choices of which species and populations to collect and how well we can store them for long periods of time may well mean that some plants survive into the next century that otherwise would not. Guerrant *et al.* (2014)

The focus and types of research and conservation programmes carried out as well as related facilities and equipment required by botanic gardens, are determined by the vision and mission of the institution (Chapter 1, Section 1.2.4) and, more specifically, its collection policy (Chapter 3). These fundamental frameworks will inform or define the species selection, sampling strategy and collection types the botanic garden is aiming at (Box 7.1.3).

Achieving genetically diverse collections representative of the wild populations is a key endeavour of *ex situ* conservation. The enormous diversity in reproductive systems in the plant kingdom that has a bearing on the amount and structuring of genetic variation within and among populations, makes the provision of general guidance on sampling strategies towards genetically representative *ex situ* living conservation collections a challenging task. Building on guidelines produced by the Center for Plant Conservation (1991) and Guerrant *et al*. (2004), Guerrant *et al*. (2014) provide one of the most comprehensive reviews. While they highlight that there is no single correct sampling strategy or protocol, a number of key questions (Box 7.1.3) will help plan and schedule collection over time.

KEY MESSAGE

No one-size-fits-all – each plan for establishing *ex situ* conservation collections should be based on the individual and specific purpose of the plant holdings, the size of and potential damage to the wild populations to be collected from, as well as the ability of the botanic garden to maintain the collections over time.

Ultimately, each situation should be evaluated in the context of the particular purposes and uses for which the collection is made. This will include the nature of the target taxa, the manner in which the samples will be stored and maintained, the period of time they will be stored, and whether wild-collected samples are to be used directly or whether their numbers will be increased by horticultural growouts (Guerrant *et al*., 2004). In conclusion, the 1) purpose of collecting plant material, the 2) potential damage to wild populations from over-collection, as well as the 3) ability to maintain the samples in good condition, should always carefully be considered by any *ex situ* collection strategy.

7.1.4 *Ex Situ* Living Collections

Ex situ conservation strategies for living plant material as pursued by botanic gardens comprise a range of collection types, including field gene banks, seed banks, *in vitro* tissue culture and cryopreservation, pollen and spore banks as well as DNA banks. While the conservation value of *ex situ* plant holdings is determined by the level of their genetic representativeness of wild populations, the various types of collections present different advantages, challenges and management approaches towards achieving this principle.

KEY MESSAGE

Whatever strategy of *ex situ* conservation employed, the conservation value of the plant holdings is ultimately determined by the extent of their genetic representativeness of wild populations.

- **Field gene banks**

Field gene banks or 'live plant' collections are a key *ex situ* conservation means especially for long-lived perennials that reach propagation maturity only after protracted periods of time, or for plants that generate short-lived, desiccation-sensitive seeds that are not suitable for storage in seed banks. In some circumstances, they may be the only viable option for *ex situ* conservation of recalcitrant germplasm. Live plant collections may also be required for species that generally reproduce vegetatively in the wild.

Box 7.1.3 Integrated sampling strategy – key questions

***Ex situ* collection policy:**
- Which plant groups and taxa to collect?

***In situ* sampling strategy:**
- For each taxon – from how many and which populations to collect?
- Within each population – how many and which individuals to collect?
- For each individual – how many and what kind of propagules to collect?
- What is the maximum sample size the population can bear without damage?

***Ex situ* collection type:**
- What collection types are serving best its purpose?
  Field gene bank; seed bank; tissue culture; cryopreservation; pollen-, spore- and/or DNA bank?

The breadfruit collections of the National Tropical Botanical Garden's (NTBG) Kahanu Garden, Maui, and the McBryde Garden, Kauai, are among the world's largest live plant holdings in this taxonomic group. (Image: National Tropical Botanical Garden)

Especially within the global crop community, this form of reproduction may also be intentional to conserve gene combinations that would be lost when changing to seed propagation. For species from remote locations, field gene banks may prove more practical for various research purposes given their immediate accessibility and availability of living plant material.

A genetically diverse collection representative of the wild population is vital to maintain its fitness and avoid inbreeding, a risk in particular for outcrossing species – plants that are not self-pollinating. Controlled pollination for seed production may be required to reduce the risk of outbreeding depression, i.e. to avoid the mixing of genetically distant individuals or populations within the collection that potentially could lead to lower fitness of the next generation. A fluctuating population size, for instance as a result of changing horticultural care and mortality rates, can also affect the field gene bank's genetic structure. Depending on the extent of the genetic diversity of wild populations, space requirements may present a key limitation of live plant collections, in addition to the challenge to protect them from natural disasters. Plants held in field gene banks may also be prone to hybridisation with closely related species. What is more, live plant collections may also be susceptible to spreading invasive species as well as pests and pathogens. They therefore should include a rigorous risk assessment for all taxa to be grown in the collections. Examples of comprehensive risk evaluation frameworks from global to national levels include the Invasive Plant Species Voluntary Codes of Conduct for Botanic Gardens and Arboreta, the European Code of Conduct for Botanic Gardens on Invasive Alien Species, or the Weed Risk Assessment of the National Institute of Water and Atmospheric Research Ltd (NIWA) in New Zealand. In conclusion, field gene banks should:

- Represent the full genetic diversity of the natural populations;
- Be established in close collaboration among the various institutions holding live plant collections to coordinate population priorities and avoid risks of cross-breeding;
- Ensure that collections of closely related species are not established in proximity to each other to prevent potential hybridisation;
- Undertake, prior to their establishment, a thorough risk assessment pertaining to the species' potential of becoming invasive and being the carrier of pests and pathogens;
- Monitor periodically the genetic condition of populations to enable the identification of potential problems related to erosion of genetic diversity over time.

Despite these challenges, live plant collections provide a vital complementary *ex situ* conservation strategy. This is supported by a growing number of molecular studies demonstrating that field gene bank collections can be representative of wild populations if established sampling methods are applied thoroughly (Case study 7.1.3).

CASE STUDY 7.1.3

Zamia decumbens – research on a model species to demonstrate that a botanic garden collection can capture the genetic diversity in a wild population

Patrick Griffith *et al*.*, Montgomery Botanical Center, Florida

Cycads are an imperiled group of plants, and *ex situ* collections present an important part of conservation planning for this group, given seed recalcitrance, difficulties with tissue culture, and ongoing *in situ* threats. The majority of the 331 extant species are recorded on the IUCN Red List of Threatened Species, and more than 75% are threatened with extinction. Given their long history – cycads represent a lineage that is Paleozoic in origin – living cycads are often used in teaching collections at botanic gardens and universities. This study sought to illuminate how well an *ex situ* collection of a cycad can capture the diversity in a wild population, thereby establishing also the conservation value of the collection.

Methodology

A model species, *Zamia decumbens*, was chosen on the basis of geographic isolation and detailed census knowledge, which allowed near-total sampling of *in situ* plants. The Critically Endangered *Z. decumbens* is known from a limited area of the Maya Mountains in southern Belize. At the time of its description (Calonje *et al*., 2009), the species was known from two main populations of 234 and 183 plants, restricted to two limestone sinkholes separated by 7 km, and a few scattered hilltop populations of no more than 12 plants each. The remote, isolated locations preclude any potential introgression of other *Zamia* spp. from horticulture or *in situ* plants. Via 10 microsatellite markers, 375 *in situ* plants were compared to 205 *ex situ* plants grown from seed collected in the wild in 2010.

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CASE STUDY 7.1.3 (CONT.)

Summary of results

Genetic-distance analysis demonstrated high fidelity of the *ex situ* collections to their *in situ* source populations as well as clustering of *ex situ* progeny by accession and strong identity with their respective mother plants. Structured resampling of allele capture from the *in situ* populations by the *ex situ* collections showed that allele capture increases as number of *ex situ* plants maintained increases, but with a diminishing rate of increase.

Conclusion

The data obtained demonstrate that botanic garden collections can better conserve the genetic diversity of *in situ* cycad populations if four recommendations are followed: 1) use the species biology to inform the collecting strategy; 2) manage each population separately; 3) collect and maintain multiple accessions; and 4) collect over multiple years.

While genetic information has great potential to inform *ex situ* conservation collections management, caution against overstating the utility of genetics for plant conservation needs to be prompted. The assay of the type described here must be considered in the context of specific biology (Guerrant *et al*., 2014). And finally, while conservation genetics study certainly provides much greater insight into *ex situ* collections management, it cannot replace the basic work of the botanist, curator, propagator, or horticulturist – it remains essential to integrate conservation genetics with other data and with tangible effort.

*Griffith, M.P., Calonje, M., Meerow, A.W., Tut, F., Kramer, A.T., Hird, A., Magellan, T.M. and Husby, C.E. (2015). Can a Botanic Garden Cycad Collection Capture the Genetic Diversity in a Wild Population? International Journal of Plant Sciences 176(1).

Zamia decumbens in its sinkhole habitat, Toledo, Belize. (Image: Michael Calonje)

• Seed banks

Increasingly, botanic gardens around the world have set up seed banks as part of their plant conservation programmes. The storage of orthodox seeds for long-term conservation is an effective *ex situ* insurance strategy to complement *in situ* conservation of plants, guaranteeing the survival of individual species. Many thousands of seeds may be stored for a particular species, each one representing a potential new plant. Seed banking provides an efficient and cost-effective means of preserving the diversity of plant species: each collection occupies a relatively small space and requires little attention over time. Skills, knowledge and data built up through the conservation of these collections will support wider plant conservation activities (Box 7.1.4).

Box 7.1.4 The Global Seed Conservation Challenge (GSCC)

BGCI's Global Seed Conservation Challenge (GSCC) aims to increase the contribution of botanic gardens towards Target 8 of the Global Strategy for Plant Conservation. This target calls for 'At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin and at least 20% available for recovery and restoration programmes by 2020'.

The GSCC has five aims:

- Engage more botanic gardens to become involved in seed banking, working 'outside the garden walls' to bring into *ex situ* collections threatened species that are not already conserved;
- Highlight and celebrate success for seed conservation including awarding prizes to gardens that excel;
- Strengthen networks to help botanic gardens share experiences and resources in seed banking;
- Establish a seed collecting 'hub' at BGCI which will provide a 'one-stop-shop' for seed banking information and training resources;
- Provide training and build capacity to support seed collecting and raise seed banking standards.

Seed collections are carefully dried and processed before being placed under storage at -20°C. These conditions allow the potential longevity of the seeds to be maintained. The viability of the seed collections is monitored periodically by germination testing. Banked seed collections are available for germination and propagation, for use in research and human livelihoods, and for the potential recovery and restoration of threatened species and ecosystems (Case study 7.1.4 and Section 7.1.6).

CASE STUDY 7.1.4

Using seed collections for *in situ* conservation

Marian Chau, Honolulu, Hawai'i

Threatened species held in the seed bank are an essential tool for preservation of genetic diversity, reintroduction, and research on germination, dormancy, and favourable growing conditions. The Seed Conservation Laboratory based at the Harold L. Lyon Arboretum in Honolulu has over 15 million seeds banked, representing more than 550 taxa of native Hawaiian plants which equates to over 40% of the flora of Hawai'i. Of the banked species over half are federally listed as endangered and/or threatened on the IUCN Red List.

The Seed Conservation Laboratory, part of the Hawaiian Rare Plant Program (HRPP), conducts crucial research into collection, preservation, and propagation of native Hawaiian plants, many of which are close to extinction. Most of the seeds collected are stored, while some are sown in the seed laboratory where they can be carefully monitored to determine their ability to germinate under different conditions and increase their chances of survival in the wild. This research is invaluable for understanding the biology of the species and aiding the reintroduction of species to natural habitats.

The endemic shrub *Cyanea grimesiana* ssp. *grimesiana* is a flowering plant native only to the island of O'ahu, which has become extinct in the wild. Re-establishment of *Cyanea grimesiana* ssp. *grimesiana* in the wild from *ex situ* tissue culture and seed collections in the HRPP has saved it from extinction.

Seeds were collected from the last individuals of this subspecies before they died and were established in the HRPP Micropropagation Laboratory. A few plants resulting from tissue culture were reintroduced to a managed outplanting site by the Hawai'i Plant Extinction Prevention Program. Reintroduced plants were hand-pollinated and produced fruits, which were deposited at the Seed Conservation Laboratory. Some of the seeds were stored for future restoration efforts, while others were germinated and grown in the growth chamber for a couple of weeks to establish before being grown up in the rare plant greenhouse. Many mature seedlings were then planted in their native habitat, re-establishing a wild population and contributing to forest restoration.

Cyanea grimesiana ssp. grimesiana propagated at the Seed Conservation Laboratory of the Harold L. Lyon Arboretum, Hawai'i. (Images: Harold L. Lyon Arboretum)

The Millennium Seed Bank Partnership (MSBP) of the Royal Botanic Gardens, Kew (RBG Kew), has established a set of Seed Conservation Standards to ensure that the partnership collections are of high quality. These standards allow collections to be recognised as a global resource and assure users of the quality of the collections stored and associated data generated through this network. Current best practice for long-term conservation of orthodox seeds is encompassed within these standards, including harvesting seeds at the optimum point of maturity, adequately representing the sampled population, and caring for collections after harvest to minimise damage and maximise potential longevity. These standards are outlined in this section:

1. Collecting

Seed collections are made from wild populations, along with representative herbarium vouchers and associated field data, according to the following guidelines:

1.1 Genetic materials, including traditional knowledge, are legally collected and conserved

Collectors must obtain permission from government and land owners/managers before seed collecting takes place. It is essential to take advice from local collaborators and national/local government offices with experience in the region.

1.2 Collection names are verified (ideally by reference to herbarium voucher specimens)

Herbarium specimens (Section 7.1.5) enable accurate identification of seed collections to a particular species. Voucher material is collected from the same population as the seeds and is linked with the seed collections and relevant field data, as well as any associated material, such as photographs. If seed is being sent out of the country, several specimens may be collected, at least one being held in the country of origin. If a field verification of the species is made, or the voucher is verified by a herbarium, data should be provided on: name of verifier, date of verification, taxonomic name and authority used.

1.3 Genetic diversity of sampled population is adequately represented

It is beneficial to rely on local knowledge and institutional priorities when establishing target species lists, so that accessible populations can be identified and seed dispersal timings can be understood. Where local botanical knowledge is not available, collecting guides may be compiled from digitised herbarium specimens, which often have information on collection locality and flowering/fruiting times. Once the target population has been accurately identified, with the help of local taxonomists, field guides and checklists, or using digitised herbarium specimens, collectors must then assess whether sufficient plants are available with mature seed to make a collection for *ex situ* conservation. A simple cut test of seeds (approximately 20 per collecting team member), gathered from plants across the population, can be used to estimate the amount of damaged, infested or empty seeds that may be collected. Assessing a Population for Seed Collection provides further information for seed collectors as to whether a population meets the minimum quality and quantity standards for seed sampling for a particular purpose or project.

In order to represent the genetic diversity of the population, seeds are collected from at least 50 individual plants, selected randomly and evenly across the population. Taking account of the future uses of the collection, including long-term viability monitoring, collectors should aim for the collection of 10,000 to 20,000 seeds per population sample. Seeds are collected using the most appropriate method according to the type of seed dispersal unit. For example, tree seeds clustered at the tips of high branches will require long-handled pruners. Shaking branches over a tarpaulin sheet spread on the ground may be more suitable for smaller, shrubby species. Collectors should avoid gathering seed from the ground as it may have been subject to ageing or insect attack since it was shed. It is also difficult to determine which parent plant the seeds have been shed from when found on the ground. Seed Collecting Techniques gives more detail on various seed collecting techniques. Seeds are collected into porous bags (i.e. cloth or unwaxed paper) and labelled with a collection number (according to the principal collector's number series).

1.4 Essential field data are recorded

Field data pertaining to the seed collection are recorded on paper forms or electronic devices. Essential data include the collectors' name(s) and institute(s), date of collection, collection number, site data (locality, latitude and longitude), habitat data (associated species), identification data (collectors' identification of the target species), sampling data (number of plants in population, number of plants sampled from, herbarium specimens taken). The field data should be transferred to the institution's seed bank database under a unique accessioning number, to which further data can be added during the processing and monitoring of the seed collection.

Training on seed collection and field data recording, Costanera Sur Ecological Reserve, Buenos Aires, Argentina. (Images: Katherine O'Donnell)

1.5 Survival of source population is not compromised
To avoid harming the plant's future survival in the wild, no more than 20% of the mature seed, available on the day of collection, should be gathered. In the case of threatened and rare species it may be more appropriate to return to the population later in the season or in subsequent years, in order to build up the collection. Collections made in subsequent years from the same population should be stored separately under a new accession number.

2. Processing

Seed collectors should aim to maintain the quality of the collection from the moment of harvest, to ensure that the viability at the point of banking the collection is as high as possible. Poor handling in the field, including holding the seeds at high humidity and temperature, will cause seed ageing. Portable hygrometers can be used to measure relative humidity of seeds and of ambient conditions, guiding the handling of seed collections (Post-Harvest Handling of Seed Collections).

Seed collections are accessioned, dried and processed according to the following guidelines:

2.1 Unique accession reference number is assigned to all incoming material
An accession number (Chapter 3, Section 3.4.3 and Chapter 5, Section 5.5.2) is allocated to each incoming seed collection so that the seeds and associated data can be tracked through their processing and storage life. Accompanying herbarium material should be given the same accession number to enable easy association with the seed collection.

2.2 Collections are placed in cool/ambient drying conditions of 15% eRH ± 3% within 4 weeks of collection
When seeds arrive at the seed bank the likely storage characteristics of the seeds can be checked, using tools such as RBG Kew's Seed Information Database. Those collections that may pose storage problems (i.e. are intermediate or recalcitrant in storage behaviour) should undergo desiccation tolerance screening (Identifying Desiccation-Sensitive Seeds).

Orthodox (i.e. desiccation tolerant) seed collections need to be dried as soon as possible after harvesting (Case study 7.1.5). This will minimise any deterioration of the seed due to aging. Any collections containing immature seeds must be ripened before drying, either under ambient conditions or in a ripening room (e.g. at 65% relative humidity and 20°C). Conditions of 15% relative humidity and 15°C are recommended for drying orthodox seeds. These conditions may be achieved in a purpose-built dry room with a sorption dryer and chilling facility, or using an incubator-dryer. Alternatively, drying can be carried out at ambient conditions using desiccants in a sealed environment. Seeds may take a few days or up to several weeks to dry, depending on the size of the seeds, the size of the collection, and other physical characteristics. Microscopic seeds (e.g. orchids) are dried for a maximum of one week. The MSB at RBG Kew has two drying rooms: one for receiving the collections on arrival prior to processing, and one located next to the cold rooms, for final drying prior to storage (Seed Bank Design: Seed Drying Rooms and Small-Scale Seed Drying Methods).

Extraction of seed of Aegle marmelos (Rutaceae), Tamil Nadu, India. (Images: Alexander Amirtham)

CASE STUDY 7.1.5

Seed banking at Cibodas Botanic Garden

Musyarofah Zuhri, Cibodas, West Java, Indonesia

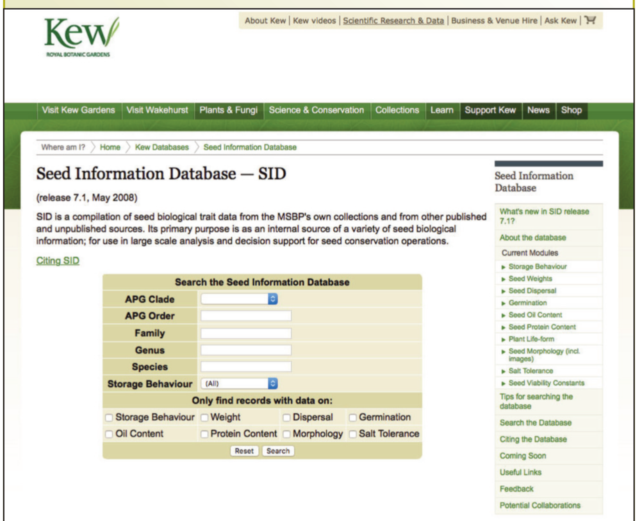
Cibodas Botanic Garden is situated in West Java, Indonesia and is a sister garden to Bogor Botanic Garden. Like many botanic gardens in tropical countries such as Indonesia there are several issues the garden needs to tackle when it comes to seed banking.

Currently the seed collecting programme is focused around seed collected from plant collections within the garden in order to fulfil the demand for seed that is required for propagation, seed exchange and material for research.

Like many other gardens that are starting seed banking programmes the future focus of the seedbank at Cibodas Botanic Garden is to collect and conserve seed of wild species. The Garden is situated next to Mt Gede Pangrango National Park, a tropical forest of Java and species within the National Park will be targeted for wild species seed collection.

Banking conservation collections requires different techniques and equipment from how Cibodas has been operating previously. The humidity in Indonesia can reach between 80-90%; these high levels mean that seed must be dried using desiccants or driers in order to bring the humidity of the seeds to levels where the seeds can be banked. Once dried the seed must be kept in hermetically sealed containers in order to keep moisture levels constant.

Another issue that affects tropical environments is that many species are recalcitrant and so cannot be dried and frozen like orthodox seed. The Seed Information Database http://data.kew.org/sid/ of the Royal Botanic Gardens, Kew has information on the storage behaviour of over 10,000 species and is a useful resource to determine which species are orthodox or likely to be based on related species.



The Seed Information Database of the Royal Botanic Gardens, Kew (data.kew.org/sid)

2.3 Collections are cleaned to remove empty, poorly-developed and insect-infested seeds and debris

Once a seed collection has been dried, it is processed in order to remove debris and reduce bulk, and to reduce the number of empty and poorly-developed seeds. The processing stage also increases the future utility of the seed collection. The seeds must be extracted from covering structures without causing damage. Much of this work is carried out by hand using sieves. An aspirator may be used for more uniform material, to winnow any debris and empty seeds from the heavier, filled seeds. The 'light fraction' is checked for the presence of good seed before it is discarded (Cleaning Seed Collections for Long-Term Conservation).

2.4 Purity is assessed by X-ray and/or cut test

X-ray analysis and/or cut tests (to look at the internal morphology of the seeds) are carried out on a small sub-sample of the main collection after seed processing. These tests provide important clues to the overall quality of the seed collections. The proportion of empty or partly-formed seeds and those that have been damaged by insects, can be determined. These seeds are recorded as 'incompetent'.

If incompetent seeds cannot be removed from the collection, the proportion of potentially healthy seeds is recorded to help interpret the results of subsequent germination tests. For example, if there are 50% incompetent seeds in a seed collection, yet 50% germinate, then 100% of the competent seeds have germinated. The number of seeds per collection must be estimated. This is done by weighing five samples of 50 seeds (or one sample of 250 for microscopic seeds) and weighing the remainder of the collection. The total quantity of seed is then calculated.

3. Storage and duplication

Seed collections are stored and duplicated according to the following guidelines:

3.1 Seed collections are banked as soon as possible after drying to equilibrium with 15% eRH ± 3% (cool/ambient temperature), and within 6 months of collection

After processing, the collections undergo a final drying stage at 15% relative humidity. When equilibrium with the dry conditions has been reached, the seed relative humidity is verified by non-destructive means, ideally using a hygrometer. Measuring Seed Moisture Status Using an Hygrometer and Low-Cost Monitors of Seed Moisture Status contain more details on determining seed moisture status using various methods. Microscopic seeds (e.g. orchids) should be banked within one week of drying.

Millennium Seed Bank of the Royal Botanic Gardens, Kew, Wakehurst, United Kingdom. (Image: Barney Wilczak)

3.2 Collections are held in air-tight (hermetic) containers
Once dried, seeds are packaged into air-tight containers of a range of sizes so that there is a minimal air space above the seeds. Containers may take the form of borosilicate glass jars with polypropylene lids or tri-laminate foil bags. Each batch of containers purchased by the seed bank should be tested for hermetic sealing properties under -20°C conditions. Silica gel indicator sachets (equilibrated to dry conditions) can be placed inside glass containers and periodically checked for colour change (indicating moisture ingress). Packaging of seed should take place under dry conditions. All collections are carefully labelled with moisture-proof labels (Selecting Containers for Long-Term Seed Storage).

It is advisable to divide collections into a 'base' collection that is infrequently accessed and an 'active' collection from which samples are taken periodically for viability testing and seed distribution. The base collections should be double packaged to reduce the risk of moisture ingress to an absolute minimum.

3.3 Collections are stored at -20°C ± 3°C
Containers are transferred to cold rooms or freezers for long-term storage at a temperature of -20°C (Seed Bank Design: Cold-Storage Rooms for Seed Storage). The longevity of the collection will depend on viability at the time of banking and on the species. Some seeds may live for only a few decades, others for centuries or millennia. As an extra precaution, small samples from collections of high conservation priority or from species expected to be short-lived may also be stored in liquid nitrogen vapour at approximately -196°C (Protocol for Comparative Seed Longevity Testing) (see also section on cryopreservation).

3.4 Collection size is monitored to ensure sufficient potentially viable seeds are available for effective management and distribution to users
When seeds are used for routine viability monitoring, for distribution and for in-house research, the seed number is re-calculated, taking account of the proportion of incompetent seeds determined during purity assessment.

3.5 Collections are duplicated at -20°C ± 3°C and 15% eRH ± 3% at a second, geographically-separate facility
It is advisable to have an agreement in place to store duplicate collections at another seed bank facility, under internationally agreed standard conditions for seed conservation. Collections sent to another facility must be accompanied by a Notification of Transfer, which provides a declaration that all material has been collected and transferred according to the terms of the duplication agreement. If the seed bank will be receiving material from across international borders, national plant health regulations must be adhered to for receipt of these collections.

4. Viability monitoring

The most reliable way to measure seed viability is through germination testing. Seed viability is monitored according to the following guidelines:

4.1 Initial viability is tested, preferably by germination test, and monitored at least every 10 years
Initial viability is assessed after at least one week of cold storage. Subsequently, collections are re-tested every ten years, or more frequently depending on their expected longevity. Seed containers for collections to be tested are removed from the cold store and allowed to equilibrate for 24 hours under dry conditions. The number of seeds used for testing depends on the range of treatments needed and the size of the seed collection. Normally 50 seeds are used per treatment, though for very small collections, as few as 20 or even 10 seeds may be used. Seeds are sown into Petri dishes containing 1% water agar and then incubated at an appropriate temperature. Information about the plant species such as its ecology and life cycle, as well as climate information, are used to predict the best conditions for germination and any pre-treatment that may be required to overcome seed dormancy.

Each germination test is checked once per week, and the germinated seeds are removed, recorded and discarded. The tests are checked in a clean air cabinet, to minimise the risk of inhalation of fungal spores produced by any mould on the seeds or agar. The test is ended when germination is no longer occurring. A cut test is used to determine whether the remaining seeds are full, empty or mouldy. Excessively mouldy but filled seeds are an indication that seed viability has declined.

4.2 Management decisions (including to regenerate or re-collect) are implemented if initial viability is below 85% and if/when collection quality drops to 85% of initial viability
The Millennium Seed Bank of the Royal Botanic Gardens, Kew has statistical tests built into the seed bank database which are used to check and re-test results when they are entered, to see if viability has declined since the last test. This information assists the management of collections by informing re-test intervals and by signalling that viability is approaching the viability standard (e.g. set at 85% of initial viability). Decisions about whether to undertake regeneration or to make a new collection are taken at this point. The presence of seed dormancy in wild species means that not all of the viable seeds will germinate in every test. A germination standard is set at a level lower than the viability standard (e.g. at 75%). Collections are awarded a 'pass' if the lower 95% binomial confidence interval on the germination percentage is above the viability standard.

Germination test results are 'accepted' if there is no statistical difference between the number of seeds that germinate and the number of germinated seeds as well as the number of fresh seeds remaining at the end of a test as determined by a 'cut test'. If the number of germinated seeds is significantly lower, further experiments are carried out to investigate dormancy, especially when the collection is rated as high priority.

See the International Rules for Seed Testing for annually updated, harmonised, uniform, seed testing methods.

5. Data management

Data are collected and collated at every stage of the seed conservation process, adding value to the collection and facilitating its use. The seed bank database should assist in collection management, meeting the needs of conservation and research programmes, and should enable data exchange with other seed banks. Statistics generated though the database will enable progress towards collecting targets to be monitored and are useful when planning future collecting expeditions.

A seed bank data management system can be organised into four main sections:

- **Donation and collection data**
  This area contains information on legal agreements under which the collections have been made, the donor institute and collectors' names, site (including latitude, longitude and altitude), habitat data, plant identification and sampling data.

– **Processing data**
All results of procedures carried out on the seed collection are recorded through its processing life. The progress of a collection through the system can be tracked. Processing stages that yield key data include: X-ray analysis/cut testing, seed number determination, storage (date banked and location within bank for active and base portions), viability testing. Moisture status may also be recorded in this area. The database will include information on herbarium vouchers and glasshouse propagation data, as well as detail of duplicate collections stored at a second facility.

– **Seed distribution data**
The agreements under which seeds are held at the seed bank should be recorded in this area. A distribution policy is also included, recording what restrictions may apply to the future distribution of the seeds. Seed samples may be made available to third parties for bona fide research under a Material Supply or Material Transfer Agreement (Chapter 3, Section 3.6.1 and Chapter 4, Section 4.5.2), with the consent of the donor/landowner, and transactions are tracked through the database.

– **Taxon data**
This area includes accepted names for species and their synonyms, conservation ratings and inclusion within plant health and CITES legislation.

Although most of the seed collection data will not be accessible publicly, information on seed characteristics such as seed germination requirements and storage behaviour can be made available online.

6. Distribution

An advantage of the carefully stored, high quality seed bank collections is that samples can be distributed for use in research via an online seed list. Seed samples may be used by researchers in the sectors of food, agriculture, forestry, health and ecosystem restoration (Section 7.1.6), and in projects that will contribute to human innovation, adaptation and resilience in the face of current and future environmental challenges.

6.1 Collections are available for use [under an appropriate Material Supply Agreement], at least in-country where banked
The seed bank will establish conditions for seed sample requests that are made. Seeds may only be supplied to *bona fide* individuals that have registered on the seed list. Seed samples are sent out following receipt of a signed and legally binding Material Supply Agreement.

6.2 A distribution policy, with appropriate risk management for pests, diseases and potentially invasive species, is in place and applied
Seed samples are only supplied to individuals affiliated with organisations involved in non-commercial scientific research or conservation, as defined in the Material Supply Agreement. The agreement prohibits any commercial use of the material, progeny or derivatives. Users must avoid the spread of invasive plants and plant pests / pathogens and should check with their national authorities concerning import regulations, sending any necessary permits with their request (Chapter 6, Sections 6.4 and 6.8). Information on known invasive species that threaten biodiversity is available via the IUCN's Global Invasive Species Database. It is advisable that seed samples and the plants grown from them, are screened for diseases and kept in quarantine conditions, even where this is beyond the requirements of national authorities.

7. Seed bank risk management

The seed bank must carry out routine inspections and assessments to ensure that risks to the seed collections are adequately controlled. A purpose-built seed bank, combining good design, high build quality, robust mechanical/engineering systems managed by a building management system with associated alarms, trained staff and access control is recommended to safeguard the collections contained within.

A number of risks to the seed collections may be identified, relating to the physical destruction or integrity of the collections or may affect collection longevity (by increasing moisture or temperature). Collections are most secure when held in hermetically-sealing containers in cold storage. However, at any one time, collections may be at higher risk when present in dry rooms/containers, or in labs when being used for germination testing or research. A simple risk rating matrix can be devised to assess incidents affecting collections, according to Hazard Severity (from 'negligible impact on collections' to 'very high: majority of collections harmed') and Likelihood of Occurrence (from 'highly unlikely' to 'highly likely'). Incidents listed in a risk assessment strategy may include: fire; structural damage due to severe weather; mechanical failure to driers, chillers or alarms; power supply failure (incl. industrial unrest, bad weather); staff or contractor error; chemical leak/explosion; pest issues (rodents, insects); malicious behaviour (vandalism/terrorism); complete failure of IT infrastructure; severe weather; earthquakes. Mitigation systems and procedures then need to be established to deal with each type of incident.

For example, to mitigate against the possibility of fire incidents, a fire alarm system must be included in the building design, with regular testing and evacuation procedures in place. Seed bank managers should identify possible fire sources and arrange for regular, documented checks and servicing of all equipment that poses a risk. Duty scientists should be allocated from amongst the seed bank staff, so that any problems can be addressed as they happen (24hrs/7days) and trained fire wardens should be appointed.

- **Tissue culture and cryopreservation**

Where *ex situ* living collections or seed banks are not viable or desirable strategies, *in vitro* tissue culture and cryopreservation technologies represent alternative and complementary methods for the conservation of wild species (Panis and Lambardi, 2006). For instance, the botanic garden may not have enough land to establish a genetically representative collection, or the target species bear only short-lived, recalcitrant seeds that cannot be stored in a seed bank for their desiccation-sensitivity. Alternative *ex situ* conservation approaches may also be required for species that are sterile, and for plants that may not easily produce seeds, or produce seeds that are not readily available for collection. Such species that cannot be conserved in seed banks under standard protocols, are also often termed 'exceptional' (Pence, 2013; Wallace, 2015) (Case study 7.1.6).

CASE STUDY 7.1.6

Research and conservation of exceptional species

Sara Helm Wallace, Longwood Gardens, and Valerie Pence, Cincinnati Zoo & Botanical Garden

Exceptional species are those which are not suitable for conventional seed banking as they cannot withstand drying and/or cooling. According to preliminary results of a study led by Cincinnati Zoo & Botanical Garden focusing on threatened, exceptional species, there are over 400 tree species in the U.S.A. and Canada that are threatened, at least 80 of which have so far been identified to be exceptional.

One iconic group in this category is the genus *Quercus*, and alternative methods are being explored to accomplish the efficient *ex situ* conservation of endangered oaks. These include cryopreserving embryo axes, which can be isolated from seeds, then dried, and frozen in liquid nitrogen, or, alternatively, initiating *in vitro* cultures and cryopreserving the shoot tips or somatic embryos from those cultures.

The success of these procedures will depend on adapting them to the needs of individual oak species. Recent work with several endangered North American oaks, including *Quercus georgiana* (Endangered), and *Q. boyntonii* (Critically Endangered), has resulted in *in vitro* propagation protocols that can serve as a source of tissue for cryopreservation. Future work is needed to identify and adapt the most appropriate approaches for each endangered oak species. While these methods are more resource intensive than seed banking, they offer a viable option for the long-term *ex situ* conservation of these exceptional species.

In vitro propagation of Quercus georgiana, an endangered, exceptional species. (Image: Valerie Pence)

The tissue-cultured plants should be maintained under aseptic conditions (pathogen and pest-free), which facilitates the multiplication and distribution of plant material to other institutions. *In vitro* cultures serve also as a source of explants for the cryopreservation (see below). Removal of infected material and monitoring of the cultures is essential to avoid contamination of the *in vitro* collections.

Slow growth techniques for medium-term storage of the plant genetic resources *in vitro*, can be achieved by modifying various parameters, such as temperature, light regimen, culture medium and the gaseous environment. However, each step in the process of establishing *in vitro* cultures requires precise conditions which have to be defined for each species and type of plant material.

While the costs for the establishment of these methods are comparatively high, they may offer a needed alternative for species of urgent conservation concern. The multiplication rate of a culture, as well as the rates of rooting and acclimation, will have a major bearing on the number of transfers needed for producing plants via tissue culture; improvements in efficiency of these steps will help lower the costs. Further research into factors affecting the growth of tissues *in vitro* is required. Equally, greater coordination efforts among institutions with such facilities are needed to successfully secure highly threatened species via tissue culture and/or cryopreservation for which other viable *ex situ* conservation strategies are not available immediately.

If long-term conservation is required, cryopreservation, i.e. storage in liquid nitrogen at -196°C, is the main method currently available for vegetatively propagated plants (Sakai and Engelmann, 2007; Benson 2008). As with tissue culture, cryopreservation methods may be restrained by the initial costs, particularly to establish multiple genotypes of many species in the collection.

Cryopreservation facilities at The Huntington Botanical Gardens. (Images: Raquel Folgado Casado)

While techniques are evolving rapidly, the reaction of different culture systems when exposed to ultralow temperatures needs to be further researched to realise the full potential of cryopreservation as a tool for conservation. Therefore, sharing the resources for research among botanic gardens and other institutions working on these techniques may help to rapidly generate standard protocols for species of interest. During cryopreservation, cell division, metabolic and biochemical processes are arrested and thus the plant material can be stored without deterioration or modification (Shibli *et al*., 2004). Hence, germplasm can be kept theoretically for an indefinite time using little space. Work input is needed mainly at the start of the process when samples are prepared and cooled down, while the costs of maintaining a collection are dramatically reduced over time. Once in storage, only refilling of liquid nitrogen is needed. Other advantages are prevention of infections and genetic changes. Further, the degree of cleanliness (free of pathogens like viruses) is the highest priority for this type of *ex situ* conservation.

Appropriate tissue culture conditions are crucial in all the steps before and after the storage in liquid nitrogen (Case study 7.1.7). The acclimation of the explants used in cryopreservation (the response of some plants to abiotic contraints helps them to better respond to cryopreservation) as well as the establishment of conducive regrowth conditions are two of the most important aspects for which protocols need to be developed.

CASE STUDY 7.1.7

In vitro repository of magnolias at The Huntington Botanical Gardens

Raquel Folgado Casado, The Huntington, California

The Huntington Botanical Gardens are developing *in vitro* repositories for different groups of plants of priority conservation concern. The strategy to establish these repositories comprises all major steps, from collecting plant material in the wild through to rooting and acclimation prior to returning the plants to *ex vitro* conditions.

Tissue cultures facilitate the generation and access to sizable amounts of plant material. The *in vitro* repository is being managed under regular-growth conditions for immediate availability of plant material, and slow-growth conditions for middle term conservation. For long-term conservation, cryopreservation protocols are being developed. Key challenges for the establishment of micropropagated plants are the state and stage of the individual, environmental conditions and different levels of contamination and oxidation.

Magnoliaceae is one of the key families for which The Huntington Botanical Gardens are developing *ex situ* conservation approaches. While magnolias can generally be propagated via seed, grafting and rooting stems, these methods are not always highly efficient to obtain large amounts of disease-free plants. Besides, a number of species appear to generate recalcitrant seeds. Therefore, The Huntington Botanical Gardens are also establishing propagation protocols using tissue culture and cryopreservation.

Experiments with shoot tips from *in vitro* cultivated plants of *Magnolia macrophylla* var. *ashei* have been carried out. Dissected shot tips are cryopreserved using the droplet vitrification technique with a solution that contains a cryoprotectant. This allows the explants to tolerate the exposure to liquid nitrogen. However, the optimal length of the treatment requires further testing. After the rewarming of the shoot tips, various parameters need to be evaluated including survival rates, shoot tip regrowth and plant recovery. Based on the observations of how the explants are developing (oxidation, callus formation, hyperhydricity, etc.), the protocols can be further amended until whole plants are successfully recovered.

In vitro plants of M. macrophylla var. ashei during initiation and multiplication stages. (Images: Raquel Folgado)

Apical tip of M. macrophylla var. ashei after rewarming following cryopreservation. (Image: Raquel Folgado)

• Pollen and spore banks

Like seeds, pollen and spores can be divided into desiccation tolerant and intolerant. Pollen and spore banks may present additional means to preserve plant genetic material. In some taxa it is possible to raise entire plants as haploids from pollen grains. While pollen and spore banks require little space, long-term storage requires freeze- and vacuum drying. Both, pollen and spores may be used like explants for cryopreservation (see above) following the development of protocols to store them at low temperatures. While cytoplasmic genes may be lost in the process, pollen and spores are easier to bank than other plant tissue types, as they are more homogeneous.

• DNA banks

The creation of DNA banks allows large quantities of genetic resources – genes – to be stored quickly and in very stable conditions. For example the DNA Bank of the Royal Botanic Gardens Kew contains approximately 50,000 samples of plant genomic DNA (as of early 2015), all stored at -80°C. While DNA banks cannot replace conventional *ex situ* conservation approaches (Ebert *et al*., 2006), DNA samples present convenient experimental materials that can be shipped easily and used immediately for further molecular research, bioprospecting, phylogenetic studies, etc. Use of DNA samples in conservation is limited as whole plants cannot be reconstituted, but the genetic material can be introduced to other genotypes for plant breeding purposes.

DNA banking facility and molecular lab at The Huntington Botanical Gardens. (Images: Brian Dorsey)

7.1.5 *Ex Situ* Non-Living Collections

- **Herbaria**

A large variety of resources are available which deal with the set-up, arrangement and management of a herbarium. The Herbarium Handbook (Bridson and Forman, 2004) is the most comprehensive reference available for anyone wishing to create and maintain a herbarium. This section aims at providing an overview of the key aspects of herbaria and highlights their value of integration with other botanic garden collections.

KEY MESSAGE

Herbaria are vital repositories of plant information and should be integrated with other *ex situ* collections towards a comprehensive understanding of the species' biology and conservation needs.

1. Definition and purpose of a herbarium

A herbarium (plural: herbaria) is a collection of dried voucher specimens which are mounted on paper along with collection information to act as a preserved and lasting record. Vouchers can be created from wild plants or living collection accessions.

A herbarium is better than any illustration; every botanist should make one. Carolus Linnaeus (1751)

Herbarium specimens and their associated collection data (Chapter 3, Section 3.5) provide a wealth of knowledge on plant species and the environment that they inhabit. This information is mainly used for identification, research and teaching. Uses of herbarium specimens include the following:

Taxonomist at the Herbarium of the Royal Botanic Gardens, Kew. (Image: Board of Trustees of the Royal Botanic Gardens, Kew)

- Herbarium vouchers act as a reference library of taxa to be used for identification purposes.
- The specimen acts as a voucher for seed or living plant collections and will allow for accurate identification and naming.
- Specimens are essential for systematic research e.g. specific families (Fabaceae, Rubiaceae and Sapotaceae) or floristic work (Flora of China, Flora of Tropical East Africa and Flora Europaea).
- If a species has not yet been described reference to herbarium specimens allows a taxonomist to confirm species new to science.
- Collection information provides useful information on flowering and fruiting time which can be useful for phenological studies or to time seed collection activities (Haggerty *et al*., 2012).
- Collection information provides habitat and distribution data for each species.
- Herbarium specimens can be used to determine the conservation status of a species (Rivers *et al*., 2011).
- Extraction of DNA for use in DNA barcoding to help identify species and in conservation genetics (Särkinen *et al*., 2012).

A list of additional uses of herbarium specimens can be found in 100 Uses for an Herbarium (Well at least 72). Funk, V. (2003).

2. Setting up a new herbarium

Before starting a new herbarium it is important to determine the infrastructure, equipment and supplies that will be needed. It is essential to think about the long-term use of the buildings and the collection over time. The herbarium at the Royal Botanic Gardens, Kew has to constantly expand and adds a new wing every 40 years or so to keep up with the growing collection. Herbarium Essentials by Victor *et al*. (2004) provides a very useful section on 'Starting a new Herbarium' which covers these points in detail.

– Herbarium types

Herbaria can be categorised as global, national or regional depending on the geographic representation of the specimens they house:

Global: The Herbarium of the Conservatoire et Jardin botaniques Genève in Switzerland has around 6 million specimens from across the globe with a specific emphasis on collections from the Mediterranean, the Near- and Middle East, South America and Europe.

National: The Herbarium of the Institut de recherche pour le développement, Nouméa, New Caledonia, was founded in 1963. All the specimens are from the Pacific region with 90% from New Caledonia.

Regional (sub-national): Chicago Botanic Garden's Nancy Poole Rich Herbarium, United States is home to 12,000 specimens. The majority were collected in the Cook Country and the Upper Midwest.

The Index Herbariorum is a global directory of public herbaria and associated staff (Thiers, continuously updated). The directory holds information on the location, contents and the history of collections. Information is also provided on the web address, contact information and areas of specialism of staff for each institution.

– Collection types

The majority of specimens within a herbarium will be voucher specimens, however it is useful to keep a variety of other collections in herbaria including carpological, wood, fossil and spirit collections, as well as illustrations, photos and slides. Illustrations and photos are usually stored with the associated herbarium specimens as they can be kept flat. Other collections are stored separately and require specific storage requirements. Spirit collections, where plant parts are stored in an alcoholic solution to preserve their 3D structure, allow for detailed features of flowers and fruits to be preserved that would be lost during the creation of the herbarium specimen. Collections that are not stored with the main herbarium collection should be linked in some way to the main collection.

– Herbarium specimen sources

Herbarium specimen material can come from a wide variety of sources. Before collecting or accepting specimens it is important to make sure that the correct agreements and collecting permits are in place based on global policy agreements.

Collections: Collections made by staff or students within the institution, usually monographic or floristic specimens. These can be taken from wild or cultivated material.

Exchange: Several collections can be made from an individual plant or population. Duplicate specimens can then be created and exchanged between herbaria. Many herbaria do this to broaden their collection to include regions that they do not focus on for collecting trips.

Gifts and purchases: Could be a whole herbarium or a few specimens from staff at institutions with no herbarium.

Loans: Specimens of interest can be requested from other institutions. Specimens are usually requested for research purposes.

Identification service: Specimens sent to herbaria for identification are usually kept at the institution. Most botanic gardens that provide a plant identification service have a policy for dealing with identification. For instance, the South African Biodiversity Institute (SANBI) maintains a plant identification service aiming to provide clients with the necessary up-to-date information required for research and conservation of South Africa's botanical diversity.

3. Collecting, preparing and mounting herbarium specimens

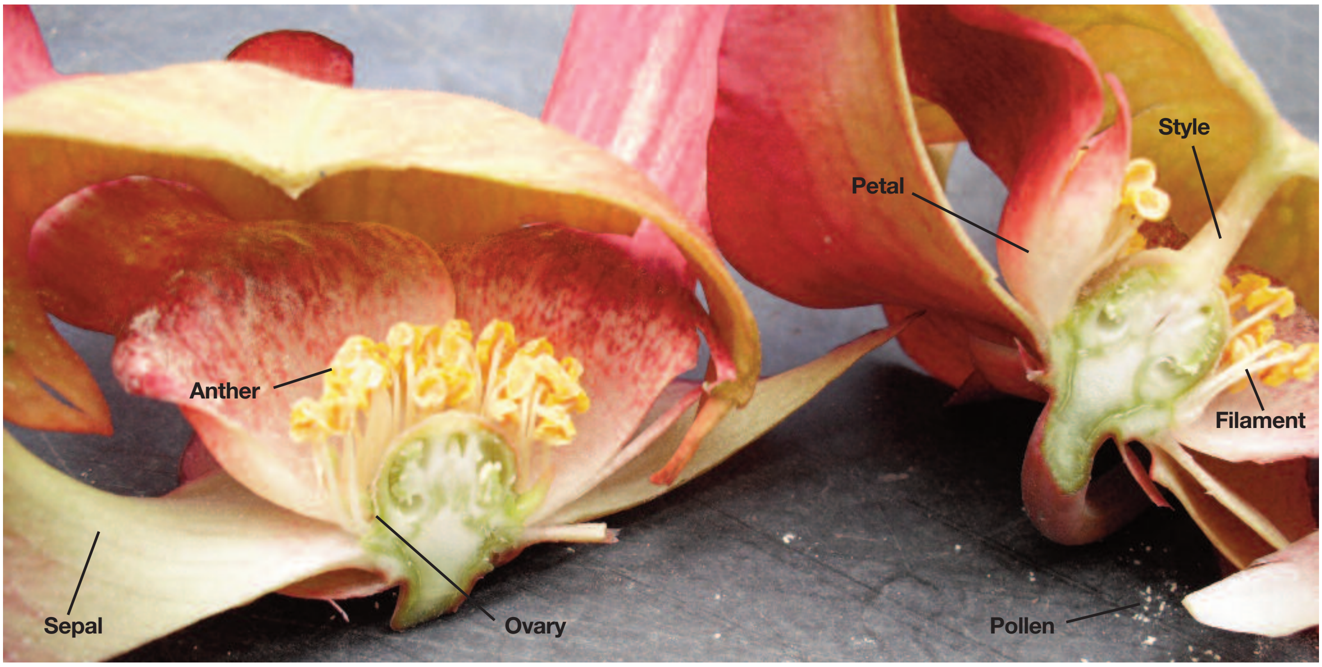
Herbarium specimens are collected in the wild or in cultivation, dried and then mounted onto sheets of paper. The sheets are then filed in folders and laid away in cabinets. The scientific value of a herbarium specimen is determined by the quality of the specimen and the associated collection data. In order to have good collections it is important to carry out the following steps to a high standard.

– Collecting

Collection information for herbarium specimens, as with living collections field data, is essential if the specimen is to represent any scientific value. This collection information must be linked with the herbarium specimen throughout the processing of the specimen so that passport information can be related to the specimen.

It is important when making herbarium specimens that attention is paid to capturing the diagnostic features which are representative of the taxa such as fruit, flowers, stems, leaves, roots and tubers. This will allow for easier identification of the specimen and provide a useful reference material for verification of other specimens. Different families have different diagnostic features and so require different plant parts to be collected. The family Apiaceae for example requires presence of ripe fruits in order to distinguish between genera and species. Ranunculaceae requires underground parts and fruits to be collected whereas for Eriocaulaceae different stages of inflorescence should be sampled. The Herbarium Handbook has an extensive list of families of flowering plants with a short note on the features which are important for identification and should be referred to when collecting.

It is recommended that when possible, identification of the specimen should take place in the field in order to determine what parts are essential for identification. It is useful to take several examples of key features such as flowers in order to be able to show both internal and external structures.



Capturing diagnostic features in the field. (Image: Garance Wood-Moulin)

In order to capture the phenotypic diversity of a species it is useful to make several specimens for a single taxon at each of the different stages of life history. This is one of the main advantages of holding herbarium specimens of living collections as taking multiple collections at different life stages is relatively easy to do.

– Preparing

A plant press should be used to dry herbarium specimens as soon as possible after collection in the field. Specimens should be laid flat and attention should be paid to making sure that all diagnostic features will be represented in the dried specimen, including the underside of leaves. Specimens should be placed inside absorbent paper such as newspaper and cardboard (with corrugated aluminium sheets), and pressed. If a press is not available heavy objects such as books should work. Drying can be achieved by leaving the plant press in the sun or by placing it in a dry room or oven.

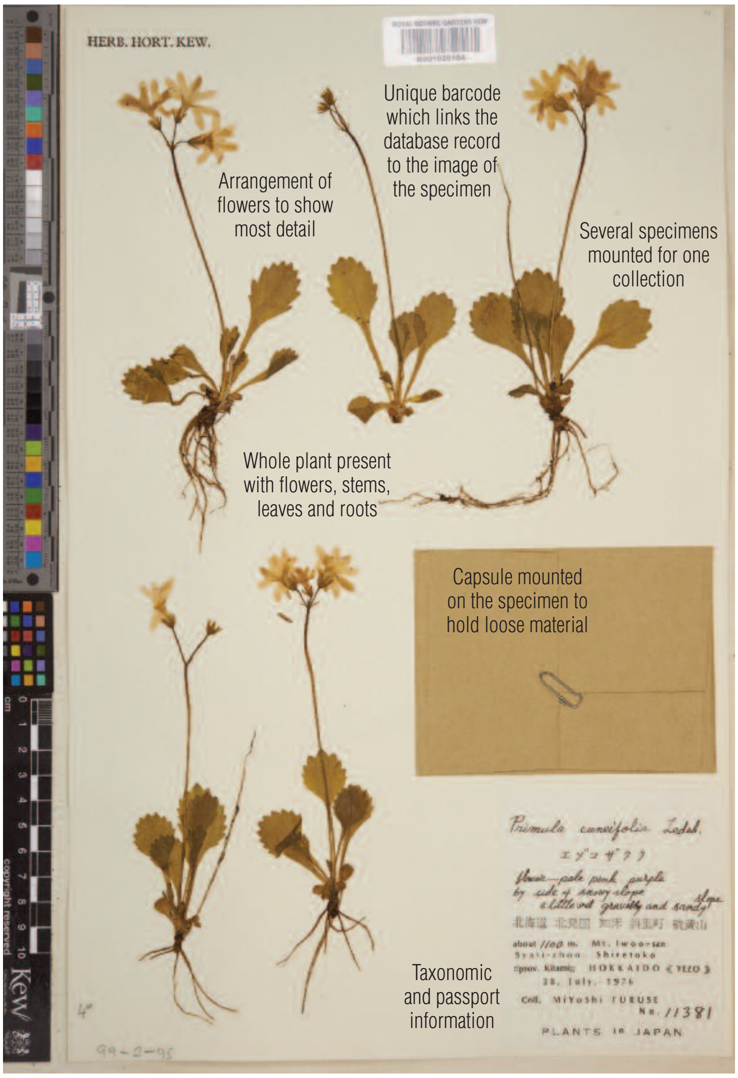
Herbarium preparation. (Images: Missouri Botanical Garden, top; Zhou Yuan, above)

Dried specimens lose a lot of the characteristics of the living plant. It is worth making notes of features such as flower colour, smell and waxes which are present in the living plant and will be lost on drying. This information along with all other passport data of the specimen should be associated with the plant material in some way. This can be done by giving the collection a unique collection number. This collection number can be attached to the specimen using jeweller's tags and should be associated with the passport data. The specimen and passport data can then be reunited when mounting the specimen.

– Mounting

Once the specimen is dried it is glued to archive paper or sewn if more bulky. The information from the passport data form (Chapter 3, Section 3.5) is used to make a label for the herbarium specimen; this is then glued to the specimen sheet.

It is important to think about the longevity of the collection when mounting. Archival quality paper (acid free) and pH neutral glue should be used for mounting specimens to ensure that the collections last. Loose material such as fruits or seed should be placed in a capsule which can then also be glued to the sheet. Any loose leaf material should be placed in this capsule to make it available for DNA extraction.



Information components on mounted herbarium specimen. (Image: The Board of Trustees of the RBG, Kew)

– 'Difficult' species

Certain specimens are difficult to collect, press or mount. In order to avoid having collections that are bias towards taxa which are easy to collect and preserve, it is important to be aware of the problem plant groups and to know how to deal with these. Specialist equipment and knowledge is required for collection of these groups:

Collecting: Trees are more difficult to collect from than small herbaceous species. For collecting specimens from trees it is useful to have a hard hat, tree loppers, ladder and binoculars. The family of Urticaceae has stinging hairs and *Mucuna* (a genus in the family Fabaceae) has irritant hairs. Gloves should be worn when collecting from these species.

Pressing: Succulents are too wet to dry using standard methods. For Aloes and Agaves the flesh should be sliced and the gel removed before drying. Cacti can be sliced thinly as this will aid drying, but the internal succulent tissues need to be largely removed using a scalpel.

Mounting: Bulky specimens such as palms are usually mounted onto oversized sheets or stored in boxes. Aquatic plants generally lose their structure when out of the water and so need to be mounted when submerged in water and then pressed.

4. Nomenclature – the importance of names

Botanical nomenclature is the system of naming plants. Names are essential for the communication of information about the taxon. The International Code of Nomenclature for algae, fungi, and plants (ICN) (McNeill *et al*., 2012) governs botanical nomenclature. The basic rules for a correct plant name are that it is legitimate and validly published.

– Identification and determination

Within herbaria taxonomists identify voucher specimens based on dichotomous keys, species descriptions or by comparison with other herbarium specimens. When a herbarium specimen has been identified a determination slip is added to the specimen with the determination date and determiner name added. Specimens can then be re-determined if the specimen is subsequently re-identified or a taxonomic revision is made.

– Nomenclatural type

When a new species is described the type specimen is the voucher or illustration associated with the species description and the taxon name. Whichever specimen was used to create the description for a new species is therefore the nomenclatural type. The specimen is a voucher for the plant name. There are various different categories of types. See the ICN for more information.

– Nomenclatural standard

A nomenclatural standard differs from the type specimen in that the specimen or illustration is the voucher for a cultivar name. The Royal Horticultural Society in the United Kingdom has an extensive collection of nomenclatural standards within their herbarium as they specialise in plants of garden value.

5. Curation of specimens

It is important to determine the arrangement of the specimens within the herbarium. The arrangement of the herbarium will depend on the type of collections and their expected use. Irrespective of the arrangement chosen, the specimens should be easy to find and lay away. The three main types of herbarium specimen arrangement are systematic, alphabetic and geographic. Most herbaria use a combination of systems to curate their collections (Case study 7.1.8). The advantages and disadvantages of these systems are discussed in detail in The Herbarium Handbook (Bridson and Forman, 2004).

– Systematic

There is a variety of systematic arrangements which are used to curate herbarium specimens. This involves the ordering of plants based on their relationship. Within the last few years many herbaria have arranged or rearranged their herbaria to follow the evolutionary classification of the Angiosperm Phylogeny Group (APG) system which was published in 2009. This results in genetically related families being grouped together so that for instance Fabaceae is next to Rosaceae and Dicksoniaceae is far away from Caprifoliaceae. Systematic arrangement at the genus, species and infraspecific level will depend on availability of APG revisions (presently APG IV, 2016).

– Alphabetic

Arranging the herbarium alphabetically involves arrangement of families, genera, and then species. For example:

Family	Acanthaceae Juss.
Genus	*Acanthopale* C.B.Clarke
Species	*Acanthopale aethiogermanica* Ensermu
	Acanthopale albosetulosa C.B.Clarke
	Acanthopale azaleoides C.B.Clarke
through to	Zygophyllaceae R.Br.

With collections that are ordered alphabetically it may be beneficial to keep major plant groups such as monocots and eudicots in separate collections.

– Geographic

Herbaria generally incorporate a level of geographic arrangement to their collections. This arrangement will depend on the areas of the world the collection is from. In global herbaria, the globe is often split into regions related to where the bulk of specimens are from. It is unlikely that specimens within national or regional herbaria will benefit from this type of curation.

– Cultivated

Cultivated and wild collected specimens are usually kept separately (Chapter 3, Section 3.5.5).

CASE STUDY 7.1.8

Herbarium arrangement at the Natural History Museum, London, United Kingdom

Jacek Wajer, Natural History Museum, London, United Kingdom

The Natural History Museum (NHM) in London has one of the largest herbarium collections in the world, containing over 5.2 million specimens. The collection is divided into four major curatorial units based on the phylogenetic position, geography and historical significance of stored material. These four sections are known as the Cryptogamic, Seed Plants, British and Historical herbaria. Arrangement of the specimens within each collection is either systematic or alphabetical depending on their intended use and available literature.

Seed plant collections

The Seed Plants Herbarium is arranged according to the latest Angiosperm Phylogeny Group (APG) system of flowering plants classification. The families recognised in this system have been given numbers 1-413 and are organized accordingly. Some 100 additional families which are not accepted by APG but represented in the herbarium are filed adjacent to the family to which all, or the majority, of genera would eventually belong. An index of the families and the genera recognized in this system is available in the herbarium to aid the location of relevant specimens. The genera within most families are arranged systematically in a sequence based on the latest available monographic treatment, with any new genera being added in alphabetical order at the end of this arrangement. In some families (e.g. Solanaceae) all of the genera are arranged in alphabetical order only. Within each genus, specimens are divided first into geographical regions, based on their collecting locality, and then sorted into species within each region. The herbarium is divided in 26 geographical regions, with cultivated specimens stored at the beginning of the sequence. Maps explaining this arrangement are available throughout the collection. Species are usually arranged systematically within each geographical region and there is often an additional alphabetical run of new species at the end of the systematic sequence. An index to the species is usually found in the first folder of each genus, unless each geographical region has its own arrangement in which case the index will be located in the first folder of each geographical section.

Cryptogamic collections

The cryptogamic collections contains the Fern, Algae, Bryophytes, Lichens and Diatoms. The Fern Collection is split geographically between British collections and the rest of the world. The British collections are arranged following a sequence of genera and species compiled in 1980 by Clive Jermy, and in vice-county order within each species. The non-British specimens are arranged according to *A new generic sequence for the pteridophyte herbarium* published in 1975 by J.A. Crabbe, A.C. Jermy and J.T. Mickel (Fern Gazette 11: 141-162). Each genus is arranged geographically, and species are curated either systematically or alphabetically.

Historic collections

Specimens of historical importance dating back to the mid-17th century, like those collected or owned by the founder of the museum's collection Sir Hans Sloane are stored separately for conservation and security reasons. They are arranged thematically rather than systematically in 265 bound volumes. Each volume contains a mix of specimens collected either by a particular botanist (e.g. Sloane, Kaempfer, Petiver, etc.) or from a specific place (e.g. Europe or Chelsea Physic Garden, etc.). A guide to this collection was published in 1956 and can be consulted to find most of the specimens.

Examining specimens in the herbarium of the botanic garden of Curitiba, Brazil. (Image: Michael Willian)

6. Cataloguing collections

The herbarium catalogue is a directory of the filed-under names of specimens within a collection. Cataloguing allows for a summary of what is in the collection to be easily accessible and queried without the need to refer to the collection itself. In addition a catalogue represents a backup which is useful when collections are misplaced or go missing.

Collections can be either catalogued electronically or on paper. Paper indexes are usually stored in the collection, for example an index to the Brazilian species in the genus *Bauhinia* is likely to be stored with the specimens and can be referred to in order to allow users to easily determine whether taxa of interest are present and if so where to find them.

Electronically cataloguing the specimens within the herbarium allows for a register of collections to be available and easily searchable. One advantage of electronic cataloguing is indexes such as the one above can be produced easily by querying the database. Additional information such as presence of a spirit collection can be linked to the specimen within the electronic catalogue.

– Integration of herbarium collections with other collections
As previously highlighted recording and managing botanical data are important in order for collections to be effectively managed as well as to ensure that they provide education, research or conservation value. Herbarium specimens can act as vouchers for other collections within a botanic garden including living, seed, DNA or spirit collections (Case study 7.1.9). When the name of the voucher specimen is changed, either when re-determined or if a new combination is created, it is important for the linked collections information to reflect this. If this does not happen then management of the collections is impossible as there will be two names associated with a single taxon. Integrating separate collections is an issue for many existing herbaria, while new ones should implement an integrated approach from the outset.

CASE STUDY 7.1.9

Linking living collections to herbarium specimens

Alison Foster, University of Oxford Botanic Garden

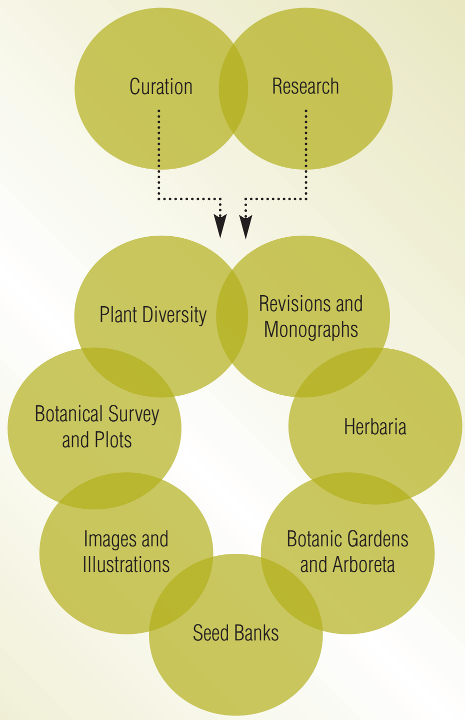
Like other botanic gardens and arboreta, the University of Oxford Botanic Garden and Harcourt Arboretum maintain detailed records about all their plants. It is vital that these records are kept up-to-date and easily accessible to those looking after the collection. The Botanic Garden at Oxford has kept records in some form or another since it began, including a catalogue listing all plants at the Garden, published in 1648.

As computers became common in the workplace, the record-keeping system moved to an electronic format. The first such system, in 1986, used a simple database filing system. In the mid-1990s, the records were moved to BG-BASE, software developed at the Royal Botanic Garden Edinburgh.

Over the past few years, as Oxford Botanic Garden has worked ever more closely with the Oxford University Herbaria (FHO and OXF), it seemed sensible to investigate whether the Garden and the Oxford Herbaria could use compatible data-management systems, allowing much closer integration of herbaria and living collection data; a key part of our future strategy. The Oxford University Herbaria use BRAHMS (Botanical Research and Herbarium Management System) to document their collections. The developer of this database (Denis Filer) is based in Plant Sciences in Oxford and had been working with Gerda van Uffelen at Leiden Botanic Garden to develop a new Living Collections module for BRAHMS, so it seemed a natural choice to make the move to BRAHMS to facilitate this integration. In early 2011, they began to transfer data from BG-BASE to the BRAHMS Living Collections module; by mid-2011, BRAHMS was up and running at Oxford Botanic Garden. Since then, they have been actively using and developing the module, suggesting new functions as they go. In February 2012, they started running over terminal services and now they can access the database from different locations using both Mac and PC workstations.

This integration of the herbarium and living collections allows the gardens to work closely with the herbarium. A recent project relating to the Japan Biodiversity Hotspot aims to collect seed and document the indigenous plants of Japan. Sharing the same database set up has allowed for all the information gathered in the field (vouchers, rapid botanical survey data, seed, etc.) to be shared effectively between the Herbarium and the Garden and Arboretum.

Moreover, the gardens are working through their living collections to enrich their plant records database by adding images of their collections as well as making herbarium vouchers. By ensuring that they are using the same protocol in both departments, maximum data sharing in the longer term will be ensured.



Integration of living collections and herbaria management at the University of Oxford Botanic Garden.

Herbarium of Jawaharlal Nehru Tropical Botanic Garden and Research Institute, India. (Image: Katherine O'Donnell)

Key reasons for integration of collections' information:

- Creates a link between science and horticulture;
- Avoids duplication of effort in recording data;
- Allows for associated data to be linked to the herbarium collections;
- Allows for one central system to be updated rather than multiple systems.

Various data record systems are available which have been designed specifically to manage the different types of collection information that a botanic garden can hold (Chapter 5, Section 5.5.2). The decision on which management system to use will depend on the specific collections of the institution and their needs.

7. Virtual herbaria

Many herbaria are now involved in the digitisation of their specimens (Case study 7.1.10). This consists of creating a database record of the passport information of a specimen and linking it to a high resolution image of the specimen. Virtual herbaria can then be created online to increase the accessibility of collections. The appeal of online collections is that information that is currently stored in cupboards and therefore inaccessible to researchers, unless they make visits or request loans, is made available.

The majority of custom-built botanic garden databases use the passport information associated with a specimen to create the herbarium labels. When this information is already in the database there is no need to database the record. It is still important to link the passport information to the herbarium specimen via a unique identifier such as a barcode or accession number.

Several countries including the United States, Japan and Australia are working towards a virtual herbarium of all the specimens from each herbarium within their respective countries. These data can then be searched, mapped and analysed and provide a powerful botanical data tool for research purposes (Case study 7.1.11).

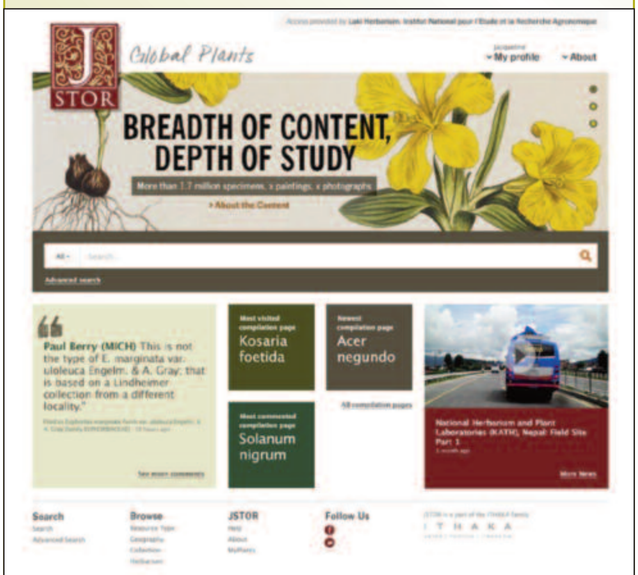
CASE STUDY 7.1.10

JSTOR Global Plants Initiative

Katherine O'Donnell, Botanic Gardens Conservation International

Funded by the Andrew W. Mellon Foundation, the JSTOR Global Plants Initiative is an international collaboration aiming to increase the accessibility of type specimens by building a comprehensive online research tool. By pulling together and linking presently scattered resources about types and other complimentary material the goal is to improve access for students, scholars, and scientists around the world. The founding partners include the Missouri Botanical Garden; Muséum National d'Histoire Naturelle, Paris; National Herbarium, Addis Ababa University; New York Botanical Garden; Royal Botanic Garden, Kew; and South African National Biodiversity Institute.

The website plants.jstor.org is a growing repository of over two million type specimens which have been made available by a community of partner herbaria around the world. Images of type specimens and their associated passport data are made available through the website. There are over 160,000 linked reference words and 20,000 drawings, paintings, photographs and other images. Features on the website include the ability to discuss and have corrected questionable determinations and specimen information. The images are high resolution to allow for detailed work online. Tools allow for specimen parts to be measured and saved. Taxonomists can update specimen determinations and carry out revision work online without having to visit the herbaria that the specimen is from.



Screenshot of the JSTOR web portal.

CASE STUDY 7.1.11

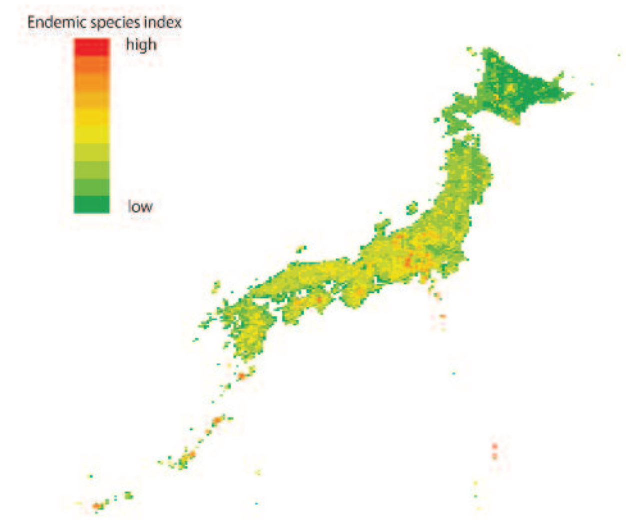
Making a map of endemic plants of Japan, using S-Net collections as well as specimens from local herbaria and museums

Tomoko Fukuda, National Museum of Nature and Science, Tokyo, Japan

While information on Japanese endemic species is available in the literature, knowledge of the occurrence and distributions of each taxon is limited. To address this gap, the National Museum of Nature and Science (NMNS) in Japan developed a map of endemic Japanese plants based on herbarium and related database records. Details of the results are provided in Kato and Ebihara (2011).

In addition to 123,061 herbarium samples deposited at the NMNS, information from other museums and institutions was collected. The S-Net (Science Museum Net) database containing specimen data from every organization in Japan was also used. This is a database of Japanese voucher specimens with associated collection and location information, including some four million data records. This information is also provided to the Global Biodiversity Information Facility. In some cases of endemic species, the herbarium materials at every museum were directly studied. As a result, 212,017 specimens of endemic plants from more than 30 organizations were used to create the map.

The *Map of Endemic plants of Japan* (Kato and Ebihara, 2011) shows the distribution of related taxa to be found concentrated in islands with mountains and in high mountains in mainland Japan. Most of these localities are already under protection as they are included in national parks, except for some that should be protected in the future. The map also highlights the most important localities for conservation of endemic plants. In conclusion, the herbarium samples and the related database records have contributed to identifying these areas.



Map of endemic plants of Japan (Kato and Ebihara, 2011).

7.1.6 *Ex Situ* Collections Serving *In Situ* Conservation

As highlighted in section 7.1.1 onwards, *ex situ* conservation provides an 'emergency ward' aimed at extinction-proofing and 'buying time' for species of urgent conservation concern. While *ex situ* collections of threatened plants therefore provide a long-term 'insurance policy' against irrecoverable loss, they are also a source of native germplasm for recovery programmes in the wild. Plant material from *ex situ* collections can be used to reinforce declining and degraded plant populations, or for reintroduction where a species or populations thereof have entirely disappeared. *Ex situ* collections of wild plants also present an essential reserve for small- to large-scale ecological restoration programmes. In the same vein, in times of rapid climate change and transforming ecosystems, botanic gardens may also hold plant material of species that likely require translocation and introduction to climatically more suitable habitats, which will lead to new species combinations that have not occurred before. These features underscore the key roles that botanic gardens play in integrated *ex* and *in situ* conservation in the twenty first century (Figure 7.1.1).

KEY MESSAGE

Botanic gardens are increasingly embracing and promoting an integrated approach to conservation. Appreciating the wide range of *in* and *ex situ* conservation measures as complementary efforts, botanic gardens are at the forefront to guide, support and implement innovative strategies aimed at securing plant diversity for future generations.

A wealth of technical resources and practical tools exist that inform and guide the development and implementation of *in situ* conservation and recovery measures as referenced in section 7.1.7. Rather than replicating these resources, this section aims to illustrate through a series of resonant case studies the vital contributions by botanic gardens to *in situ* conservation and recovery efforts. While numerous terms at various levels of complexity for different recovery approaches are in use in the conservation community, this section employs 1) population reinforcement, 2) population reintroduction, 3) ecological restoration and 4) population introduction to exemplify this work.

- **Population reinforcement**

Population reinforcement aims to assist the recovery of declining or degraded populations of species and enhance their viability that without intervention would not regenerate. For instance, this could be due to restricted seed dispersal abilities and the absence of a sufficient natural stock of seed in the soil following fragmentation of the population as a result of a natural hazard or human activity. The aim is to enlarge the effective size of remaining populations by increasing genetic diversity or representation of specific demographic groups or stages (IUCN, 2013) and, where possible, re-establish their original connectivity in the wider landscape.

Botanic gardens are uniquely placed to conduct successful population reinforcement action, especially for plants of urgent conservation concern. Based on their expertise to prioritise species, collect propagules in the wild, grow in horticultural trials and establish sizable numbers of individuals, they are equipped with the vital fundamentals to reinforce wild populations and monitor their survival over time (Case study 7.1.12).

CASE STUDY 7.1.12

Population reinforcements of critically endangered plant species in grassland habitats

Sandrine Godefroid, Sarah Le Pajolec, Fabienne Van Rossum, Botanic Garden Meise, Belgium

Nutrient-poor grassland habitats and several of their characteristic plant species have reached a critical state in many European countries. The main reasons for this situation are: habitat fragmentation, forest recolonization due to abandonment of the traditional agro-pastoral activities, and the intensification of agricultural practices leading to eutrophication. There is an urgent need to preserve, manage and restore these few remaining, often degraded, habitat patches. Part of this task includes the recovery of populations of threatened plant species that without intervention would not regenerate naturally due to restricted seed dispersal abilities and the absence of a persistent seed bank in the soil.

Field surveys and collection of Arnica montana. (Image: Sandrine Godefroid)

Southern Belgium is an important area for the conservation of semi-natural grassland types listed in the annexes of the Habitats Directive. In the framework of the European Commission LIFE project 'Herbages' (LIFE11 NAT/BE/001060), the Botanic Garden Meise, as a centre of excellence in *ex situ* conservation and plant propagation, has implemented population recovery measures in the wild for four highly threatened species: *Dianthus deltoides, Helichrysum arenarium, Arnica montana* and *Campanula glomerata*. The aim is to increase the effective size of remaining populations (reinforcement) and to restore extinct populations (reintroduction) in order to improve connectivity in the landscape.

The population recovery measures adopt a four-step approach: 1) selection and profiling of the target species; 2) source population selection and seed collection; 3) development of propagation protocols and 4) assessment of plant fitness of the populations used as seed source before planting out. For each species, a population of 500 to 700 young individuals was transplanted into three to six sites. Once *in situ* these plants (which are permanently labelled) were precisely mapped to facilitate their long-term monitoring. Each population consists of a mixture of plants from different origins arranged in order to maximise pollen exchanges between different origins.

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Propagation of Arnica montana at the Botanic Garden Meise. (Image: Sandrine Godefroid)

CASE STUDY 7.1.12 (CONT.)

Planting in situ on a target area where potentially competing plants have been removed to maximise the survival rate; the saplings have been furnished with permanent labels to facilitate long-term monitoring. (Image: Franck Hidvégi)

The initial results have been very positive: the survival rate of planted individuals is over 90% while the flowering rate (>30% on average) is also remarkable, in some species just a few months after planting. Seedlings and clonal propagation have been observed indicating a potential for population expansion. Monitoring of reintroduced populations will continue for at least 10 years to gather ample data about their long-term development. A demographic survey (e.g. survival, floral production, reproductive success, and population extension by clonal propagation or seedling recruitment) is recorded yearly in the field. Germination trials are continuing to estimate the fitness of the progeny in order to test for inbreeding or outbreeding depression.

Helichrysum arenarium and Dianthus deltoides populations following reinforcement planting. (Images: Daniel Parmentier)

- **Population reintroduction**

Reintroduction is the intentional release of an individual or a group of individuals in their natural area of distribution from where they have disappeared. The aim is to re-establish a viable population of the target species in its original range (IUCN, 2013). This can either concern the reintroduction of a particular population that is no longer present where it formerly occurred, or the species at large, if all of its populations have entirely ceased to exist in the wild.

As repositories of wild plant material, botanic gardens par excellence play a key role in population reintroduction programmes. There are numerous instances of plant material held in *ex situ* collections from populations that no longer exist, let alone of species gone extinct in the wild such as the emblematic *Sophora toromiro* (Fabaceae) in the Easter Island or *Encephalartos woodii* (Zamiaceae) in southern Africa. Plant material of both these species however has survived in botanic gardens in Chile and Germany, and South Africa respectively, and is used in population reintroduction trials. Other examples include *Cylindrocline lorencei* (Compositae) and *Normania triphylla* (Solanaceae) – two species endemic to Mauritius and Madeira respectively (Case study 7.1.13) and *Erica verticillata* (Ericaceae) in South Africa (Case study 7.1.14).

Sophora toromiro, grown in the Jardín Botánico Nacional, Chile, and subject of an ambitious reintroduction programme. (Image: Óscar Fernández)

CASE STUDY 7.1.13

Recommendations for successful reintroduction – experiences from recovery work of *Cylindrocline lorencei* and *Normania triphylla*, two plants endemic to Mauritius and Madeira respectively

Stéphane Buord, Conservatoire botanique national de Brest, France

National Parks and Conservation Service nursery 'Robinson', where several species endemic to Mauritius are being propagated. (Image: Stéphane Buord)

Scientific literature is poor in studies providing analytical details of successful reintroduction of plant species (Godefroid *et al*., 2011). Several reasons explain this shortfall. First and foremost, failures are manifold, and, as a result, are not published. Often, these are due to insufficient knowledge of the reasons why the species disappeared and of the degradation of ecosystem in which the population was embedded. Without addressing these and initial ecosystem restoration efforts, reintroductions are unlikely to be successful.

Reintroduction trials with animal and plant species are being carried out for over 25 years by different conservation stakeholders in the Mauritian archipelago. In a very degraded environment resulting from deforestation and introduction of alien invasive species, the National Parks and Conservation Service (NPCS), Mauritius Forestry Service (MFS) and Mauritian Wildlife Foundation (MWF) decided to trial restoration in selected tracts of forests. Referred to as Conservation Management Areas, these one to two hectare-large areas are fenced to pre-empt any undesired interference with the restoration action. Invasive vegetation is being eradicated with remaining roots eliminated with the aid of chemical agents. While this work is carried out manually often over many years, the results are remarkable. On the site of Pétrin, NPCS was able to re-establish forest fragments on laterite; hitherto impeded by the proliferation of the introduced and highly invasive *Psidium cattleianum*, germination of seed of indigenous species having remained in the soil was observed. These preliminary efforts are quintessential prior to initiating actual reintroduction work. Following these interventions, NPCS has started to plant *Cylindrocline lorencei* (Compositae) – a species endemic to Mauritius but extinct on the island – with plantlets generated from remaining specimens in the *ex situ* conservation collection of the Conservatoire botanique national de Brest (CBNB).

Based on the same approach, MWF and MFS aim to initiate native flora recovery trials on Aigrettes island through assisted colonisation by very rare species. In situations where the indigenous flora is particularly degraded, nurseries are established on-site to produce thousands of saplings of the target species, to be able to draw on average on 4 to 12 plants/m^2, and to ensure the *ex situ* conservation of especially rare species. The sites being regularly managed and monitored in this way, reintroduction of *Dombeya mauritiana* (Malvaceae) – a species of which a single specimen was known to remain in the wild in the 90s – is another example yielding promising results to date.

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CASE STUDY 7.1.13 (CONT.)

The absence of close monitoring and evaluation following reintroduction efforts is another major obstacle to success. The return of a plant species to its restored natural environment requires to be accompanied by a well-defined monitoring method to evaluate the development of the reintroduced populations and establish best practice. Such monitoring will have to extend over often long periods, several years or even decades, in order to observe in particular the emergence of a second generation *in situ* and to quantify the evolution and dynamic of the populations. These stipulations are essential but are often not included in the funding arrangements which frequently focus solely on the initial reintroduction activities. Finding a local, institutional partner to carry on this work is therefore quintessential.

Normania triphylla, a Solanaceae endemic to Madeira, is another example of how plant material held in *ex situ* collections can be used for population reintroduction. Following an entire century during which this plant was believed to be extinct, the species was rediscovered by Padre Nobrega in the 1990s in Madeira's Laurisilva. As an insurance policy, he donated seed to the Conservatoire botanique national de Brest. A couple of years later, as the population was no longer found in the wild, a reintroduction programme was initiated by the CBNB and the Jardin botanique Rui Vieira of Funchal. Thousands of *N. triphylla* seeds were selected for germination, and saplings were subsequently planted in the wild. However, in the absence of a careful management and monitoring plan in the weeks following the reintroduction work, the intervention ended in failure.

A second trial in 2008 closely involved the Madeira National Park forest service. The new strategy adopted consisted of creating small gardens with mother plants at the homes of the forest personnel in the Park. This proximity allowed the regular maintenance of the plantlets by the Park staff. The aim was to create population nuclei of densely cultivated *Normania*, likely to generate a sufficient magnitude of seed to ensure a progressive recolonisation of the surrounding environment. The concept of 'recolonisation nurseries' *in situ* has led, several years later, to the occurrence of numerous *Normania* populations not far from the sites initially chosen for reintroduction. This method would benefit to be tested further in other species reintroduction programmes, accompanied by rigorous monitoring of the cultivated populations and of the areas that are being recolonised.

Reintroduced sapling of Cylindrocline lorencei in Plaine Champagne, Mauritius. (Image: Stéphane Buord)

Normania triphylla (Solanaceae) in the conservation collection of the Conservatoire botanique national de Brest, France. (Image: Loïc Ruellan)

CASE STUDY 7.1.14

Reintroduction of the Whorl Heath – *Erica verticillata* in South Africa

Anthony Hitchcock, Kirstenbosch National Botanical Garden and A. Anthony Rebelo, South African National Biodiversity Institute (SANBI), South Africa

A species gone extinct in the wild

Regarded as extinct in the wild by the second half of the 20th century, *Erica verticillata* used to grow in Cape Flats Sand Fynbos on the lowlands of the Cape Peninsula from the Black River to Zeekoevlei in South Africa. The sketchy information on herbarium sheets and in the literature suggests that this species preferred seasonally damp, acid, sandy soils near streams and wetlands. Overharvesting and agricultural and urban development that occurred as colonial Cape Town expanded resulted in the destruction of populations and its natural habitat. The last herbarium specimen collected from the wild dates back to 1908. Other records of this species in South Africa are herbarium specimens of a plant that was growing at Kirstenbosch National Botanical Garden (KNBG) in 1943 and a specimen submitted by J. E. Repton in 1961 from a cultivated plant in the Pretoria district.

Rediscovery in *ex situ* collections

Thanks to the enthusiasm and efforts of a few botanic gardens and some dedicated collectors and growers, the search for *ex situ* collections of *E. verticillata* began, becoming an exercise in detective work. With assistance from members of the British and American Heather Societies, botanic gardens, Erica growers in Europe and by searching the internet, several locations and collections were tracked including Tresco Abby Gardens on the Scilly Isles, a private Erica collection of Dr. Violet Gray via the British Heather Society, a trademarked selection from Monrovia Nursery in California called *Erica verticillata* Ruby Lace, two from a nurseryman in Germany and another collection from Royal Botanic Gardens Kew. To date, eight confirmed collections have been found three of which have been used in reintroduction efforts.

Reintroduction

The rediscovery of *E. verticillata* excited interest amongst conservationists to attempt reintroduction to its natural habitat. Following experimental planting to determine appropriate habitat conditions, Ericas of the Pretoria clone 'African Phoenix' formed the first population returned to a wild habitat in 1994. The plants attracted a number of pollinators such as the southern double collared sunbird, hawk moths and bumblebees. Despite this, they did not produce seed. A second clone, *Erica verticillata* 'Adonis', was planted in 2001 to encourage seed production. The first seed was collected from the plants at Rondevlei Nature Reserve in 2003 proved viable and seedlings were generated at the Rondevlei nursery. In 2013, fire was put through some 150 plants of the newly created population to simulate natural conditions. This was a major step in re-establishing a natural wild population and towards changing the species' conservation status from 'Extinct in the Wild' to 'Critically Endangered'. Three generations are needed to achieve this.

The first record of post fire recruitment from seed of the species was observed in 2015. However, the seedlings were overwhelmed by competing plants such as the buffalo grass, *Stenotaphrum secundatum* and the fountain bush, *Psoralea pinnata*. A pilot project started at Rondevlei in 2016 to study the role of herbivory through the reintroduction of the southern eland, *Tragelaphus oryx*, is yielding positive results as the animals are browse feeding on grass and woody vegetation, but ignoring the Ericas.

A further trial to establish this species in natural habitat was made in the Kenilworth Racecourse Conservation Area (KRCA) regarded as the best and least disturbed example of Cape Flats Sand Fynbos remaining on the southern suburbs of Cape Town. In 2004, 100 plants comprising two clones of *E. verticillata* were planted in a seasonally wet depression where another highly endangered and endemic Erica, *E. margaritacea*, grows. Introduced in mature vegetation to protect them from the summer heat and wind, the plants have survived and flower profusely every year. Seedlings have been observed in open patches near the parent plants. Cape Nature organized a control burn in an adjacent section of the KRCA in March 2005 after which further saplings grown in unigro plugs were planted in the burnt but moist area. Another planting was established on the eastern-end of the KRCA using plants in 1kg bags. This area was also burnt, but was more protected by sprouting grasses. The plants in unigro plugs all died during the hot, dry summer probably because they were too exposed to the desiccating summer winds and summer heat. Another factor may be that the unigro plants do not allow for sufficient root development to support the young plants through the first summer. The other planting from bags amongst the grasses fared better with about 30% surviving the first summer. The main lesson learnt when reintroducing nursery grown plants to a natural habitat is the value of the supporting vegetation structure as protective nurse plants. However, in a natural system after fire seedlings will germinate and being much smaller get protection from the emerging vegetation around them.

Monitoring growth of Erica verticillata plants reintroduced at Rondevlei, South Africa. (Image: Adam Harrover)

CASE STUDY 7.1.14 (CONT.)

Tokai, part of the Table Mountain National Park, is another trial site for reintroduction. Once a commercial plantation of *Pinus radiata*, the lower Tokai area, is one of the last spots in the world where the endangered vegetation type, Cape Flats Sand Plain Fynbos, survives in a large enough area for effective ecological rehabilitation. Efforts are under way to provide it with long-term protection. Most of the restoration is passive relying on plants germinating from the seed bank remaining in the soil. Only 25 local species have been actively introduced because they are of special conservation concern and have not reappeared after fire which is the natural ecological process that fynbos depends on. These include *Erica verticillata*, the Critically Endangered Rondevlei Spiderhead, *Serruria foeniculacea*, saved from the last two surviving plants at Rondevlei, resprouters which have very small seed banks such as the Wynberg Spiderhead, *Serruria cyanoides* and species with aerial seed banks (stored in fireproof cones) that do not have soil-stored seeds (e.g. Sugarbushes and Conebushes in the Proteaceae). Following initial failures, Ericas reintroduced in Tokai Park established splendidly, and have become a key feature admired by park visitors. A reintroduction experiment of 5000 plants was carried out in the Prinskasteel wetlands in 2008 using three clones planted separately and alternately in rows one meter apart, Pretoria clone 'African Phoenix', Kirstenbosch clone 'Adonis' and Vienna clone from Belvedere Palace. Each row was planted in a transect from dry to the wet area. With a 40% overall survival rate, the initial surprise was that the establishment of *E. verticillata* in the wetlands was more successful than originally anticipated. The experiment showed that despite some sedges outcompeting the species in the wettest habitat, and aliens in others, and some unfortunate management decisions that resulted in significant deaths (careless herbicide application when subcontractors controlling invasive *Rubus* spp. also sprayed some of the Ericas), the recovery was still comprehensive and extensive over the area. The variety of pollinators visiting the Ericas is astounding with far more pollinators than just birds, including wasps, carpenter bees, honeybees, hawk moths and various beetles.

Planting Erica verticillata along the Tokai Restoration Trail. (Image: Anthony Hitchcock)

Public outreach

Species recovery especially at Tokai is a sensitive process and the public are asked to keep out of the restoration areas to allow the recovery process to proceed with as little human impact as possible. Promoting awareness is however critical and necessary. To this end the South African National Parks authorities and the Friends of Tokai Park identified a dedicated area near one of the entrances where some of the threatened species are planted in display collections. The Tokai Restoration Trail includes interpretation boards explaining the restoration process and management plans for the area.

Conclusion

The restoration of *Erica verticillata* is a long process and has to survive through natural recruitment over at least three generations, i.e. three burn cycles without further restocking, replanting or reseeding before its conservation status may be reassessed based on IUCN Red List Categories and Criteria. The evaluation will depend on the numbers of plants that survive after three generations, whether these are stable, declining or increasing, how fragmented these are and the sustainability of the area that these have been restored to.

A number of lessons have been learnt through the reintroduction efforts with *Erica verticillata*. Recovery of a target species on its own is not sufficient. A cohesive management plan is required that encompasses restoration of the entire ecosystem, in this case including fire management. Reintroduction success depends upon a healthy stand of the vegetation type being in place, along with pollinators and other animals and soil fauna and flora, i.e. mycorrhizal fungi required for maintaining the system. If this is not in place steps must be taken to restore missing components. Any imbalance in this system might result in one part/component becoming a problem rather than having a beneficial influence. In particular, the role of herbivory needs to be explored further as this might be a crucial factor in success or failure.

Despite these significant efforts, conservation of the rich Cape flora remains a great challenge, especially given the increased demand for land and resources, and the effects of climate change. Many species may not be as lucky as *Erica verticillata* and could be lost forever. An example is *Erica pyramidalis*, which grew together with *Erica verticillata*, but is now extinct with no *ex situ* cultivated plants known to exist. Many species will go extinct unless the endangered vegetation type, Cape Flats Sand Fynbos, is conserved as a matter of urgency. *Erica verticillata* plays a crucial role in raising awareness of this threat as this plant has become an emblematic species symbolising the general plight of our vanishing flora that helps to create awareness that.

- **Ecological restoration**

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2004). A fundamental distinction between ecological restoration and other forms of ecosystem repair is that ecological restoration seeks to 'assist recovery' of a natural or semi-natural ecosystem rather than impose a new direction or form upon it. That is, the activity of restoration places an ecosystem on a trajectory of recovery so that it can persist and its species can adapt and evolve (McDonald *et al*., 2016).

Ecological restoration can and should be a fundamental component of conservation and sustainable development programmes throughout the world by virtue of its inherent capacity to provide people with the opportunity to not only repair ecological damage, but also improve the human condition. For restoration to be successful, it is essential to have understanding of the dynamics of the ecosystem being restored, and to ensure the genetic integrity of its plants by using locally propagated species.

As long-term custodians of common, rare and threatened plants, botanic gardens manage the most thoroughly documented and diverse repositories of live plants, seeds and other types of plant material from around the world. Over the centuries, they have accumulated a wealth of scientific and applied knowledge on the genetic, physiological, horticultural, ecological and other biological characteristics of plants (Hardwick *et al*., 2011). In addition, a great asset of many botanic gardens, especially in the tropics, is their maintenance of areas of primary, natural vegetation, which potentially facilitate the implementation of activities focussed on *in situ* conservation (Costa *et al*., 2016). As Case study 7.1.15 clearly illustrates, botanic gardens are therefore uniquely positioned to play an increasingly important leadership role in ecological restoration on a global scale (Box 7.1.5).

Brackenhurt Botanic Garden, Kenya – view of forest restoration site before (c. 2001) and after (2013). (Images: Barney Wilczak)

Box 7.1.5 Ecological Restoration Alliance of Botanic Gardens (ERA)

The Ecological Restoration Alliance of Botanic Gardens (ERA) is a global consortium of botanic gardens actively engaged in ecological restoration. The mission of ERA is: *To mobilize botanic gardens, arboreta and seed banks to carry out science-based ecological restoration by marshalling their expertise, networks, and resources to help achieve the restoration outcomes needed for human well-being and a sustainable future for life on Earth*. Members of the Alliance have agreed to support efforts to scale up the restoration of damaged, degraded and destroyed ecosystems around the world, contributing to the Sustainable Development Goals and the United Nations' target to restore 15 per cent of the world's degraded ecosystems by 2020. ERA member botanic gardens are carrying out ecological restoration projects in a diverse range of ecosystems. ERA is coordinated by Botanic Gardens Conservation International (BGCI).

The ERA has five goals:

1. Work with local partners to set up, maintain and document a series of long-term sustainable exemplar restoration projects in diverse biophysical, political, and cultural contexts around the globe that provide training and demonstrate the value of a carefully designed, science-driven approach to sustainable ecological restoration.
2. Improve the quality and volume of science-based ecological restoration practice by deploying scientific and horticultural skills to applied work on the ground.
3. Conduct ecological restoration research, to develop an enhanced knowledge base for restoration and identify and inform best practice.
4. Disseminate research and lessons learnt from projects.
5. Build expertise and restoration capacity through collaborations between botanic gardens, large and small, as well as with partners in local communities, professional societies, academia, industry, government, NGOs and international bodies.

Botanic gardens have launched, and maintain, successful ecological restoration projects throughout the world. Their expertise in teaching, training and outreach, and their mission for public service gives them the capacity to work with a wide variety of stakeholders, including governments, civil society, industry and local communities, providing the tools and knowledge to achieve long-term ecological restoration goals.

Screenshot of the ERA web portal.

CASE STUDY 7.1.15

Recovery of the original montane forest of Hong Kong – Ecological restoration efforts by Kadoorie Farm and Botanic Garden, Hong Kong

Gunter A. Fischer and Jinlong Zhang, Hong Kong; Yvette Harvey-Brown, Richmond, United Kingdom

With 7.2 million residents in 1,104 km^2, Hong Kong is one of the most crowded places on earth. Its primary forests were destroyed centuries ago and have not recovered since then, due to continued disturbance by humans, mainly by fire. Most of Hong Kong's natural landscapes are now covered by secondary grasslands and forests of different successional stages. In 2013, Kadoorie Farm and Botanic Garden (KFBG) established an ambitious restoration project on the upper slopes of KFBG's premises, 'Ecological restoration of the original montane forest of Hong Kong'. In order to be able to monitor the project from the first planted tree throughout the evolution of the forest, a 20 x 20 m grid was established over the total project area of 10 ha. Every planted tree and also every existing shrub and tree was identified and tagged with a unique number. Not all plots were planted as some act as monitoring plots for natural succession. Two automatic weather stations permanently monitor the climatic conditions remotely, allowing KFBG to link growth and survival rates to climatic patterns.

One of the key questions of the project is whether it is possible to shortcut natural succession and avoid the shrub and early tree stages of succession by planting climax trees at the beginning of the ecological restoration process. To address this, a series of experiments was established to overcome factors that reduce survival and growth rates of climax trees in an open grassland environment, such as strong wind, wind desiccation, strong sunshine, herbivory, competition by grasses for nutrients and water, soil erosion etc. The experiments included the use of different types of tree guards, different types of weeding mats, different types of fertilizers, soil amendments with compost and biochar and different weeding regimes. First results have been very promising and currently more than a hundred different woody species have established in the core area of the restoration site.

The experiments and strict monitoring regime in place have allowed a large amount of information to be gathered across a relatively small area and for recommendations to be made for future projects. For example, KFBG has learnt that good arboriculture is needed early on to make sure that rare climax trees grow straight, do not branch too early and are free of competition so they are not outperformed in the stem exclusion phase of succession by overly vigorous pioneer trees. Although little is still known about how plant species coexist and interact with each other in this particular ecosystem, KFBG restoration experiments enable them to compare natural succession initiated by a limited species pool caused by massive deforestation in the past with succession initiated by an artificially increased species pool. This provides a unique opportunity to test hypotheses on community assembly, species coexistence, habitat preferences, environmental filtering in a phylogenetic, functional and ecological framework. These experiments are still on-going and KFBG plan to publish a series of scientific articles in the coming years to share the knowledge gained and guide restoration projects elsewhere.

Tree planting plots with sapling guards at Kadoorie Farm and Botanic Garden. (Image: Gunter Fischer)

• **Population introduction**

Contrary to reintroduction, introduction is the intentional movement and establishment of an individual or a group of individuals outside their natural range (IUCN, 2013). The aim is to prevent extinction of populations of the target species by establishing new ones in suitable habitats with favourable environmental conditions in areas where they have not been recorded from in recent geological history. Population introduction may be required as climate change and global warming and/or other change agents threaten the survival of a population or the entire species in their present habitat.

A critical aspect of an intended population introduction is to undertake a rigorous risk assessment as regards the potential of the species becoming invasive in its new location. Many introduced species may not demonstrate clear signs of invasiveness only until several decades later following their establishment. Thus, introduced target species should continue to be monitored in the long run (Smith *et al*., 2013). Equally, a risk assessment should evaluate the danger posed by any pests and pathogens that the introduced plant material might be carrying, as well as the probability of hybridisation between related species. Botanic gardens in particular are well-aware of the potential threats posed by newly accessioned plant material for their existing collections as well as for wild plant populations (Chapter 3, Section 3.4.4 and Chapter 6, Section 6.8). This technical knowledge and practical knowhow coupled with the wide range of areas of expertise in plant identification, sampling, propagation and cultivation, make botanic gardens also vital stakeholders of all stages of introduction in the wild, from planning to provision of plant material over to actual introduction work and monitoring (Case study 7.1.16).

CASE STUDY 7.1.16

Securing the future of a unique Sicilian plant on the verge of extinction – population introduction of *Zelkova sicula*

Giuseppe Garfi and Salvatore Pasta, Palermo, Italy; Stéphane Buord, Brest, France; Gregor Kozlowski and Laurence Fazan, Fribourg, Switzerland; Joachim Gratzfeld, Richmond, United Kingdom

Discovered in 1991, only two small populations of the relict plant *Zelkova sicula* are known, located on the slopes of the Iblei Mts. in south-eastern Sicily (Italy). The species faces an uncertain future and has been included in the IUCN Red List of Threatened Species as Critically Endangered. Both populations are restricted to the bottom of small gullies with rivulets. Although *Z. sicula* appears to be partially adapted to the Mediterranean climate (suggested for instance by the sclerophyllous leaf traits), recurrent dieback triggered by summer-drought indicates that the populations are located in an area with suboptimal environmental conditions. Sexual reproduction in the wild has not been recorded to date, although a few dozens of plants in each population perform uneven flowering and fructification. Fertile fruits have not been found probably due to the triploidy of all individuals in both populations. The species proliferates however vegetatively, via root suckering or basal resprouting following disturbance or injury. Due to their clonal identity, the two populations have a very low adaptive potential. In addition, they are confined to the present enclaves situated within the thermo-Mediterranean belt, whilst a swift adaptation to rapidly changing, drier and warmer environmental conditions seems impossible. Population introduction may therefore represent the most effective conservation strategy, if not the last resort, to secure the survival of *Z. sicula*.

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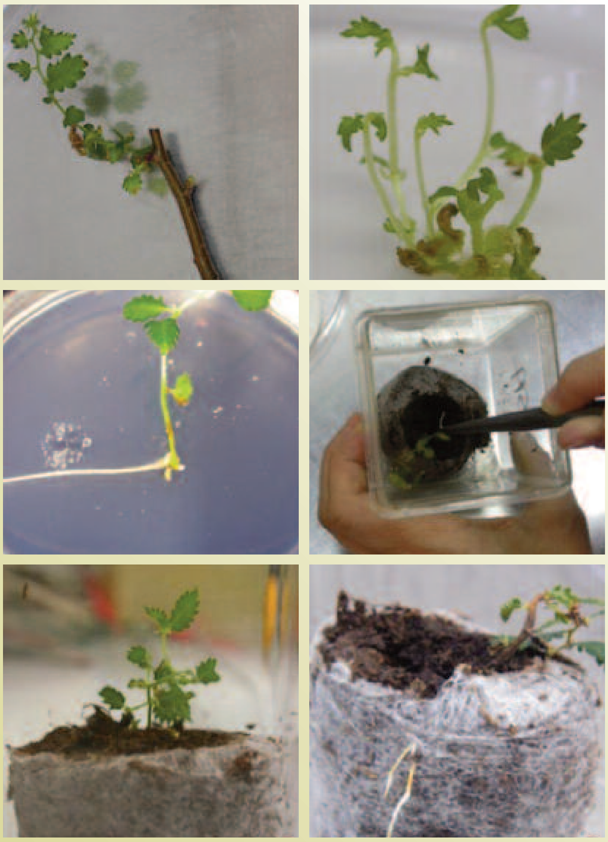
Zelkova sicula wild population (Contrada Ciranna) – habitat and habit. (Images: left: Giuseppe Garfi; right: Joachim Gratzfeld)

CASE STUDY 7.1.16 (CONT.)

Planning for long-term conservation – plant material collection and development of propagation protocols

Recognising the urgency of rapid intervention, the Institute of Biosciences and Bioresources, Unit of Palermo (IBBR-CNR), Italy, the Conservatoire Botanique National of Brest (CBNB), France, as well as the Botanic Garden of the University of Fribourg (BGF), Switzerland, joined hands to devise a conservation programme for *Z. sicula* aiming at population introduction to new habitats. Two fundamental actions preceded this endeavour: i) evaluation of the genetic diversity within the species to capture the highest genetic adaptive potential; and ii) collection of plant material and development of propagation protocols.

The molecular analyses revealed a clear difference between the two populations but identical genetic profiles within each population, confirming two different clonal lineages. To reflect occasional genetic changes arising from mutations, collection in both populations targeted material from as many mother plants as possible. Capitalising on their longstanding experience in germplasm conservation, seed germination and propagation of endangered plants, CBNB and IBBR-CNR developed vegetative propagation protocols using cuttings and *in vitro* techniques. Supported by the European Commission LIFE project 'Zelkov@azione' and BGF, propagation protocols are continuously refined, and the stock of plants is steadily growing.



In vitro propagation and explant stages of Z. sicula. (Images: Angela Carra)

Initial population introduction trials

The next step consisted in the selection of suitable sites for introduction of new populations. Data gathered on significant growth performance of a few individuals raised in *ex situ* collections suggested more humid sites in the meso- and supra-Mediterranean belt as suitable new habitats, characterized by mixed forests with summer-green, broadleaved deciduous trees. These plant communities are similar to those where the other extant West-Eurasian *Zelkova* species thrive, and match the species composition of communities with *Zelkova* spp. based on palaeoecological data. A further key requirement included the proximity to small streams as observed in the current habitat.

Three out of 17 initially identified sites were evaluated as providing the best habitat suitability and adequate site accessibility (i.e. Bosco Tassita, Nebrodi Mts.; Bosco Pomieri, Madonie Mts.; Bosco Ficuzza, Sicani Mts.). Two supplementary plots where chosen in the thermo-Mediterranean belt at Bosco Pisano, near one of the extant populations. To ensure long-term conservation and sustainability, only public land and locations within the Natura 2000 network or other protected areas were selected. However, as all sites are within protected areas, a longwinded administrative procedure was necessary to obtain permission from the managing authorities to introduce the plant into the local forests. A thorough risk assessment of the potential impact (such as invasiveness and introduction of pests) was undertaken, followed by the establishment of a detailed monitoring plan. Prior to outplanting, all saplings were transferred for acclimatization to a forestry nursery located in an area with meso-Mediterranean climate conditions, and regularly checked for eventual pests and diseases. In four of the five sites fences have been established to prevent browsing disturbance by wild and domestic ungulates.

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Wild populations of Zelkova sicula (green dots):
A: Bosco Pisano, B: Contrada Ciranna, Iblei Mts.
Introduction sites (red dots):
1: Bosco Pisano; 2: Bosco Tassita, Nebrobi Mts.;
3: Bosco Pomieri, Madonie Mts.; 4: Bosco Ficuzza, Sicani Mts.

CASE STUDY 7.1.16 (CONT.)

Letting nature take its course – yet under controlled conditions

First planting trials were carried out in June 2016 in the pilot sites of Bosco Ficuzza and Bosco Tassita using 15 plantlets per plot. They were introduced in the forest understorey at irregular intervals, prioritising streamside locations and half-shade conditions. Additional measures were taken, such as the use of hydrogel (a high water retention polyacrylate, able to prolong water supply) as well as covering the planting holes with a biodegradable mulch mat to reduce evaporation. Watering was provided right away and an irrigation plan was established for the first growing season to respond swiftly to potential drought. Planting activities continued during winter 2016 in these and two new sites (Bosco Pomieri and Bosco Pisano), raising the total number of saplings planted to over a 100 (on average some 25 per site). These efforts will be further consolidated over the coming years, including additional planting in all sites.

A truly novel approach to save a unique plant from the brink of extinction, this population introduction experiment complements ongoing efforts to secure *Z. sicula* in botanic gardens and other institutions working for plant conservation (Kozlowski and Gratzfeld, 2013). If the introduced individuals successfully establish over the coming years to form new populations, this endeavour will serve as a practical illustration of using horticultural excellence and *ex situ* conservation as an insurance policy in a future marked by rapid climate change and altering ecosystems.

Introduction of Zelkova sicula (Ulmaceae) to a new habitat, Bosco Ficuzza, Sicily. (Images: Giuseppe Garfì)

As many ecosystems and habitats are transforming into new, non-historical configurations owing to a variety of unprecedented local and global transformations including climate change, novel combinations of species are emerging that have not occurred before. Management of such 'novel ecosystems' (Hobbs *et al.*, 2009) as of targeted population introductions that also represent new species assemblages, is one of the great conservation challenges in the twenty first century. Botanic gardens which are steadily embracing and promoting an integrated *in* and *ex situ* conservation approach, are once more at the forefront to guide, support and implement innovative strategies aimed at securing plant diversity for future generations.

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7.2 PUBLIC ENGAGEMENT – EDUCATION

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7.2.0 Definitions

Behaviourism, cognitivism, constructivism: Behaviourism is a learning theory that focuses on objectively observable behaviours and discounts any independent activities of the mind; cognitivism focuses on mental processes, including how people perceive, think, remember, hypothesise and solve problems; constructivism argues that students construct their own understanding and knowledge, through experiencing things and reflecting on those experiences.

Inquiry-Based Science Education (IBSE): IBSE involves a learning process in which not only facts are explained but where students are encouraged to question, hypothesise, explore different approaches to a problem, debate and discuss issues and present their findings. This learning approach includes a wide range of activities e.g. case studies, research projects, fieldwork and investigations.

Pedagogy: Pedagogy is the art or science of teaching, including the range of instructional methods.

Child protection: A child protection policy provides guidelines for organisations and their staff to create safe environments for children. It is a tool that protects both children and staff by clearly defining what action is required in order to keep children safe, ensuring consistency of behaviour so that all staff follow the same process.

Risk assessment: This is an estimate of the likelihood of adverse effects that may result from exposure to certain hazards e.g. trip or slip hazards, water hazards, poisonous plants, garden machinery, etc.

Adult education: In adult education, adults are engaged in learning beyond traditional schooling. Adult education programmes in botanic gardens are usually provided in two contexts. 1. formal – structured learning that typically has a set curriculum and is accredited or certificated; 2. non-formal – learning that is organized but non-accredited and informal and which is often related to hobbies, leisure pursuits and personal lifelong learning e.g. workshops on 'how to propagate plants', 'plant photography', etc.

Higher education: Formal education beyond the secondary level; especially education provided by a college or university.

Student teacher: Student studying to become a qualified teacher in a school.

7.2.1 Introduction

KEY MESSAGE

As public destinations that play host to an increasing diversity of visitors, we have the opportunity (and obligation) to encourage every person we encounter to learn more, care more, and do more with the plants in their lives. (Sheila Voss)

Botanic gardens offer a wealth of learning opportunities for all, irrespective of whether for adult students in further / higher education and schoolchildren (formal education) or the general visitor, community groups and families who learn through a range of interpretative materials or activities (informal education). Usually in the centre of large urban areas, botanic gardens offer green, safe and calm havens for study. Exciting living and preserved collections, and staff expertise, can be used to engage learners directly and make clear links between plants, habitats and our everyday life.

We need to foster deeper relationships with our audiences, both children and adults, to encourage them to live more sustainable lives. Education in botanic gardens, along with interpretation, is key to the delivery of this understanding and is central to the implementation of the Aichi Biodiversity Target 1 and Target 14 of the Global Strategy for Plant Conservation (GSPC) as well as supporting the Millennium Development Goals (MDG) (Millennium Project, 2006).

Education programmes offer benefits to the botanic garden including:

- Enhancing reputation;
- Supporting visitor flow around the site;
- Supporting business development;
- Bringing in new audiences;
- Contributing to the garden's corporate social responsibility.

This section discusses the pedagogical approach currently being integrated into educational programmes and also outlines a range of approaches to educational strategies. It explores the different programmes and resources to deliver these programmes such as staffing, space and funding. These elements required for the development of an educational programme are noted in Figure 7.2.1.

Figure 7.2.1: Four key elements to consider in the development of an educational offer

Pedagogy	Towards a more professional approach to learning
Strategy	Key strategic approach to delivering programmes – the what, why, where, to whom and when
Programmes	Programmes and their audiences: for schoolchildren, adults, teachers and educators
Resources	What you will need; inspirational spaces, staffing, budget, etc.

7.2.2 Pedagogy in Botanic Gardens

KEY MESSAGE

Botanic gardens need to develop a more professional attitude towards teaching at botanic gardens in the next decade.

To provide good learning experiences and an effective educational programme, we need to consider how, why and where learning takes place. The process of learning is complex and general philosophical theories such as behaviourism, cognitivism, or constructivism often fail to provide detailed guidance about how to organise teaching (Weibell, 2011).

Focusing on content accuracy is not enough in modern botanic garden teaching and learning. One needs to recognise the prior knowledge and experience that the learner brings to the learning process as well as their socio-cultural background, different beliefs and attitudes (see audience development in interpretation). Botanic garden educators should also be aware that their own cultural background and life experiences influence their own teaching and learning processes.

The following principles are now more visible in modern botanic garden education and serve as building blocks for the future:

1) The individual is responsible for his or her learning. Programmes need to create a 'learner centred' learning environment. Educators should discover what the learner knows and take this into consideration to adapt the programme to participant needs. Space is required for individual learning processes to occur and learners should be supported to interact with each other.

2) The learning programme has an explicit goal. Goals are set by the programme designer, however participants should also be allowed to set their own goals e.g. the Inquiry-Based Science Education (IBSE) approach. For reflections on the effectiveness of the IBSE approach see Case study 7.2.1.

3) Education programmers need to be reflective practitioners. Education staff need to reflect on how successful educational programmes are in supporting learner knowledge, skill and/or attitude development.

CASE STUDY 7.2.1

IBSE and the schools programme in Lomonosov Moscow State University Botanic Garden

Alla Andreeva, Lomonosov Moscow State University Botanic Garden

The 'Inquire' project was run by BGCI and 16 botanic garden partners across Europe, including the Moscow State University Garden, to develop the use of IBSE and reflective practice amongst educators and visiting schools (INQUIRE, 2016). Since it was first introduced in Moscow University's Botanic Garden (Aptekarskiy Ogorod), IBSE has created new opportunities for the development of education programmes and has helped to establish and expand contacts with schools, teachers, pupils and parents. It has also boosted the garden's popularity, particularly amongst teachers and families.

The botanic garden has become an experimental educational space for schools, helping to attract investment and enhance the garden's status both within Moscow University and in the eyes of the city's government. IBSE has brought with it fresh thinking on issues such as the quality of knowledge, standards of teacher training and garden resources. The garden now proactively engages university faculty, students, postgraduates and experts in the education process, including the search for new research methodologies and the application and development of existing resources.

Moscow city Education Department has given support to these IBSE-based lessons where the botanic garden hosts lessons on a contractual basis with schools. Classes visit the botanic garden monthly throughout the year, and training is devoted to specific topics, discussed in advance with the teachers. As a result, each school has its own tailor-made programme of garden-based learning. Knowledge and experience gained are often a starting point for future studies and individual project work by students, with garden experts acting as research supervisors. This collaboration has already produced important scientific results and encourages students to participate in conferences and project competitions. It also provides garden specialists with experience of project-based research.

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CASE STUDY 7.2.1 (CONT.)

The new skills enhancement course for teachers has been well received by schools, with workshops run for teachers and garden educators to discuss new practices and methodologies and promote IBSE benefits. These workshops have expanded the audience of school teachers for garden-based education. Frank and open discussions of the pros and cons of new approaches include presentations by teachers of their own IBSE-based practices.

Following its adoption of IBSE, the botanic garden has devised a new programme for its Ecology School, (run on a voluntary basis every Sunday). It is mostly attended by pupils interested in scientific research, often sparked off by school lessons in the garden.

Teachers note the impact of IBSE in pupils wishing to visit the garden and interest in the lessons held there. Pupils show greater motivation in studying biology / nature, carrying out research and a willingness to express ideas, build hypotheses and argue points of view. These lessons help to develop the children's creative potential and stimulate an interest in scientific work, including independent study of plants, contemporary natural processes and links between nature and human activities. This perfectly aligns with Russia's new educational standards and ongoing educational reform.

Constructing models of flowers. (Image: Moscow State University Botanic Garden)

Recording data on plant morphology. (Image: Moscow State University Botanic Garden)

CASE STUDY 7.2.2

A strategy for Education in Missouri Botanical Garden

Sheila Voss, Missouri Botanical Garden

At Missouri Botanical Garden, our education strategy is prepared for by first establishing a solid, multi-dimensional foundation of support: 1) investment in people; 2) everyday excellence; and 3) active participation in and advancement of the field.

1) This is about staff, volunteers, interns, colleagues, and community partners who make up the teams of professionals who provide our products – the actual experiences people have in our gardens. Ensuring quality, meaningful life-shaping experiences and learning moments for our visitors happens with intent and sustained support, with a team of creative, collaborative people who are challenged, supported and equipped for success.

2): Visionary, multi-year, mission-driven strategic plans help set institutional trajectories, but it's in the everyday realm that learning moments should enthusiastically be seized – the everyday excellence. What's right under our nose is often overshadowed by the new exhibit, the future expansion, the next big thing. What basic, simple improvements, as well as new, compelling learning moments, could happen in the reception lobby or those little garden niches that families love exploring? There is undoubtedly no lack of creative ideas; however, these ideas are not acted on as often as they could be. Other priorities populate the working day: pressing deadlines, staff constraints, and budget woes.

3): There is so much to learn from each other. This happens by intentionally reaching out to, connecting with, learning from, and challenging our colleagues close to home and across time zones. What specifically do we want to learn more about, dig deeper in, and get better at? Answer this question, and, as Captain Jack Sparrow would say, "*you've got your heading*".

7.2.3 Developing an Education Strategy

There should be an overall education strategy linked to the garden's mission and direction, developed in association with the botanic garden strategy and with agreed outcomes, target audiences, implementation and evaluation plans (see interpretation strategy / master plan). Cross departmental meetings, with senior management, will ensure buy in and appropriate subject / resource allocation. Many botanic gardens such as Missouri Botanical Garden already have a strategy (Case study 7.2.2), however there are always new perspectives and improvements to explore. The Eden Project has published an essay on their philosophy / strategic approach (Blewitt, 2004).

7.2.4 Managing and Resourcing an Education Programme

There are a number of key items that you need to have when setting up and implementing an education programme.

1. Resources – staff

KEY MESSAGE

Staffing presents one of the highest investments; however, skilled staff will ensure quality programmes which have potential to raise revenue.

Dedicated staff that have the skills and expertise to develop creative programmes, administrate, teach, communicate well and evaluate are vital for managing education programmes. Providing good staff training and giving staff opportunities to share experiences across the network of botanic gardens is also important. Staffing might be considered via:

- Full or part/time employees;
- Contract teaching staff who are paid on a daily or session rate;
- Trained volunteer staff.

The Royal Botanic Gardens, Kew employed teaching staff on a contract basis for many years, which had many advantages. Staff were recruited from freelance trained teachers, who either did not work full-time due to childcare responsibilities or were older teachers, semi-retired from full time teaching. Teachers were recruited from all teaching levels and/or subject disciplines, offering good programme opportunities for Kew. The school programme cost covered hiring the teachers and programme resources. This option is possible providing you are within the legal constraints of pension provision and working time rights. The botanic garden employs full-time teachers as these provisions have now changed in the United Kingdom.

If using full-time volunteers, these should be fully vetted, trained and assessed. Volunteers require pastoral care, training and supervision and ideally a member of staff to manage them. Travel costs, uniforms and equipment need considering, so volunteers are not necessarily a cheap option. You can assess the overall value of volunteers to the organisation by working out a 'VIVA' ratio. VIVA - the Volunteer Investment and Value Audit is a measurement tool that assesses the 'outputs' of volunteer programmes (the value of volunteers' time) in relation to the 'inputs' (the resources used to support the volunteers) (Gaskin, 2011). This value is, however, just a financial one and does not take into account other valuable aspects of the volunteering process.

Volunteers are an excellent resource, however it is their right not to turn up and not to be accountable for any difficult situations that develop during an educational visit. It is better to take on volunteers in educational support roles such as 'meeters and greeters', teaching assistants, administrative support, resource management or as play facilitators. Several gardens do have a hierarchy of volunteers, with volunteers managing other volunteers; this may be necessary due to budget constraints. Careful consideration is needed in this case, so that neither volunteers nor senior management teams are put at risk regarding accountability.

Other resources you may need to fund are:

- Books, images and research resources, e.g. on-line web access;
- Staffing plus training / capacity building costs for staff / volunteers;
- Travel costs for staff attending meetings and /or volunteer travel costs;
- Artefacts to engage groups – artefacts that make links to everyday plant use, e.g. chocolate bar, toothpaste, vanilla flavouring, bead necklaces, paper, etc. Botanic garden teaching staff can use these to demonstrate items of interest during talks, tours and workshops;
- Technological support.

Education is capable of bringing in good revenue. Charges vary, so explore a number of botanic garden websites to see current costs for schools and adult education programmes in your region.

2. Resources – learning spaces

KEY MESSAGE

In botanic gardens, students are 'outside the classroom', so replicating a classroom experience on-site is pointless.

When considering educational building design, requirements include: a lot of storage; accessibility for all; adequate toilets; sturdy, correctly sized furniture; ample power points; flooring to withstand messy activities. Blackout and soundproofing may also be needed.

An educational room at the Eden Project. (Image: The Eden Project)

Although not vital to have an education building, you need to carefully consider the spaces available for education on site. Lunch space is useful for school groups and families; picnic table areas are fine, preferably covered against wet weather. Toilets and water for hand washing are important, especially if visitors are handling plant material. Have drinking water available; a water fountain or a nearby tap to refill water bottles is fine. The Case studies from Kings Park in Australia (Case study 7.2.3) and the National Botanic Garden in Nepal (Case study 7.2.4) show how staff from the respective gardens considered and developed their garden layout to maximise impact with their educational audiences.

CASE STUDY 7.2.3

Naturescape, Kings Park, Australia

Marcelle Broderick – Botanic Gardens and Parks Authority, Kings Park and Botanic Garden, Perth, Western Australia

Kings Park and Botanic Garden is in the centre of Perth, Western Australia. It is the most visited destination in the State, recording c. six million visitors a year, a remarkable figure in a city of 1.74 million people, and in a State of 2.39 million. It is 400 hectares in total, with two thirds of the land maintained as natural, managed bushland; the remaining land is developed areas, including the 17 hectare State Botanic Garden.

In October 2011, Kings Park opened its new six hectare, nature-based environmental discovery facility for children, the Rio Tinto Naturescape Kings Park. Believed to be the first of its kind in Australasia and possibly the world, this new development was a significant departure from the previous types of facilities offered to children. The opening was the culmination of more than four years of planning, consultation, design and construction and significant financial support was received from several sponsors including Rio Tinto, Water Corporation, Lotterywest through the Friends of Kings Park and the Perth Solar City programme. Since opening, Naturescape has welcomed c. 10,000 visitors a month.

Naturescape is set within a bush environment and invites children to immerse themselves in a natural Australian landscape, exploring and connecting with nature and doing what comes naturally – building cubbies, climbing high, playing hide and seek, making dams and wading in a creek.

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CASE STUDY 7.2.3 (CONT.)

Paperback Creek at Naturescape. (Image: Jody D'Arcy)

The concept for Naturescape evolved in acknowledgement of the increasingly urbanised environments and the corresponding diminishing opportunities for children to experience nature first hand. Australia is one of the most urbanised countries on Earth, with approximately 85 percent of the population living in cities. Kings Park and Botanic Garden had a vision to provide a fun, educational facility that would entice children away from their computer games and electronic screens to spend more time outdoors learning about nature.

As part of the planning for the development of Naturescape, a number of formal and informal focus groups and community discussions were held. A common concern expressed was about nature based experiences of people growing up in Western Australia in the 1950s, 60s and 70s that were no longer easily available to children and grandchildren growing up between the 1980s and the present. Many people remembered, with fond nostalgia, a childhood dominated by more freedom and play outdoors.

In Kings Park and Botanic Garden, we decided to try to develop new, relevant ways to enable children to engage with nature and the natural world. Naturescape was designed to offer children the opportunity to '*escape into nature*' and explore the natural world in a fun way, to develop their sense of adventure and do the simple things that many of today's adults experienced while growing up. This nature-based experience is intended to assist children to develop an appreciation and understanding of the natural environment through unstructured activity, which in turn will hopefully encourage them to become future advocates for its ongoing protection and survival. The site also has a more formal education role, with an area dedicated to the delivery of a range of curriculum based environmental education programmes for schools, developed and delivered by Kings Park Education.

In summary, the site is based on a philosophy of '*hands'* (immersion, experiences, hands on opportunities), '*heads'* (informal and formal learning opportunities based on environmental education messages) and '*hearts'* (experiences plus understanding plus knowledge should hopefully lead to wanting to nurture the natural world and actively care for our environment). Children need nature, and nature needs children.

Kings Park has created online resources with practical advice on how to create a nature space (Botanic Gardens and Parks Authority, 2015).

Tree hide and mixing bowls in Naturescape. (Image: Jody D'Arcy)

CASE STUDY 7.2.4

Biodiversity Education Garden at the National Botanic Garden, Nepal

Kate Hughes, Royal Botanic Garden Edinburgh

A new botanic garden has been developed in Nepal with education as its principal focus. Hence the whole design of the garden was implemented with visitors and biodiversity-learning in mind. Collaboration and capacity building between staff at the National Botanic Garden, Nepal (NBG) and Royal Botanic Garden Edinburgh (RBGE) began in March 2015. Funding was awarded by the British Embassy, Nepal to enable two horticultural staff from RBGE to deliver a basic horticulture course over three weeks to 15 members of staff. The aim was to raise capacity levels in essential horticultural skills in preparation for the 9 month project to renovate an area and construct a new garden at NBG called the Biodiversity Education Garden (BEG).

The horticulture course was adapted from the Certificate of Practical Horticulture (an annual certificated RBGE course) to suit the facilities and skill levels at NBG. Staff attending the course came from different levels and departments of NBG including horticulture, botanical and administration staff. Non-horticultural staff benefitted by gaining an understanding of the work required of the horticulture team; this improved morale, communication and facilitation of horticultural activities for all involved. The BEG introduces many less common Nepalese species to visitors and is designed to provide an aesthetically pleasing, educational display of native Nepalese plants. Informative panels describe the plants and habitats represented and thousands of schoolchildren, as well as local and international visitors annually can now pick up an information leaflet on this resource or get further information through QR codes on the panels which link to a website (beg.dpr.gov.np).

From August 2015 to March 2016, RBGE staff made six trips to work alongside NBG staff to deliver the garden development stages. These included: which plants and features to preserve/remove and how to safely remove undesirable items, choosing plants/features to install, collection/sourcing and propagation of plants, care of plants, construction of infrastructure and all aspects of interpretation.

NBG staff have extensive knowledge of the climate and growing environment of their garden and are able to inform RBGE staff about their practices for the success of planned planting and where to source plants. Local contractors made the new path system using local methods in keeping with the rest of the garden. RBGE staff used their knowledge of plants from other regions of Nepal, introducing several unfamiliar plants and increasing the plant collections of NBG. RBGE staff also used their plant display experience to demonstrate RBGE practices and introduce new ideas which NBG staff can now adopt and adapt as suits.

Interpretation was another collaborative exercise with tasks split between NBG and RBGE staff. Part-produced in Scotland for availability of particular materials, the information panels are installed on a range of structures made from local products and the interpretation is in Nepalese, English and Latin. The QR codes link to the Nepalese Government Department website which is maintained and updated locally. NBG produced the general plant labels and RBGE have worked with NBG staff to ensure taxonomy and distribution information is current.

The project has environmental and educational benefits on four levels:

- Visitors will learn about the medicinal, practical and financial value of many plants in Nepal, supporting awareness for plant conservation;
- NBG staff have been introduced to more techniques for making successful garden spaces;
- NBG staff have been introduced to techniques which can help to grow and conserve plants;
- RBGE staff have learned about environments outside their experience, which will help to inform their working practices and to improve displays in Edinburgh.

The constructive exchange between NBG and RBGE strengthened as the project developed, illustrating that quantifying benefits of capacity building and collaboration takes time.

NBG staff check the interpretation panels. (Image: Royal Botanic Garden Edinburgh)

3. Marketing

KEY MESSAGE

The botanic garden website is the easiest way to promote your offer; make it easy to navigate and provide comprehensive information.

Marketing the education programme offers a wide 'reach'. Marketing tools include:

- Promotional visits to the local education authority that can cascade information through their own networks and media, saving you time and money;
- Local media – radio, TV and press;
- Regional science networks and clubs;
- Social media such as Twitter and Facebook;
- Talks and displays at 'open days' for teachers / organisations either on your own site or at educational events;
- Brochures and leaflets: These are often less effective as they are costly, soon out of date and not guaranteed to get to the right person; they often end up in the waste bin.

More information on developing botanic garden marketing strategies is in Chapter 1, Section 1.7.8.

4. School programmes

KEY MESSAGE

Delivering education programmes for schoolchildren is hard work; plan in detail, train your staff, link programmes to the curriculum and make it easy for schools to visit by getting the basics right.

Practicalities to consider for school programmes:

- Schools should pre-book for activities: Online booking (when possible) is quick and easy;
- Risk assessment / child protection policies: Ensure that activities / spaces used are covered by the Health and Safety guidelines for your area. A child protection policy (imperative in some countries) and staff training on this is useful;
- A dedicated entrance: School groups entering the botanic garden often cause queues. Consider a separate entrance or volunteer 'greeters' to welcome your school group and offer advice and support;
- The first things schools usually wish to have is access to toilets: Toilet visits take time; make sure you schedule this in;
- Assisting teachers or parent helpers: Clearly state the ratio of visiting children to adults; adults should stay with the group at all times.
- School bags: Botanic gardens are big sites. Children get tired carrying heavy bags over long distances. Consider a lockable 'bag cage' or lockers to keep bags safe;
- Have equipment for activities in the right space at the right time: Some activities require big equipment (e.g. ecological surveys). Locate your equipment ahead of time. Several gardens have tricycles with trailers or trolleys to move equipment;
- Schedule your activities: School arrivals are often delayed, so be ready to adapt activities. Visit time is often short; e.g. UK schools usually arrive at 10.30 am and leave at 2.30 pm. Don't be too ambitious! Ensure activities fit the schedule, including refreshment breaks;
- Vary your teaching style: Children learn in a variety of ways; make sure you have variety in your teaching, including Inquiry Based, hands-on and minds-on activities.

Several botanic gardens, e.g. Chicago, Sydney and Kirstenbosch offer excellent education programmes off-site for communities and schools, bringing their skills and expertise, particularly horticultural, into gardening schemes. For ideas on how to develop and run similar programmes see SANBI (2016), The Royal Botanic Garden Sydney (n.d.), and Chicago Botanic Garden (2016b).

Each botanic garden is, of course, unique including the staff and volunteers and the schools groups that visit. The education programme should relate to the particular ecological, economic, social, cultural, political and educational context of the garden. The example from Mérida (Case study 7.2.5) outlines the approach of a botanic garden in Mexico.

Before introducing a technological element into a school visit to a botanic garden, it is vital to ensure that this is adding a real benefit. A visit should be an opportunity to closely observe a rich variety of plant life. Mobile technologies used well can help to enhance this by encouraging students to look carefully and think about what they see. This can be as simple as using a camera on a phone to record specific examples or as complex as using a 'quest' application to set up a treasure hunt style activity. Attempts to create bespoke applications for use in gardens and museums have not proved lasting as yet. Although popular with students, the cost and overhead to learn a new system are not popular with teachers. More successful is to use technology teachers and learners are already familiar with and which is compatible with what they use in schools. So keeping it simple is generally more likely to succeed.

Information in the form of web content can be used to prepare for a visit. This is likely to be accessible to teachers and students prior to a visit, either at home or in school. Content they collect during a visit, in the form of photographs, short video clips or sound recordings and text can also be shared. This could be as simple as a digital slide presentation in response to a challenge set at the botanic garden, and shown to rest of the class, or a more complex presentation which is shared with the wider public via the botanic garden website. In the latter case, care would have to be taken to ensure children were not identifiable and parental permission had been obtained. The objective of producing such presentations and the prospect of an audience are both very motivating for learners.

CASE STUDY 7.2.5

Establishing a schools education programme in Mexico

Veronica Franco, Jardín Botánico Regional, Mérida, Mexico

In Mérida, formal education programmes are offered to organized groups, from a range of academic levels, who have scheduled a visit. They come with expectations related to achieving curriculum goals through the programme. The following points were considered during the development process:

1. Staff should have, or be trained in, basic teaching and learning skills. The Mexican education system has many challenges in achieving its education goals and educational approaches. Botanic gardens have good opportunities to design hands-on programmes focused on the plant displays and can plan programmes with relevant topics, goals and curriculum approaches, developing educational materials for teachers as well as for students. This requires people that know the collections and displays and the various teaching and learning approaches.

2. Programmes, whether facilitated or self guided, should link to the curriculum. Take time to analyse and become familiar with the current curriculum; this will help create relevant educational programmes. The impact of globalization on social and individual lifestyles, environmental problems, the use of new technology and changes in educational approaches amongst other issues are more and more related to the need for new paradigms in education models. Botanic gardens are well suited to develop innovative programmes that link these.

3. It is recommended to work in collaboration with the rest of your garden staff. Guided tours for groups will be enriched with the participation of all staff, not just those in education. Non-education staff may need basic training related to educational requirements, communication methodology and environmental interpretation.

4. Your education programme should be formally planned. This can include pre-visits by schoolteachers to the garden to get to know the site, exhibitions, facilities and the educational programmes. Where appropriate include follow up activities for the teacher to use back in school. This builds on the learning experience during the visit.

5. It is essential to have an evaluation strategy for your programme to help you analyse the impact that guided tours, activities, workshops, educational materials and other educational offers have on your target audiences. Evaluation strategies should be designed with visiting school staff to ensure appropriateness and effectiveness.

6. Provide essential information in your marketing. Clearly state how to arrive at the site with estimated drive times / distances and inform groups about the basic facilities on site (toilets, visitors centre, picnic areas, disabled facilities, medical services, etc.). Additional information should include activity / programme length, entrance fee / school group fee, hire costs for any kits or resources, attendance regulations and recommended behavior of schoolchildren on a visit.

Trained garden educators exploring plant growth with young students. (Image: Jardín Botánico Regional, Mérida)

7.2.5 Adult Education at Botanic Gardens

KEY MESSAGE

Botanic gardens are uniquely positioned to offer educational and enrichment opportunities for adult learners in horticultural, botanical, environmental, and related fields.

Staff and collections, and in many cases libraries and research facilities, provide the resources for the delivery of an extensive and diverse educational portfolio.

While approaches and audiences differ by type of botanic garden and their available resources, the provision of adult education programmes can fulfil mission-based and practical goals. Adult education programmes provide a context and opportunity to deliver targeted, content-specific programmes that support each garden's individual focus. Education programmes can also build or strengthen a garden's visitor and membership base by providing them with continuing opportunities for engagement, and creating a community of returning programme participants. This can result in increased public awareness and recognition of a garden in the outside community. Lastly, adult education programmes, if managed efficiently, can be a source of revenue, bringing in funds to cover staff time and contributing to the operating budget.

Audiences can be classified into three broad categories: individuals looking for personal enrichment, professionals continuing their education, and adults preparing for careers in gardening and horticulture. Adult education programmes can also be categorized into three dimensions: enrichment, professional, and career preparation. With the addition of lectures and symposia they may appeal to a variety of audiences. Casual learners often enrol in certificate programmes or professional courses, if they are looking for a greater level of expertise. The structure of courses varies from short courses (one or two class sessions of a few hours focused on a particular topic) to multi-week courses covering a topic in depth, to certificate programmes (multiple classes covering an entire domain). For example, the Chicago Botanic Garden offers short courses, multi-session courses and a certificate programme in garden design, providing opportunities targeted towards a wide variety of audiences (Chicago Botanic Garden, 2016c).

Audiences for adult education are diverse, so in developing a programme portfolio you must know your audience – who they are, their communities, their interests, and other local opportunities for learning. An audience profile can be matched to the garden's mission, resources and expertise to identify potentially successful programming opportunities. Resources might include collections, staff, infrastructure, technology, libraries, or ongoing research projects providing course content or support programme delivery. Once course content is determined, programme structure and delivery method should be identified – class size, length of each session, length of course, location, and resources needed. Content and the course format can be used to develop a business plan for implementation, ensuring that the course meets desired revenue goals. Finally, ongoing evaluation of students' experiences and revenue goals will ensure consistently successful and high quality programming. Evaluation can be used to fine tune programme offerings, and better understand changing audience preferences.

An adult education class studying gymnosperms. (Image: Chicago Botanic Garden)

Teacher and student teacher training

KEY MESSAGE

If you teach student teachers how to use the garden effectively for education, they will keep bringing their school groups back.

Several botanic gardens have experienced difficulties in supporting large numbers of school children due to staffing, space or budgetary constraints. Through teacher or student teacher training, participants trained are able to cascade the experience, skill and knowledge to their own students. The Royal Botanic Gardens Kew (Case study 7.2.6) have run a student teacher training course for many years and have developed an effective approach to course delivery.

7.2.6 Higher Education

KEY MESSAGE

Historically, botanic gardens have been used as key resources for the study of botany and biology. Today, this provision is enhanced by training students in science communication skills.

Many botanic gardens worldwide offer programmes for students in higher education as many botanic gardens are closely linked to or part of a university complex. The vital role that botanic gardens offer to students of the natural sciences as well as other disciplines are exemplified in Case study 7.2.7.

CASE STUDY 7.2.6

Student teacher training at the Royal Botanic Gardens, Kew

Gail Bromley, consultant Planting Values

The Royal Botanic Gardens Kew ran a programme developed with science tutoring staff from a leading UK teacher training institute, the Institute of Education (IOE). The four day programme was developed as an overview of how to use a botanic garden for secondary level (11-16yrs+) science teachers. The annual cohort of trainee science teachers (c80), spend day one participating in a rotation of workshops and discussion.

The workshops, which included activity hints and tips, games and other topics, focussed on current teaching / learning about:

- Plant adaptation to their habitats;
- The vital role plants play in our lives;
- Sustainability and plant conservation;
- Details of organising a class visit to the garden.

On day two, the students worked in small groups to:

- Plan topics / activities to be taught to a visiting secondary school class;
- Decide roles for each student teacher during the visit (activity deliverer, school contact person, resource management, etc.);
- Schedule and route plan the activities on site;
- Develop a Health and Safety plan;
- Agree on / produce resources needed for the activities;
- Develop a 'wet weather' plan;
- Agree on / develop an evaluation plan.

Each group discussed their plan with Kew education staff and their course supervisors to ensure they covered all aspects adequately.

Educators being trained to deliver science education. (Image: The Board of Trustees of the RBG, Kew)

Days three and four were used for the delivery and assessment of the student teacher led activities. Secondary school classes were enlisted (free) to trial the student teacher led activities. Each group delivered their activities to the school children, repeating their activities with three or four groups.

The activities were observed by Kew and IOE tutoring staff. Post-activity discussion sessions were also held with the school teacher attending with the school group. The student teachers collected evaluation data from their groups and carried out a self evaluation of their delivery / impact. Observational / evaluation notes and reflections on the process were discussed during a final plenary session.

The IOE was charged for this programme offer, bringing in good revenue. A shorter programme has also been provided to other teacher training institutes for student teachers of Geography, Mathematics and History. It can be adapted to any subject where plants can be introduced, e.g. art, technology, citizenship.

This student teacher training programme builds knowledge and confidence about the value of visiting a botanic garden and provides an excellent incentive for the later qualified teacher to visit a botanic garden with their own schools.

CASE STUDY 7.2.7

Hortus Botanicus Vindobonensis: a training and education resource for university students

Michael Kiehn, Botanical Garden of the University of Vienna, Austria

The Botanical Garden of the University of Vienna (HBV, Hortus Botanicus Vindobonensis) is a core facility of the Faculty of Life Sciences. The HBV acts in close collaboration with other departments of the Faculty of Life Sciences, especially at the Rennweg site. The garden links botanical science and conservation issues with art, politics and society for the general public (c. 200,000 visitors annually), providing school programmes, exhibitions, plant displays and events.

As a university garden, the HBV is especially engaged in higher education. Two major areas of activities can be identified: the garden provides plant material for university courses and research projects and acts as a platform for teaching botany/biology in theory and practice. The quantity and quality of plants provided for courses is remarkable: the HBV cultivates and/or organises plants for c. 30 courses annually, including general identification courses as well as special lectures or seminars on plant morphology or phylogeny. In addition, a number of research projects depend on material cultivated in the HBV. Per year, c. 8,000 whole plants and plant pieces of c. 400 species are provided for these purposes. To optimize logistics of this plant supply, the HBV has started a new database system where requests can be logged for taxa required.

The platform for teaching in theory and practice is provided through different university seminars and lectures developed by garden staff, allowing an effective use of the garden collections and expertise. These courses are offered for all types / levels of biology curricula of the University of Vienna and are relevant for both future researchers and future teachers. Courses are directly linked with garden activities and include options for the students to get directly involved in the practical work of the HBV or to continue work on subjects dealt with in the context of Master- or PhD-theses.

The garden-related courses divide roughly into two types: (a) plant-based hands-on approaches to botanical research, and (b) science teaching experiences based on botanical objects and questions. In both course types, practical botanical training and knowledge transfer, leading to applied insights into theory and practice of scientific work in botany, form the basis of all work. An example of the first type of course is the lecture 'Higher Plant Diversity and Phylogeny'. The target audience is students in the Bachelors-curriculum of biology with specialization or interests in botany. The course structure provides training in important skills including careful, theory driven observation, comparative analysis, development and testing of scientific theories and hypotheses, and critical discussion of findings. The second course type, offered each semester, is a series of science education seminars, e.g. 'Central Topics in Biology and Environmental Sciences: Environmental Protection', from which student teachers select a range for their study. Each student teacher makes a presentation based on the lecture series theme, along with their presentation development plan. Post-presentation, the student cohort discusses the scientific content and presentation skills. The seminars are also open to other biology students. This example of 'added value' incorporated in the HBV-related courses provides opportunities to connect experiences gained in these courses with later work in science-communication or research projects. A number of Master-theses on the potentials, structures, and topics of outreach activities of the HBV have additionally resulted from student involvement in garden-related courses.

In summary, the HBV higher education programme is set up to improve scientific and science-education skills of biology students, from a range of biological disciplines, by incorporating them into the practical work of the botanic garden at all levels.

Training for future teachers: students explain aspects of woodland ecology at the botanic garden to a school class. (Image: R. Hromniak)

7.2.7 Evaluating Educational Programmes

KEY MESSAGE

Evaluation provides information for communicating to a variety of stakeholders and can show the worth of programmes.

Evaluation is often seen as being synonymous with the measurement of outcomes and can be considered as both, a tool and a process. It is an important aspect of the development of all avenues of work, including education programmes, activities and interpretation. Evaluation tools also offer a mechanism for monitoring progress and therefore enable reflection amongst practitioners leading, if necessary, to changes and developments in programme structures. Opportunities for reflection can also help the programme developers identify unanticipated outcomes, or factors for success not previously recognised. Evaluation is therefore a constant process of reflection and adaptation for improvement – a cyclical process as shown in Figure 7.2.2.

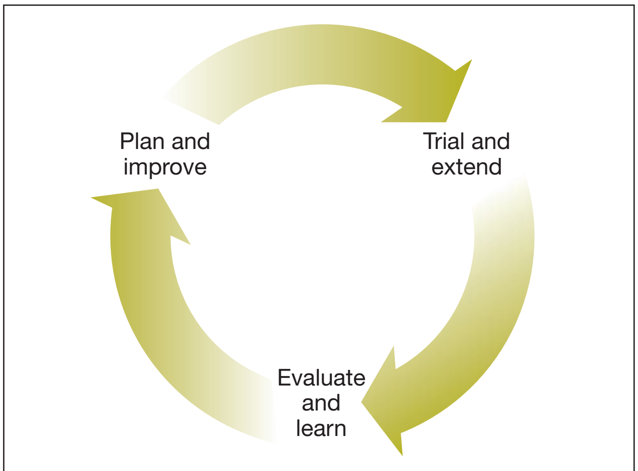
In essence, evaluation supports informed decision-making about how to spend your time and money. It does not have to be expensive or time-consuming; it is about proving what works for your visitors and what does not. There are a variety of approaches and methods for conducting evaluation and monitoring impact in informal science education settings.

1. Types of evaluation

Front-end evaluation describes the processes of determining what the target audience already knows and what they are interested in. It involves checking that proposals and ideas for events and programmes are appropriate and are likely to be well received.

Formative evaluation involves testing early versions of a programme to check whether it is going to plan (known as a process evaluation) or that it will meet its objectives or goals (progress evaluation).

Figure 7.2.2. The evaluating interpretation cycle



Summative evaluation describes the process of gauging the impact or success of the finished product, often against pre-determined performance indicators.

Remedial evaluation describes the process of conducting a final review and making amendments or remediation as necessary prior to completion of a programme or project.

Action evaluation involves identifying the aim of a programme or event before explicitly identifying the ways in which progress towards this will be monitored, including the evaluation tools to be used. At this point the design and structure of the programme can be finalised and the mechanism for monitoring the activity becomes an integral part of the activity's implementation (Stroud *et al.*, 2007). It has become accepted wisdom to incorporate evaluation at the start of a project rather than just at the end.

2. Evaluation strategies

The whole process is based on social and market research methods and can include aspects such as:

Evaluation and testing: looking at the impact of your programme or activities at a specific point in time.

Monitoring: counting things, e.g. visitors and ensuring things are on track all the time.

Consultation: talking to your current or potential visitors about your plans.

Quantitative evaluation focuses on aspects of impact that can be measured numerically, such as how many people attended, and can offer a broad overview of impact. It also describes types of questionnaires or feedback forms where limited choice answers (closed questions) are used, such as yes/no or agree/disagree.

Qualitative evaluation seeks to uncover the detail of particular actions such as what did the participants or audience think about a programme. Techniques include open-ended interviews and observations.

3. Methods of evaluation

Examples of evaluation tools include traditional approaches such as recording numbers attending, or length of press columns covering the event, as well as participant observations, snap-shot/full interviews with visitors, feedback questionnaires and 'reflective journaling' – notes made by practitioners regarding the nature and structure of observed events which build upon the individual's own professional knowledge and experience as a botanic garden educator. Modern technology can also be employed, such as using a sophisticated Global Positioning System, to digitally track how visitors move around your garden. Alternatively, you can simply observe how visitors use an interpretation panel, trail or plant labels. It is worth noting that the reliance on one tool only, will limit the breadth of any analysis; overuse of qualitative tools at the end of every programme or event can result in a declining response rate, and degree of depth.

Surveys are useful for obtaining a wide range of answers from a large number of respondents.

Interviews offer an opportunity for participants to express their own opinion rather than being confined to a set of responses as in a survey. The disadvantages however, are that some respondents try to please the interviewer rather than offering genuine views and time is required to analyse the data.

Focus groups comprise groups of 6-10 people gathered to discuss particular topics, facilitated by a researcher. They allow the generation of data through group interaction, as people bounce ideas off each other, and are useful for identifying the strengths and weaknesses of a programme.

Observations of participants in a programme (including overheard comments) offer an understanding of the wider context and may help identify unanticipated problems or outcomes.

Open-ended written or drawn responses from questions such as 'describe your reactions to…' offer insights into the ways a programme is being received.

Issues to consider in conducting evaluation:

- Follow ethical guidelines regarding the collection, use and storage of data. For more information see BERA (2011).
- If appropriate, ensure that participants' responses are kept confidential.
- Consider whether questions are appropriate and culturally sensitive, also be aware of what people do and do not say and look for non-verbal responses.
- For greater reliability, obtain as large a sample size as possible.

Above all your evaluation must be tailored to what you want to know and who you are asking. Answer the questions below to help you plan your evaluation.

- What do you really want to know?
- Who can advise you on how to answer these questions?
- Which evaluation techniques can you use?
- Do you have the skills and capacity to carry out an evaluation or do you need help?
- Who will read your results and how would you like them to be used?
- How can the results help to improve future activities?
- Have you thought about any legal or ethical considerations of your evaluation?

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7.3 PUBLIC ENGAGEMENT – INTERPRETATION

Gail Bromley, Planting Values; Asimina Vergou and Liliana Derewnicka, Botanic Gardens Conservation International; Angela McFarlane, College of Teachers; Pat Griggs, Astrid Krumins and Julia Willison, Royal Botanic Gardens Kew; Kate Measures, Heritage Insider

7.3.0 Definitions

Audience development: Audience development incorporates all of what we need to do in order to build and continually nurture supportive and loyal audiences. It is occasionally used when just referring to building new audiences or engaging hard to reach audiences.

Audience research: Any communication research that is conducted on specific audience segments to gather information about their attitudes, knowledge, interests, preferences, or behaviours, so as to better design targeted interpretation or educational programmes or materials.

Co-creation: Co-creation is a process where the interpretative staff and key stakeholders actively involve their targeted audiences in the development of the interpretative concept, its design and delivery.

Demographic: The statistical characteristics of human populations (e.g. age, educational level, income) used particularly to identify markets or audiences.

Focus groups: A group of people assembled to participate in a discussion about your interpretation or education programmes, usually at concept stage and before ideas are fully developed or a group to provide feedback on a particular issue or campaign.

Public programmes: Events or educational activities to engage the visiting public, usually informal.

User group: A set of people who have similar interests, goals or concerns and who meet regularly to share their ideas.

Wayfinding: Signs, maps, and other graphic or audible methods used to convey location and directions to garden visitors.

Zoning: Interpretative zoning in the botanic garden is a process of separating out particular sections of the garden to provide certain experiences, e.g. an arrival zone where visitors feel welcomed and can plan their visit. Zoning also provides a way of ensuring that particular areas within your garden appeal to a particular audience.

7.3.1 Introduction

Botanic gardens and arboretums worldwide attract millions of visitors per year. Collectively, they are well-placed to showcase to their audiences the interrelationships among plants, animals and humans and their interdependence.

Interpretation is an essential element of a botanic garden making it different from a park. It connects the garden to its visitors, adds to the visitor experience, helps to develop new audiences, inspires people's interest in plants, makes the collections meaningful and helps gain public support.

Interpretation is not synonymous with signage. It has an educational role, acting as facilitator, enhancing audiences' experiences and enabling them to construct meanings related to botanic gardens and their plant collections. Tilden (1957), one of the first advocates of heritage interpretation summarises: *'Interpretation is an educational activity which aims to reveal meanings and relationships through the use of original objects, by first-hand experience, and by illustrative media, rather than simply to communicate factual information…'*

The development of interpretive materials should be informed by current theories about how people learn when they visit botanic gardens (physically or virtually). The nature of learning in botanic gardens, if we exempt the highly structured school visits, is in general free-choice; this means that *'the learner exercises a large degree of choice and control over the what, when and why of learning'* (Falk, 2005).

Research (Ballantyne *et al*., 2008) has found that motivations for visiting a botanic garden include the aesthetic value, spirituality, tranquility, recreation, for social interaction, and an interest in gardens, horticulture and plants. Learning does not usually come high in the usual visitor's agenda, posing a challenge for botanic gardens.

A garden is like a 500-piece puzzle and what visitors see as they move through the grounds may very well be these puzzle pieces in random order (Veverka, 2005). An interpretation master plan helps a garden to organize their main messages for visitors, making them clear during a visit; it also helps deliver the messages at key interpretive points.

This section introduces the principles underpinning interpretation in botanic gardens, how these can be adapted and extended to create highly effective learning environments.

Interpretation at the Botanic Garden Meise, Belgium. (Image: Botanic Garden Meise)

7.3.2 Characteristics and Principles of Effective Interpretation

KEY MESSAGE

Interpretation should:

Provoke (a response to an image, caption, idea)

Relate (speak to the individual or connect with their everyday life)

Reveal (the meaning, answer or result in a surprising way)

Address the Whole (through one unifying theme)

(Veverka, 2011)

Successful interpretation:

has a theme

is organised for easy processing

is relevant to the audience

is enjoyable to process

(Ham, 2013)

There is still a great fear amongst some curators that making it easier for visitors to understand the ideas that collections represent and that exhibitions tackle will initiate a slide into poor scholarship, facile interpretation and mindless entertainment. This fear must be converted into an understanding and appreciation of the desire of a great many people to like museums and to find them both useful and enjoyable. Hooper-Greenhill (1994)

This curatorial fear also arises when interpreting botanic gardens' collections for the visitor; however by following the good principles and practice in this manual this fear can be mitigated.

Two excellent evaluation surveys of interpretation are Veverka's 'Visitor Center Evaluation Strategy' (2011b) and Masters and Carter's 'What have we got and is it any good?' (1999). Within the Masters and Carter's survey, assessing readability (the ease of reading and understanding text) can be quickly done using an online SMOG (Simplified Measure of Gobbledygook – unintelligible jargon) calculator (NIACE, 2009). A SMOG score of 10-12 (approx. ages 11-13 lower secondary level) is Masters and Carter's ideal level for interpretation to reach most people). By utilising these various tools, a good grounding is gained in understanding what makes an effective piece of interpretation and of course what does not!

7.3.3 How to Start Your Interpretative Journey: The Master Plan

KEY MESSAGE

The interpretative master plan details what messages and themes should be provided for the visitor, what outcomes are hoped for (a change in attitude or behaviour, support for the botanic garden, etc.) and how best to achieve this.

The interpretation master plan should be an integral element of the overall strategic plan for your garden. For newly established botanic gardens, or those that are re-landscaping or redesigning an area, this is an ideal time to integrate your interpretation plans (Chapter 1, Section 1.5.4).

Interpretation master plans should start with an inventory of the garden site including landscaping, key features, key equipment / techniques on public view and the plant collections available for display. Once you know what you have in the garden, it is easier to decide what can be used effectively as the stimulus for any stories you want to tell.

The interpretation master plan should be comprehensive and address the following points:

- Aims and objectives: What will be the outcome of people engaging with your interpretation? There needs to be a point to it!
- Audience development: Who are you planning to engage with this interpretation?
- What are the key messages that you want to get across, e.g. the vital importance of plants?
- What stories can you tell to get your message across?
- Types of interpretation: What is/are the most appropriate method/s to convey your message? Does that method work for the site where you are placing your interpretation?
- Themes: How can you achieve cohesion across your interpretation? Individual interpretative items should fit together to make up the 'big picture'.
- Does the interpretation match your 'brand', e.g. the tone of voice, colour considerations, style.
- Co-creation / participatory approach: Who will develop your interpretation? Is it just being managed by your in-house team, or are you going to involve any of your target audiences?
- How can you build on your interpretation? Can you reinforce the messages through other media, e.g. text on serviettes in the cafe; strap lines on literature.

Examples of interpretation master plans can be seen in Çevik (2013) and in resources from parks and recreation sites (CSP, 2016; Wells *et al*., 2009). At the Royal Botanic Gardens Cranbourne, staff worked cross-departmentally to develop an excellent interpretative master plan for their Australian Garden (Case study 7.3.1). Wakehurst Place in Sussex, United Kingdom (Case study 7.3.2), explores how an interpretative refresh can be developed efficiently and with a limited budget.

CASE STUDY 7.3.1

Interpreting the Australian Garden at the Royal Botanic Gardens Cranbourne

Sharon Willoughby, Royal Botanic Gardens Cranbourne

The 15-hectare Australian Garden (AG) sits at the centre of the Royal Botanic Gardens Cranbourne. Sitting on the fringe of the suburbs, this significant patch of remnant bushland is an ark of biodiversity in a rapidly developing area of Cranbourne, NSW. Constructed between 2006 and 2013, the design of the AG created a revolution in thinking about the role of Australian native Botanic Gardens. The AG is striking and bold, rich with the colours and textures of the Australian landscape, a showcase of Australian native plants.

The Scribbly Path, Cranbourne. (Image: Royal Botanic Gardens Victoria)

When funding became available, the Public Programs team developed and delivered the interpretation master plan, setting out what stories to tell visitors, plus where and how. A multi-disciplinary team was established to develop the interpretation master plan for the AG (Veverka, 1994). A mix of perspectives from horticulture, marketing, public programmes and plant sciences proved invaluable in understanding the AG in a number of different contexts.

Laying the draft garden designs out on a table and 'virtually walking' around them with marker pens imagining we were a number of different user groups helped us to understand the plans and the ways in which visitors might experience the garden. It allowed us to see where visitors would need seats, information signs, maps, drinking fountains and other services as well as letting us think about which senses we might activate at any given point. We also considered other ideas, e.g. photo opportunities and placement of fragrant plants (Sensory Trust, n.d.).

The typical visitor to an Australian botanic garden is over 55 years old, of Anglo-Saxon/Celtic origin, female and tertiary educated. We wanted to broaden this audience and attract new visitors. By comparing the demographic data of visitors coming to Cranbourne Gardens to the demographic profile of surrounding suburbs, the current audience gaps became evident. We prioritised young families with new houses and empty gardens, and to attract them, developed programmes of particular appeal to them.

Working with designers, we created a set of sign types for the AG including plant labels, directional and interpretation sign-boards. This allowed us to plan more effectively as we knew sign costs, production times and word counts before starting to write anything, saving time and money.

What stories, plus where and how, to tell visitors, is more of an art that a science and having a multi-disciplinary project team helps. Appealing to hearts and minds is key; engaging visitors with cultural stories about plants, creating moments of fun and laughter and provoking curiosity through the unexpected. The AG was created to inspire visitors to use and grow Australian native plants in their home gardens. The garden also wanted to interpret the work of a modern botanic garden, highlighting conservation and plant science. Built during a decade long drought in Southern Australia, issues such as water conservation, climate change and sustainability were also important. →→→

The Red Sand Garden, Cranbourne. (Image: Royal Botanic Gardens Victoria)

CASE STUDY 7.3.1 (CONT.)

We used a thematic planning approach, linking stories or conversations that we wanted to share with our visitors in each area around an overarching theme. All the stories in the AG sit under four topics: plants, water, culture and home gardening. Colouring in a plan with these topics ensured that we had a good mix of stories across the landscape. Each topic concludes with questions about the future, enabling us to round out these ideas and keep them fresh. Working out how to deliver these stories was the next step, for instance we decided that the 'home gardening' theme was best delivered by face-to-face interpretation. This led to the establishment of a volunteer Garden Ambassador Programme. We recruited knowledgeable home gardeners to talk to visitors about gardening with Australian native plants.

Now that most of the interpretation master plan has been delivered, we are assessing what visitors take home from their visit using two strategies: a) After events we ask visitors to complete an evaluation form in return for a small prize; b) We are exploring visitor perceptions of the AG and whether we are influencing how they garden.

The Future Garden, Cranbourne. (Image: Royal Botanic Gardens Victoria)

CASE STUDY 7.3.2

From check-in to check-out – refreshing the Millennium Seed Bank visitor offer

Astrid Krumins, Royal Botanic Gardens, Kew

Kew's Millennium Seed Bank Partnership (MSB) is sited in Wakehurst Place, West Sussex, England. Wakehurst is RBG Kew's 465 acre country estate with a stunning combination of botanical gardens, mixed woodlands and Sites of Special Scientific Interest focused around an Elizabethan mansion and the MSB (RBG Kew, 2014a). The MSB is the largest *ex situ* plant conservation project in the world; saving and conserving seeds outside their native habitat. With its partner countries it also undertakes *in situ* conservation, restoring and conserving species in their native habitats. Its focus is on conserving global plant life that is a) endangered b) endemic or c) has economic value. With support from partners across 80 countries, it is on the way to bank 25% of the world's wild species by 2020 (RBG Kew, 2014b). Visitors include general visitors to Wakehurst Place as well as education groups (upper primary, secondary and university).

The interpretive displays had not been updated since the MSB opened in 2000; the interpretative focus was then on the collection and storage of seeds ('check-in'). Since 2009 the focus of the MSB has shifted to include using the seeds back in the wild for habitat restoration, agriculture, forestry and improving livelihoods ('check-out'). These stories now needed to be told.

A detailed audit of the existing interpretation was undertaken, based on Veverka's 'Visitor Center Evaluation Strategy' (2011) and Masters and Carter's 'What have we got and is it any good?' (1999). Additionally, a visitor survey on the current offer was commissioned.

A small in-house project team (project manager, head of content, head of design) was established to implement as many of the low cost, quick-win recommendations from the audit and survey as possible. A Project Board and other MSB, Wakehurst and Kew staff supported the team. The main audit and survey recommendations were: improve the readability of the text for non-specialist audiences, introduce family friendly sections, introduce colour, improve external and internal wayfinding, update images and stories, include 'check-out' stories, provide context to the seeds, make the experience feel more welcoming, provide face-to-face contact and include some hands-on activities for both adults and children. →→→

New wedge shaped panels showing 'Check in' seed processing. (Image: Anne-Catherine Sheen)

CASE STUDY 7.3.2 (CONT.)

The project constraints included a restricted budget of £20,000 to cover all external requirements i.e. print, production, installation, removal of old hardware and commissioning of visitor research. Job commitments had to be put on hold or delegated for 6 months to allow the project team to work. There could be no infrastructural changes and no additional lighting, heating or audio visual equipment. Due to lab layout, the linear journey the seeds make through the processing labs to the vaults had to be kept and a multi-purpose space, the central area needed to be kept clear for large gatherings and events.

The new interpretative approach fulfilled many of the recommended changes. In the central area of the visitor gallery, colour was added through images of banked seeds with interesting stories. A team of Volunteer Explainers were recruited and trained to engage with visitors and provide access to handling objects; this face-to-face interaction is especially important when no scientists are visible in the labs. Colour-coded headings to the labs were added, making it easier for the visitor to orientate themselves at each stage of the linear seed journey. The colours linked to the new interpretation panels which explained each stage.

The central box exhibits were removed giving increased space for events and a useable central surface. Wedge shaped panels were used in front of the MSB lab windows; tilted to make them accessible for wheelchair users. Key pieces of equipment visible in the labs were labelled to link to text and where suitable, family-friendly sections denoted by the magnifying glass symbol were added to the interpretative labels.

Interpretation in the central visitor hall area of the MSB after the renovation. (Image: Anne-Catherine Sheen)

7.3.4 Audience Research and Development

KEY MESSAGE

Knowing which audience you are targeting is critical for developing relevant and effective interpretation.

Botanic gardens are learning how to ask questions of visitors and use their learning to strengthen interpretation and education offers, formulate marketing strategies, improve visitor services and reach new audiences. Initial audience development research may include:

- The total number of visitors;
- The socio-economic background of the visitors (age, gender, etc.);
- Visit motivation (e.g. free entry, tranquillity, child friendliness, etc.;
- Visit schedule (time / day / season);
- Time spent;
- Places visited;
- Address / email.

This can be done by visitor exit surveys, visitor interviews or questionnaires, focus groups or telephone / on-line surveys if you have already have contact details captured.

The questionnaires and interviews can be supported by volunteers or intern students provided they have been trained. Focus groups are best done by external professionals.

7.3.5 Catering for Hard-to-Reach Audiences: Broadening Participation

KEY MESSAGE

Botanic gardens have a social responsibility to be accessible to all.

The audience development process will highlight a number of audiences that for one reason or another may not visit your garden. This may be due to cost (e.g. families on low incomes), lack of knowledge of the site due to language barriers or ethnicity / cultural background (e.g. refugees) or issues with physical or intellectual access. Some may have the perception that a botanic garden is just not for them (Section 7.4).

Making the botanic garden physically accessible will not only benefit those who have impairments, but often improves the visit experience for others – mothers with pushchairs or the elderly. Garden features should be easily navigated by visitors with mobility problems. Consider the positioning of interpretation. Is it too high for wheelchair users? Do you have staff trained in sign language or offer additional visual stimulation for those with audio impairment? Do you offer tactile interpretative experiences or audio interpretation for those with visual impairments? The Scottish Natural Heritage (2016), and Paths for All (n.d.) offer online resources on this matter. Each country usually has its own legislation and permissible design strategies for public spaces and exhibitions.

Prague Botanical Garden has a trail for the visually impaired using the wooden posts that line the route through the southern area of the garden and which carry their standard visitor interpretation. At the back of each post are metal panels with the same information in Braille. The garden additionally has a tactile display area where visitors can explore some of the botanical artefacts. The garden aims to enhance the trail by including acoustic guidance to make the location of each post simpler, accompanied by orientation maps specially designed for the visually impaired.

7.3.6 Botanic Garden Location and Zoning

KEY MESSAGE

Botanic gardens have a social responsibility to be accessible to all.

Signage, visitor information desks and clever layout of pathways may help 'direct' visitors to areas you want them to see, but visitors often randomly wander around the site. Multiple entry gates to the garden make it almost impossible to ensure that visitors are steered to specific displays. Finding out where visitors gather in cafes, play areas or glasshouses; and knowing which plants/landscapes (hot spots) offer the best wow factor is useful. Another consideration is how much interpretation to put out. People do not always want a sea of labels or to be confronted by a costumed interpreter; they may prefer to interpret the collections by themselves. Provide some tranquil and reflective zones in your garden where visitors can relax and just enjoy the space. Westonbirt Arboretum in the UK developed their 'zoning' strategy to ensure that the needs of their varied audiences were met (Case study 7.3.4).

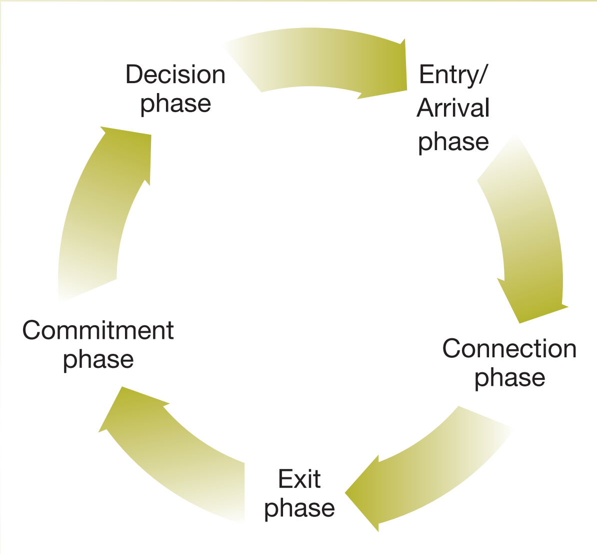
CASE STUDY 7.3.4

Get in the zone – Westonbirt, The National Arboretum, Gloucestershire

Ben Oliver, Westonbirt, The National Arboretum

Numerous studies confirm the importance of visitor motivations and expectations to the success of interpretation (Falk, 2009; Davies, 2013; McIntyre, 2013), but how do we ensure different audiences know what our gardens have to offer them? Site zoning is an effective tool for organising spaces and experiences so that visitors are able to make informed choices about where they want to go and what they want to see, so organise your site from (pre) start to (post) finish.

Experiences begin with a decision to visit. The arrival phase prepares the visitors for their day; welcoming them and setting the stage for the visit. Signage, landscaping, architecture and traffic flow, amongst other items, create a rich introduction for the experience ahead. Central to the visit is the connection phase, when visitors engage with the collections. If the decision and arrival phases are right, visitors will have made informed choices about how they want to engage with the collections and know exactly where they want to go. An organised exit experience invites people to return and get more deeply involved. The commitment phase is the follow-up; perhaps an e-newsletter or invitation.



Brochu's visitor experience model (the VEM)

In 2014, Westonbirt created a new visitor arrival zone to help orientate visitors on arrival. Entering through our Welcome Building enables visitor access to interpretative displays and trained volunteers, providing them with a clearer picture of what Westonbirt offers and, more importantly, how they can personalise this offer to their needs. The Welcome Building also acts as the defined exit point, to re-engage with visitors as they leave. →→→

CASE STUDY 7.3.4 (CONT.)

A new map subtly zones the arboretum and highlights particular features of interest. It defines areas of ornamental and native planting, helping visitors distinguish between formal and informal gardens. First time visitors are shown the key 'collection' experiences; regular users looking for a quiet walk are catered for by highlighting more secluded areas. Sites of special interest are identified with monograms, which also feature on site signage. The map is regularly updated to flag up seasonal hotspots.

The VEM should be used for individual interpretation projects. It is easy to forget the importance of a proper arrival to displays; we got engrossed in developing a new propagation viewing area but forgot to invite visitors in. As a result, evaluation showed that many people did not enter the area as they thought it was 'out of bounds'! A simple sign encouraging people to come in has rectified this.

Zoning ensures interpretation is located sensitively and where visitors are likely to engage with it. Through VEM, Westonbirt is zoned from intensive high use areas, with more interpretation, to 'wild' natural areas where visitors are seeking to escape (very limited/no interpretation). Similarly, seasonal rhythms influence visitor behaviour; seasonal zoning through trails, 'what's out' notice boards and themed guided walks cater for visitor preferences and ensure a constantly changing offer; a key requirement for a site with 70% repeat visits. Using visitor interests to zone/locate interpretation has dramatically impacted on how much they engage with our interpretation and reduced complaints about inappropriate interpretation. Visitor evaluation shows that certain tree specimens have a wow factor that makes visitors stop. Simple 'key tree' boards identifying these specimens have proved very successful.

Lastly, zoning allows the various audiences different experiences without causing conflict. An example of this is our family play trail. By positioning activities in quieter shelterbelt areas near, but not in, ornamental areas, families are able to have a bespoke hands-on experience alongside our more traditional audiences. Our play trail helps overcome parental anxiety by giving families their own space and clear rules on issues such as climbing trees, making dens or picking up natural objects.

Overview of Westonbirt site with new zoning for visitor arrival and departure. (Image: Forestry Commission)

Westonbirt map highlighting 'hotspots'. (Image: Forestry Commission)

7.3.7 Developing the Right Approach

KEY MESSAGE

Visitor's learning styles differ widely. Some visitors prefer visual stimuli, some audio and yet others learn best when they are actively encouraged to do something (kinaesthetic learners).

1. Face-to-face interpretation

Visitors enjoy 'face to face' interpretation, giving them the opportunity to ask questions, dig deeper into topics or directly handle artefacts or resources given to them by guides or interpretative staff. The personal interpretation by a guide or costumed interpreter is often cited as bringing a topic to life.

Many botanic gardens have face-to-face interpretation, using either volunteers or paid staff as guides. At the University of Oxford Botanic Garden, their (Plant) Family Days engaged audiences by focussing on a single plant family. The garden-trained, costumed actors played the part of historic plant collectors, botanists and scientists, engaging families by strolling round the plant collections talking about such subjects as how the potato first came to England or how they used medicinal plants in the 18th century. Contemporary botanic garden illustrators were also encountered in the garden, illustrating plants from the plant family being celebrated. Visitors could chat to them and have the plant characteristics explained – or try drawing themselves. These personal interactions proved hugely popular and each Family Day was richly augmented with family picnic foods made available using some of the foods or flavourings that originate from the designated plant family.

Several botanic gardens run themed tours, seminars or lectures on a range of topics such as 'Fungal Forays', 'Celtic Trees' and 'Poisonous Plants'. Many also offer 'behind the scenes' tours, showcasing rarely seen collections and the work that goes on behind closed doors. This encourages other staff, such as scientists and horticulturalists to engage visitors with personal anecdotes and amazing facts about the collections. Chicago Botanic Garden, and the National Tropical Botanical Garden (n.d.) in Hawaii are examples of gardens that run such tours. Tours for young children often prove very popular as well; Royal Botanic Garden Edinburgh (2015) and Wakehurst Place (n.d.) use their 'green fairy' tours to engage tiny tots!

2. Non-personal interpretative media

There is a large range of non-personal interpretative material, including brochures, posters, labels and panels, audio guides, trails, touch trolleys and activity stations, exhibitions and, increasingly, technological interpretation media such as smart-phone apps. Each of these applications has strengths and weaknesses which should be carefully considered before application. Considerations include ease of updating information, durability, accessibility and management, e.g. Can you mow round this panel? Can you water near this electronic interactive? Is your Wifi coverage good enough? Is this sign easy to clean?

3. Interpretation and technology

Currently, many sites are considering interpretation through technology, however screen based technologies in botanic gardens are a challenge. If outdoors, they must be able to withstand wet, cold and extreme heat, as well as general wear and tear. Screens which are not working or show out of date content are a sorry sight, so before embarking on a screen based installation it is vital that there is a maintenance budget which includes refresh of content as needed. Screens readable in daylight are now more common, but are costly. Sound can also be an issue as hearing a sound track against background noise can be difficult; headphones are an option, but again subject to weather and wear and tear.

An alternative to providing static screens is to offer content for personal mobile devices, although to work well the garden needs good mobile signal coverage. A trial of bespoke devices at RBG Kew was reasonably popular when free, but not something visitors would pay to use. An 'app' which offers free content to smart-phones proved more effective in terms of reach, although again paid for content was less popular. The advantage of such content is that it can be updated readily so is always current and can be made location relevant. As their Smartphone is with the visitor at all times, content can be called up as and when required or prompted by on site signage. The development costs are significant, and early research suggests many visitors see a trip to a botanic garden as an escape from technology, especially for their children. At the Royal Botanic Gardens, Kew, the App proved most popular with frequent visitors and took many to parts of the gardens not previously discovered (Waterson and Saunders, 2012).

4. Choose stories well

KEY MESSAGE

Telling strong stories is a wonderful way to engage the public; a simple message is most effective in communication terms so don't try to tell everyone everything.

Once you have your take home message (theme) for interpretation you need the best story to deliver your message. Interpretation should reveal the significance of your story and provide more impact than simply stating facts. Translate technical terms and concepts into language that non-scientists can engage with. Try to get your main message across quickly and then reinforce it, at the end of the panel or talk. Do not rely on words – use photos, drawings or cartoons. Ask questions, encouraging visitors to discuss your messages amongst themselves. Providing interpretation where the visitor can participate or contribute encourages critical thinking and reflection. Give specific examples rather than abstract ideas: talk about an area of rainforest equivalent to two football pitches disappearing every second. If you're describing work on the Apiaceae, mention a member of the family that your audience might know, such as coriander. Avoid 'scientific language' and jargon, make your words personal and involving, and use humour whenever possible. If someone laughs at your story, they'll probably remember it. Try to write active phrases, for example '*the plant grows*' rather than '*the plant was found growing*'. Not only is this easier to read, but it saves on numbers of words too! Whenever possible try to ensure that you provide details of a webpage or other source of further information. Then all those people who have been inspired by your interpretation can find out more.

The Care for the Rare project (BGCI, n.d.) has developed clear messages and great conservation stories that can be adapted to any botanic garden. Choosing a catchy title for the panels, and layering the information to make it easily digestible, is good practice. In the panels, some provide information on individual iconic species while others address the importance of plants and plant conservation. Templates of these panels and the logo are available to download for use by any garden across the globe.

A recent advancement in content development for interpretation is co-creation, where the garden interpretation team works with the audiences (both existing and new) to create content together and sometimes the design and the interpretative outcomes as well. The co-creation process, which until now has been mostly adopted in museums, can be quite open, allowing the outputs to develop across the project or be produced within a framework. This process often provides interesting and relevant material with a very fresh perspective, however it is a process that needs brokering and one where the expectations of both the audience participants and the garden staff must be sensitively managed. Govier (2009) discusses co-creation benefits and issues and presents relevant case studies.

7.3.8 Managing Interpretation

KEY MESSAGE

Labels and panels need regularly checking for repairs, cleaning or replacement; time for this should be built into volunteer roles /staff job descriptions.

Interpretation needs managing and maintaining. This requires a dedicated member of staff, or a team, that works continuously to develop and enhance your interpretation. The skills for interpretation delivery include planning, evaluation, theme development, content development and text writing. Both initial and continuing training is needed for those working with face to face interpretation, e.g. guides, to ensure programmes are up-to-date with both content and communication skills.

Weather conditions, price and availability will often limit the materials you can use in the garden. For non-personal interpretation there are a number of materials available including bespoke technological / digital solutions, vinyl, enamel, glass, wood, stone, aluminium, resin and laminates as well as paper. Interpreters from a number of sites across the globe share their choices in Table 7.3.1.

Table 7.3.1 Interpretative materials for labels and panels

RECOMMENDATION	CONTRIBUTOR AND COUNTRY
Digitally printed vinyl (with artwork and printing being done in house where possible): lasting 5-7 years (RBG Sydney have used brands such as Versatec and Polycure). These can be applied to metal frames and changed as needed. For longer lasting interpretation – etched anodised aluminium signs can be used.	Janelle Hatherly, Education and Interpretation Specialist, Australia. Region with temperate climate and mild winters.
Black etched on aluminium is longest lasting If staffing time allows – regularly replaced laminated signs work well (n.b. laminated signs disintegrate after a year or two).	John Roff, South Africa. Wet temperate climate.
Large signs: laminated A3 sheets attached onto permanent supports with double-sided sticky tape. This is cheap and easy and we use the A3 printer and an A3-plus laminator on-site. Laminated properly, these last for a year, snow and low temperatures not being a problem at all, however they fade, particularly in the sun, lose gloss and become dirty, so they are changed annually. A3 and A2 format in PVC plastic has been tried outside, however these also need changing annually and are more expensive. Large banners for exhibitions and temporary navigation are made from thin and supple double-sided plastic attached to frames on eyelets. These will last through a cold winter. Permanent plant name labels are A6, printed on plastic and attached to a thin aluminium angle bar with two rivets. The upper bar end is straightened and inclined at 30 degrees, the lower is cut at a sharp angle to go easily into the soil. The bar itself is of different length depending on whether it's destined for a tree, a shrub or a herbaceous plant. These last for 3 years and longer, unless broken or scratched and are easy to wash (better with a pressurised jet than a cloth to avoid scratching). Temporary A6 labels, for example with varieties names for short-lived tulip displays, are laminated and discarded once the display is gone. A last option is two-coloured engraved plastic. These labels seem to last forever (some are 10-years old and are in good shape) but they are considerably more expensive.	Artem Parshin, Moscow. Humid continental climate, with warm humid summers and long cold winters.
Metallic labels are used which are etched or painted and these, although expensive, last a long time. Plastic / fibre is also good, as these can be moulded or embossed and given shape; they also last a long time. Laminated interpretation can be used, however these have to be regularly replaced.	Suma Tagadur, India. Warm, moist conditions.

7.3.9 Evaluation

Evaluation is one of the most powerful tools in the interpreter's kit, supporting informed decision making about how to spend time and money and moving the botanic garden's interpretation from being mediocre to accomplished. It does not have to be expensive or time-consuming, it is about proving what type of interpretation works for visitors and what does not. Guidance on how to evaluate a botanic garden's interpretation programme and facilities is in Section 7.2.7.

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7.4 PUBLIC ENGAGEMENT – A SOCIAL ROLE FOR BOTANIC GARDENS

Asimina Vergou and Liliana Derewnicka, Botanic Gardens Conservation International; Gail Bromley, Planting Values

7.4.0 Definitions

Growing a social role: Developing botanic gardens' commitment to working with their local and global 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 (Vergou and Willison, 2013).

Community engagement: The process of working collaboratively with community groups to address issues that impact the well-being of those groups. It includes a broad range of interactions between people.

Participation: The different mechanisms for the public to express opinions, take part and exert influence regarding political, economic, management or other social decisions and activities.

Social inclusion: The term is usually defined as the opposite of social exclusion which is 'the dynamic process of being shut out, fully or partially, from any of the social, economic, political and cultural systems which determine the social integration of a person in society' (Walker and Walker, 1997)

7.4.1 Introduction

KEY MESSAGE

Botanic gardens depend on establishing strong links with their local community. Plant conservation issues do not exist in a vacuum and are intertwined with people's lives.

From the Charco del Ingenio Botanical Garden in Mexico, supporting fair trade for the local producers through their gift shop, to Wuhan Botanical Garden in China, giving away free plants that clean the air and training the community on how to use them to reduce the impact of dust haze, botanic gardens worldwide are showcasing their social relevance. These activities indicate that botanic gardens have a social role, some within their core activities for many years and others who are starting to consider this approach.

The role of botanic gardens has been evolving since their inception, responding to social, economic and environmental changes. Their origins can be traced back to the medicinal gardens of monasteries, university gardens, and gardens that were set up to support the expansion of Empires (Sanders, 2004). More recently, because of the dramatic human impact on the environment, botanic gardens have been motivated to adjust their role to contribute to plant conservation (Heywood, 1987; Powledge, 2011). Maunder (2008) argues that, in the last 20 years, botanic gardens have found a sense of mission as providers of environmental education and science communicators, and highlights that gardens now recognize that their future depends on conveying the importance of their work and establishing strong links with their local community.

At an international level, environmental policies emphasise the need to ensure that biodiversity conservation benefits communities (e.g. Aichi Strategic Goal D, CBD 2010). Similarly, the Global Strategy for Plant Conservation (Sharrock, 2012) Target 13 calls for 'Indigenous and local knowledge innovations and practices associated with plant resources to be maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care'. Governing and funding bodies emphasise the need for the social impact of the work in botanic gardens and the wider museum sector. In recent years there has been an increasing emphasis on breaking down barriers to access and providing services for a much broader range of people. In particular, publicly funded botanic gardens and other museums are being called upon to demonstrate that their services represent good value, are responsible and relevant to the needs of their communities and are developed in partnership with them (Lang, 2001; Dodd and Jones, 2010). Further encouragement within the sector comes from either passionate professionals, eager to share their expertise for the benefits of the wider public (Black, 2005), or networks and associations that emphasise the need for change, e.g. the UK Museums Association (2013) with its visionary publication Museums Change Lives. The revised action plan from the European Botanic Gardens Consortium includes a new section on growing a social role while Objective 6 seeks to 'Develop the capacity and raise the status of botanic gardens as socially relevant organisations' (European Botanic Gardens Consortium, to be published in 2017). Since 2010 BGCI has led the Communities in Nature Programme which aims to support botanic gardens to change and become more socially relevant organisations by being part of a Community of Practice of botanic gardens who share the same vision (Case study 7.4.1).

At Westonbirt, The UK National Arboretum, participants of the Bristol Drugs Project are trained in sustainable woodland management practices. (Image: Westonbirt, The National Arboretum)

CASE STUDY 7.4.1

Communities in Nature Programme

Liliana Derewnicka, Botanic Gardens Conservation International and Alicia Fernández Rodríguez, The Linnaean Society

Communities in Nature is a BGCI strategic programme, funded by Calouste Gulbenkian Foundation, built on the results of the research report 'Redefining the role of botanic gardens: towards a new social purpose' (Dodd and Jones, 2010). This study offered a picture of the work that botanic gardens were undertaking and demonstrated how social and environmental responsibility are inextricably linked. The aim of the report was to identify the potential of botanic gardens to address their social role, by reaching all levels of society, to promote education and awareness about plant diversity and the need for its conservation. The report also identified the barriers and forces for propelling botanic gardens towards growing their social role. Based on that report, between 2011-2013, BGCI coordinated community based projects in 7 UK botanic gardens, provided training in community engagement methods and project management, ran organisational workshops in the gardens, and ensured that the projects' impact was documented through evaluation (Dodd and Jones, 2011; Vergou and Willison, 2013a). This led to the formation of a working definition of the social role of a botanic garden. Moreover, the lessons learnt and input from gardens around the world were compiled in the practical manual 'Communities in Nature: Growing the Social Role of Botanic Gardens. A Manual for Gardens' (Vergou and Willison, 2013b), a step-by-step guide for gardens on how to reach communities, create partnerships and embed a social role into the organisation's culture and practice in order to achieve long-term sustainability. This was followed by the publication of a second manual on how botanic gardens can address social issues 'Caring for your community: a manual for botanic gardens' (Derewnicka *et al.*, 2015). This time a case study approach was used to inspire other botanic gardens to carry out similar projects.

Care home resident watering Calendulas as part of the Bristol Community Plant Collection - Communities in Nature project. (Image: Bristol Zoo Gardens)

The initiative is now entering its scaling-up phase, looking at how UK botanic gardens' experience of growing their social role can be combined with examples from gardens in other countries and drive international collaborations advocating for gardens' potential to achieve social impact.

This phase includes disseminating the outcomes of the initiative at conferences, writing publications in practitioners and peer-reviewed journals (Vergou and Willison, 2014a; Vergou and Willison, 2014b), offering new training opportunities and developing new large-scale projects based on this practice. In 2014, evaluation of the programme was commissioned to look at the overall impact of Communities in Nature and suggest ways of moving forward. Encouraging and supporting botanic gardens to examine their current roles in conservation, scientific research, education and recreation and to become socially relevant institutions that work towards social justice and address social exclusion is not an activity that can be achieved through one-off projects. Communities in Nature aspires to be a long-term initiative that will continue to advocate for organisational change within the botanic gardens sector as well as raise their profile as institutions that address social issues at the public, government and international policy levels.

Despite the increasing need and pressure for botanic gardens and museums to grow a social role and the evidence to indicate the impact of this work (e.g. Silverman, 2010; Urbis, 2004; Vergou and Willison, 2014b; Dodd and Jones, 2011) critics have argued that a focus of the organisations on socially relevant activities may lead them astray from their mission and distort their organisational focus. Silverman (2010) points out that some directors may rank other priorities higher, especially when resources are scarce, whilst others may question a botanic garden's capacity to engage in social work.

If saving the world's flora is considered a major priority for the work of botanic gardens it's clear that environmental issues do not exist in a vacuum and that they are intertwined with people's daily lives. It is not easy, or indeed always possible to address one without considering the other. The Village Botanists project of The Institute of Trans-disciplinary Health Sciences and Technology in India (Case study 7.4.2) illustrates how projects can satisfy an environmental goal by tackling social issues. Moreover, engaging people is considered part of the solution for conserving plants. The Aichi Biodiversity Target 1 states that: 'by 2020 all people need to become aware of the values of biodiversity and the steps they can take to conserve and use it sustainably'. Therefore it is important for botanic gardens to engage with a wider spectrum of society. This means that, according to Dodd and Jones (2010), gardens that have a demographically narrow audience of mainly white, older people with high socio-economic status, need to change. This is what O'Neil (2006) calls the 'unequal distribution of the good' of museums that can only be redressed by adopting a new view of museums which involves a theory of justice (O'Neil, 2006). David Rae (2012), former director of horticulture at the Royal Botanic Garden Edinburgh, warns that *'There's no point in preaching about environmental sustainability to only 5 percent of the population, it has to be to 100 percent, and that means everybody...So, we've got to find new ways of reaching people who don't naturally come here.'*

Social inclusion/exclusion, social justice and social impact are all terms closely related to the social role of botanic gardens. Sandell (2003) clarifies that social inclusion work in museums should not be regarded as simply a synonym for access or audience development but as work that requires the organisations to rethink their purposes and goals and to renegotiate their relationship to, and role within, society.

CASE STUDY 7.4.2

Village Botanists course, Institute of Trans-disciplinary Health Sciences and Technology, India

Deepa Srivathsa, Foundation for Revitalisation of Local Health Traditions (FRLHT), Bangalore

The Institute of Trans-disciplinary Health Sciences and Technology in India was an experienced NGO which became a university in 2003; it also houses a botanic garden. Its mission focuses on conserving medicinal plants and documenting traditional knowledge in relation to medicinal plant use. One of the ways the Institute is fulfilling this is through its 6-month training course, Village Botanists. The course aims to build the local communities' skills in identification, documentation, conservation and sustainable use of medicinal plants. It was initially funded by the Ministry of Environment and Forestry and has been running annually since 2003. Since 2010 it has been run four times a year, with 30 people trained in each course. The course is always taught in the local language and involves the basics of botany, assignments documenting medicinal plants and local knowledge in the area, field visits and comprehensive evaluation.

Originally the main focus was on conservation. The Village Botanists course builds the capacity of local communities to document their natural resources and traditional knowledge, and fulfils the requirements of India's National Biodiversity Act (aligned to the CBD). Hence the course participants (often folk healers) are recruited from areas important for the conservation of medicinal plants and these are usually villagers with low income. As the course idea developed, it became clear that by cooperating with the community, the project could link the organisation's conservation efforts to the development of these rural communities. The Institute has now established a long-term relationship with the trainees, whose contact details are included in a registry to allow continued communications. The trainees regularly monitor the populations of medicinal plants in their local areas and contribute the data to the Institute. In a conversation with Deepa Srivathsa, the course coordinator, she explains about the role of the trainees: *'Without the community help, we can't do conservation. The main vision of the organisation is conservation of medicinal plants and revitalization of local health traditions. Without community help, we can't achieve our vision. So when the community comes, they will not work for free, they will request some economic return. So this is like linking the economy with conservation'*.

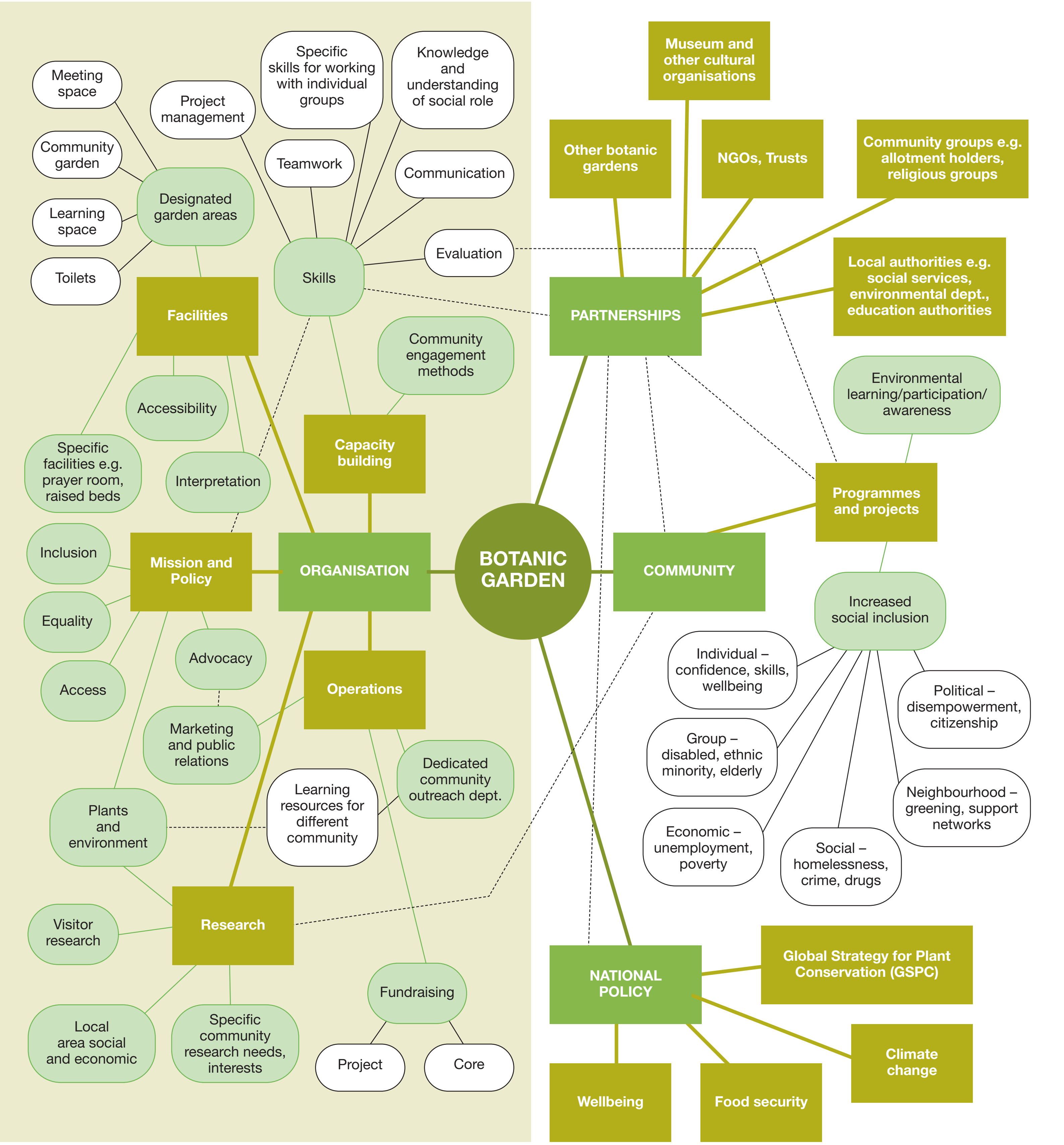
Participants on the Village Botanist training course discussing their herbarium sheets, part of the course assignments. (Image: Institute Trans-Disciplinary Health Sciences and Technology)

Thanks to the course, the trainees have found additional income by conducting surveys for the Forestry Department, becoming ecotourism guides, being involved in the People's Biodiversity Register (National system documenting biodiversity and traditional knowledge) and developing their own enterprises, e.g. selling plants grown in their own nurseries or medicines based on plants. Importantly, the course also supports women's equality by establishing women's self-help groups. Here, women learn how to improve the health of their family with the use of medicinal plants and are supported to establish community enterprises sustainably utilizing medicinal plants.

Since 2003, approximately 350 people have been trained, 75% of whom have found a job through attending this course. Although accurate data has not been collected regarding the income of the trainees, the project coordinator estimates that, on average, the annual income of the trainees who found jobs as a result of attending the course has been increased by 10%.

Growing the social role of botanic gardens is a long-term process that is influenced by many factors within and outside the organisation and at different levels, i.e. within the organisation, its partnerships with other organisations, in the community, and at policy level. Figure 7.4.1 provides an overview of all these factors and how they are interlinked. It provides a tool for holding discussions within a botanic garden and reflecting on which aspects are well developed and which need further development in order to grow a social role.

Figure 7.4.1 What it means to develop the social role of a botanic garden (Vergou and Willison, 2014a)



7.4.2 Making your Garden Accessible

KEY MESSAGE

A local 'Access Consultation Group' made up of people with different impairments can help you deliver excellent access for all. Collectively they will be aware of the problems and can offer simple recommendations for resolving them.

Growing a garden's social role requires ensuring that the garden is accessible and inclusive. Ensuring good access to all those with physical impairments is extremely important. Not only is this an essential part of any gardens corporate social responsibility (CSR) but it also supports all visitors to the gardens, in particular the elderly and parents or carers with young children. Access to interpretation in the garden is dealt with in the interpretation section (see Interpretation section on Catering for All Audiences) however the layout of your botanic garden and access strategy should also clearly address the physical access issues.

Providing physical access is not only about laying out paths suitable for wheelchairs, offering disabled car parking spaces or providing visual aids to help the partially sighted get around the garden. The cause of people's additional needs may not necessarily be visible, but should be considered when developing the garden. Making sure your catering offer includes gluten free or dairy free products, or at least clearly labelling your food products with ingredients, can help those with dietary problems decide what is safe to eat. Good positioning and a plentiful supply of seating and toilets can help those suffering from other debilitating illnesses such as cancer or heart conditions. Funds and existing building constraints may naturally influence what you are able to provide, however some issues can be dealt with cheaply and easily, e.g. the simple idea of providing a shelf in a toilet cubicle can enable those suffering from diabetes to self-inject with insulin in privacy.

An excellent way to ensure that you consider all the physical access issues in the botanic garden is to bring together, on a regular basis, a local Consultation Group made up of people with different needs. Collectively they will be aware of the problems and can often offer simple recommendations for resolving them, or put you in touch with other organisations that can help. They will additionally be excellent ambassadors for you, marketing your botanic garden to disability networks. Ensuring all your staff can recognise and support visitors with impairments will also be key to providing better access. For example, being able to recognise children with autism can stop staff from thinking a child is just being naughty and instead offer garden activity ideas that can mitigate unruly behaviour! Providing good physical access is therefore a win/win solution for all concerned.

For some top tips on museum access, that can be adapted for botanic gardens see Euan's Guide (2015) and for examples of access groups see APN (2015). Case study 7.4.3 shows how to create an accessible garden from the beginning of its development.

CASE STUDY 7.4.3

Therapeutic garden, Il Giardino SottoVico, near Florence, Italy

Stefano Battistini, Il Giardino SottoVico, Italy

Il Giardino Sottovico opened in 2009 after a group decided to build a therapeutic garden on an illegal waste disposal site. The garden seeks to tackle the social exclusion faced by people with physical disabilities or learning difficulties, whilst giving them exercise. This is accomplished by allowing them to work and mix with new groups of people. There is no dedicated project associated with this activity, rather it is integrated into the ethos of the organisation, it is part of the way the garden operates and it is aligned with its main concept: 'to involve children, families, the old and the less able-bodied in both the managing and developing of the place employing a range of skills' (garden staff). For 3 years, in partnership with the local authorities and social services, people with physical and learning disabilities have been involved in running and maintaining the garden. Four service users visit the garden each week and support its day-to-day functions i.e. germinating, collecting plants, cleaning, making labels, etc. Through this process, the garden staff have developed their skills in working with these audiences. This has not always been easy; it has taken time to learn to work well with each other. Some staff have different attitudes towards their work, for example some may prioritize the garden's appearance. One member of staff pointed out that for the garden to be therapeutic it needs to be so for the staff as well. For this reason, when conflict or different opinions emerge they try to bring them to the fore rather than 'sweeping them under the carpet'.

The garden is a non-profit organisation, with its core funding coming from donations from banks, companies and the chamber of commerce. In some cases the families of the disabled participants offer a contribution towards paying for the staff. Entrance is free and all areas are accessible to those with physical disabilities.

A crucial force behind the focus of the garden is the vision of its president whose 30 year old son has autism and was involved setting up the garden. During this process his communication skills improved and he became engaged in the tasks he was responsible for. As a consequence, the garden contacted the local authorities and social services and offered to work with people with disabilities. Nowadays, it is the local authorities and the social services that contact the garden and request spaces. Through questioning and working closely with the individuals, activities are matched to their needs. The disabilities specialist uses the *Globalità dei Linguaggi (GdL)*, a non-verbal communication method developed by Stefania Guerra Lisi.

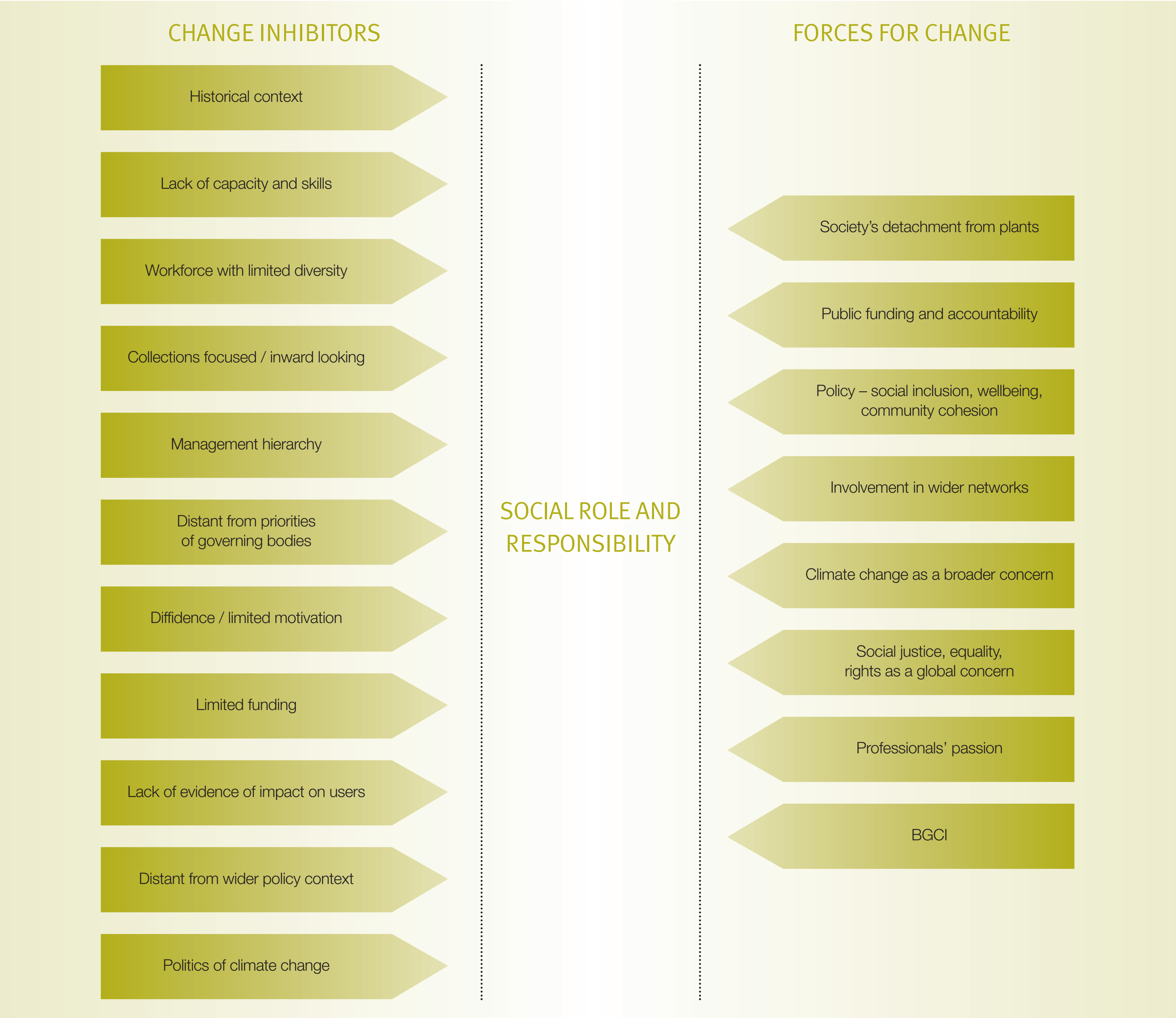
Above: As well as taking part in running the garden, Giardino SottoVico supports people with learning difficulties to take part in creative activities. (Image: Il Giardino SottoVico)

7.4.3 Key Socially Relevant Activities

Research by Dodd and Jones (2010) identified that botanic gardens already had experience in seven key areas related to their social role: broadening their audiences, enhancing relevance to communities by meeting the needs of communities, education, conducting research which has socio-economic impact locally and globally, contributing to public (and political) debates on the environment, modelling sustainable behavior and actively changing attitudes and behaviour. The research (ibid) pointed out that botanic gardens are already taking action, although there is more that could be done, and identified a number of factors that inhibit such change as well as a number of forces that can drive the change (Figure 7.4.2).

For example, small workforces, limited funding and the lack of diversity of the workforce have created hurdles for most gardens. Similarly, lack of motivation for a social purpose and a focus on collections have ensured that some gardens are content to remain as they are. On the other hand, botanic gardens may be motivated to consider their social role, especially if they are publicly funded, and they have to demonstrate their social value. Other forces include: policy developments that acknowledge the role of museums/heritage and cultural institutions in social inclusion, wellbeing and community cohesion and the involvement of botanic gardens in wider networks making them less isolated and more confident in addressing issues, like reaching a broader audience or communicating difficult issues such as climate change to their audiences.

Figure 7.4.2 Change inhibitors and forces for change towards botanic gardens having a greater social role and responsibility (Dodd and Jones, 2010)



7.4.4 'How to' Grow a Botanic Garden's Social Role

KEY MESSAGE

Participation takes time and it is important to be clear to your partners about the part they play in the process, your role and what level of participation is offered to the partners (Wilcox, 1994).

There is no single 'recipe' for growing a social role. A manual developed to support that process (Vergou and Willison, 2013b) suggests different actions that a botanic garden may undertake to become more socially relevant.

a) **Getting started:** Baseline research looking at the current and missing audiences, pressing social issues that face the local community and different audiences' needs may be a good starting point. Growing a social role is a long term process, hence many practitioners suggest starting small, e.g. by running a local community project, evaluating its impact and building slowly on the successes.

b) **Working in partnership:** Working with community groups and organisations that provide services for the community and have experience in addressing social issues and community engagement is a very effective way to develop your socially relevant work.

c) **Community engagement:** Community engagement is the process of working collaboratively with and through groups of people to address issues affecting their well-being (Fawcett et al., 1995). Growing a social role requires working for, but most importantly working with, community groups and moving away from didactic approaches. There are different ways and levels that communities can get involved in a project. Wilcox (1994) suggests a framework of participation (Figure 7.4.3) based on Arnstein's (1967) ladder of participation. Wilcox, identified different levels of community engagement and explained that different levels are appropriate for different situations and interests.

Levels of community engagement (based on Wilcox, 1994)

- Providing information (telling people what will happen);
- Consultation (offering options and receiving feedback);
- Deciding together (opportunities for ideas/joint decisions);
- Acting together (taking joint decisions forward in partnership);
- Supporting independent community interests (providing support to organisations to develop their agenda).

Case study 7.4.4 from Brooklyn Botanic Garden in the United States showcases how its Garden Bridge initiative, with its five sub-programmes, offers socially relevant activities to New York communities. The programme uses different levels of community engagement depending on the purposes of each activity ranging from providing information to supporting community interests. The case study illustrates that community engagement levels have been chosen not on the basis that the higher the level the better but based on whether they are fit for purpose.

d) **Incorporating environmental issues into a social inclusion project:** There are many environmental issues that are very relevant and can spark the interest of communities. By getting to know the community participants, their level of understanding, skills and interest you can ensure that the environmental issues are relevant to the participants' lives and can effectively engage them.

e) **Skills and qualities:** Enhancing botanic gardens' relevance to communities is an 'intensive, long term and difficult task. It requires people with specific skill sets and experience who are not always found on the staff of botanic gardens' (Dodd and Jones, 2010). These skills and qualities vary from interpersonal/communication (active listening, flexibility, respect) to more practical types of skills (project management, evaluation, teaching skills) essential for understanding the communities, meeting their needs and engaging with them in a meaningful way. These skills can be added to a botanic gardens staff team by employing new staff with experience, for example in community engagement, or by providing appropriate training to current staff. Some of the required skills may also be developed by doing socially relevant work and learning from experience.

f) **Evaluation:** Dodd and Jones (2010) have noted that one of the barriers to botanic gardens growing their social role is the lack of evidence of the impact of their work, hence, conducting evaluation of socially relevant activities should be built into project management processes. The findings of the evaluation can be used internally by the staff to drive improvement in future work (including improving project management) as well as externally to demonstrate achievements, e.g. for fundraising purposes. More information regarding different types and methods of evaluation and resources can be found in Sections 7.2.7 and 7.3.9.

g) **Sustainability:** Starting small, e.g. by running a community project, may be a pragmatic and realistic approach to growing an organisation's social role, however the process should not stop with a one-off project. To ensure the sustainability of this new role, it is important to disseminate information about socially relevant activities within the organisation, gain the support of senior management, trustees and other staff members, create new positions with distinct responsibilities for community-based work and look at the organisation's policies and operations. It is equally crucial to raise the profile of the botanic garden as an organisation that can address social issues with stakeholders outside the organisation, funders and the general public, using a variety of methods.

Figure 7.4.3 Framework of participation (Wilcox, 1994)

CASE STUDY 7.4.4

Green Bridge, Brooklyn Botanic Garden, United States

Nina Browne, Brooklyn Botanic Garden, New York

Brooklyn Botanic Garden's (BBG) Green Bridge is an integrated series of projects, focussed on urban gardening. The aim is to mobilize the local community to interact with each other and the garden and beautify their surroundings for the benefit of the environment and the individuals' health and wellbeing. The projects complement each other, involve many of the same people and work on various levels of engagement. The projects are: The Greenest Block in Brooklyn Contest, Making Brooklyn Bloom, Street Tree Stewardship initiative, Community Garden Alliance and the Brooklyn Urban Garden Training Programme (BUG).

Making Brooklyn Bloom is a free, annual, urban gardening symposium. The event entails a series of exhibitions, workshops, films and networking lunches, attended by as many as 1000 people each time. It can be seen to work on two distinct engagement levels. It can be seen as 'providing information', but, by providing an arena for interested parties to network, the symposium also supports their independent interests, thus satisfying a much deeper level of engagement. The symposium also works as a launch pad to engage people in the Greenest Block in Brooklyn Contest which sees around 200 entrants a year.

During the contest, as well as providing entrants with support through fact-sheets, BBG offer urban gardening clinics to 10 groups on a first come, first served basis. The content of these clinics is based on the results of a survey of the specific group, therefore representing the 'consultation' and 'deciding together' levels of engagement, as outlined by Wilcox. These clinics include a 'street tree 101', which also forms the basis of The Street Tree Stewardship initiative.

The Street Tree Stewardship, which includes a series of workshops on street tree care, has joined forces with the Million Trees NYC project (MTNYC) – a city-wide sustainability initiative focussing on environmental impact and green infrastructure. MTNYC aimed to plant one million trees by the end of 2015. To support the continued care for them, BBG, through workshops, engages people with the importance of the trees and how to care for them. The importance of street trees is discussed with the local people and their opinions gathered and considered. Hence, although the aim of the project is to provide information and gain support, the initiative does consider people's opinions.

Consultation is also a significant element of the Green Bridge Community Garden Alliance. To be part of this, community gardens from across Brooklyn register by completing a biannual survey about topics related to community gardening that they are interested in. The results are used to design workshops. So the information provided to the participants not only caters for their needs, but also supports their interests and enables them to develop their community gardens independently. These projects are supported by graduates of the BUG programme, which trains young people to deliver urban gardening training. As well as class time, the course includes service to community greening projects that have requested help. The trainees visit them and help the group to develop in the direction they wish to, in a way that can be sustained by the group themselves. This way of working is at the heart of 'asset based community development'. This model, employed by BBG, ensures that training offered is customized to the context. Each BUG trainee starts by finding out what a community already has to offer in order to work out how they can develop in the direction they choose. BUG graduates offer training to groups on request, as well as contributing to the other projects in Green Bridge by delivering workshops and clinics, depending on their individual skills and tastes. In this way the BUG programme not only delivers information to the trainees and the community but supports the independent and personalized development of the BUG trainees and the community groups they interact with. This project therefore manages to satisfy all the levels of engagement outlined by Wilcox (1994).

Upcycle garden created by children from East 25th Street – Greenest Block in Brooklyn 2014. (Image: Brooklyn Botanic Garden)

In 'Museums Change Lives' (2013), the Museum Association points out ten actions that will help museums improve their social impact; these could similarly be applied to botanic gardens:

- Make a clear commitment to improve the museum's social impact. Regard it as core business. Have long-term strategic goals for the impact.
- Reflect on current impacts, listen to users and non-users, involve all staff and supporters in thinking about whose needs you could serve better.
- Research what other museums are doing to have beneficial impact.
- Seek out and connect with suitable partners, e.g. local charities, social enterprises or public sector organisations.
- Devise practical proposals, working with your partners as equals. Be clear about your shared objectives.
- Allocate resources and you may need to work with your partners to fundraise.
- Review your practices and procedures so you can meet the needs of your partners and the people you aim to reach.

- Reflect on your work. Learn from and with partners and participants. Consider the benefits of evaluating and measuring your impacts.
- Encourage wider participation in all aspects of your work: bring more voices into interpretation and devolve power. Encourage people to contribute to decision making about what to do, what to display and what issues to address.
- Strive for long-term, sustained change based on lasting relationships with partners and long-term engagement with participants, maintained beyond time-limited work and one-off projects (Museums Association, 2013).

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7.5 TOURISM AND RECREATION

Richard Benfield, Central Connecticut State University

7.5.0 Definition

Tourism: 'Tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/ professional purposes. These people are called visitors (which may be either tourists or excursionists; residents or non-residents) and tourism has to do with their activities, some of which involve tourism expenditure.' World Tourism Organization (2010)

7.5.1 Introduction

KEY MESSAGE

An estimated 500 million people visit botanic gardens every year – presenting an invaluable potential to raise the profile plant conservation, and offering a vital opportunity for recreation, relaxation and contemplation.

Tourism is probably the world's fourth largest industry after fuels, chemicals and food (Lew et al., 2014) contributing 9% of the global GNP, one in 11 jobs worldwide and accounting for USD 1.4 trillion or 6% of all the world's exports. In 2013 international tourism arrivals reached 1,087 million after surpassing the billion mark in 2012. With an estimated 7.15 billion people living on the Earth, this means that over 15% of the global population is travelling internationally for tourism purposes every year. This figure does not take into account domestic tourism which in some countries (e.g. the United States) may be as much as 95% of all tourism travel. Furthermore these percentages are expected to rise as leisure time increases, emerging economies steadily contribute to global tourism numbers and as per capita incomes grow. Tourism will be a major economic force in the twenty first century.

Botanic gardens worldwide are a major, if often still unappreciated, destination for tourists. Based on extrapolated records from BGCI's GardenSearch database, it is estimated that some 500 million people visit botanic gardens every year. Individual botanic gardens also post some impressive numbers when compared with other tourist attractions worldwide. Singapore Botanic Gardens regularly exceeds four million visitors, Beijing Botanical Garden over 2 million and all of the botanic gardens in Australia's major cities exceed 6 million visitors yearly. When aggregated together, visitation numbers of the more than 800 botanic gardens in the United States amount to over 80 million in one year – more than those of Disneyland and Disneyworld combined and more than those of Orlando or Las Vegas, America's two most popular tourist destinations. Thus, botanic gardens are now significant tourist destinations. Their impressive visitor numbers make the tourist an integral part of botanic gardens' mission fulfilment and their economic viability.

7.5.2 Assessing Tourist Demographics

KEY MESSAGE

Botanic gardens cannot know to whom they are attractive without understanding their current and potential future visitor.

In 1954, the marketing leader Peter Drucker said '*If we want to know what a business is we have to start with its purpose. … There is only one valid definition of business purpose: to create a customer.*' It is the customer who determines what a business is. For it is the customer, and he alone, who through being willing to pay for a good or service, converts economic resources into wealth, things into goods. What a business thinks it produces is not of the first importance – especially not to the future of the business and to its success. What the customer thinks he or she is buying, what he or she considers 'values', is decisive. Because it is its purpose to create a customer, any business enterprise has two – and only these two – basic functions: marketing and innovation (Drucker, 1954).

Botanic gardens fulfil a wide range of functions and roles including research, conservation, education, pleasure provision and/or entertainment, thus creating a customer as indeed the 'one valid' definition of purpose. Botanic gardens have historically been the locus of public events, usually horticultural in nature, that attract customers to the venue. In recent years, these programmes have become more varied – art and concerts in the garden, displays, exhibits and museiculture that have what has been called a 'wow' factor. In the future, it might be expected that there will be growing innovation which will provide the motivation for greater visitation. However, this will not materialize without making the visitor aware of either of the traditional or innovative programmes that botanic gardens are offering, and marketing to visitors will become very important. Furthermore, botanic gardens cannot know to whom they are attractive without understanding their current and potential visitor.

- **Approaches to knowing your visitor**

In attempting to assess its tourism or visitor potential, the botanic garden can address the following research areas:

1. Membership;
2. Source of knowledge of the garden including media used;
3. Media habits in general (reading, watching, technological use of media);
4. What was the specific motivation or reason a visitor came to the botanic garden today – if there was one;
5. Satisfaction with the botanic garden and its constituent parts (displays, gift store, café);
6. Age of visitors;
7. Income;
8. Educational level;
9. Number in party and relationship of visitors;
10. Origin of the visitor (postal or zip code).

While these data generally are readily collected, it is becoming increasingly apparent that the botanic garden visitor is a complex individual that possesses specific opinions, values and lifestyle traits and habits. Furthermore, these personality traits are expressed in the need for relationships with other individuals and products that cater to those needs and wants. This realization has been addressed by those botanic gardens developing and promoting a particular institutional brand (Case study 7.5.1) and appears to have clear links with other botanic gardens enjoying success through new social media (Section 7.5.3). These types of data that explore the visitor psyche have been termed 'psychographics' and yet there are few botanic garden studies that probe this area of visitation. One landmark study of botanic garden tourist psychographics found that 69% of visitors had '*always been interested in gardens*' (Connell, 2004). Of the 30% who had not always been interested, ages 25-40, with a mean of 32.97, were the years in which they generally became interested, probably as a result of home ownership. Connell indicates only 10% became interested in gardening in their teen years. MINTEL Ltd. (2005) states however, that gardening interest reaches its apogee upon retirement and botanic garden visitation probably follows a similar pattern. Significantly, Connell notes that interest in botanic gardens seems to be cyclical, holding a greater appeal for those whose formative years were pre-World War Two, but has been growing steadily now amongst younger age groups. Connell goes on to indicate that motivations for visiting botanic gardens are often a mixture of reasons, and probably more complex, best summed up as '*to enjoy the peace and quiet along with the natural environment*'.

CASE STUDY 7.5.1

Atlanta Botanical Garden – 'Ten Years of Success'

Richard Benfield, New Britain, Connecticut

The Atlanta Botanical Garden (ABG), Georgia, United States, is one of a number of American botanic gardens that arose in the late sixties and seventies (Chicago, Memphis, Denver) as part of urban development to make cities and especially downtown areas more liveable. Thus, a botanic garden was first proposed for Atlanta in 1973. Like most botanic gardens, the collections and infrastructure were slow in developing and perhaps the first 'full' year of the development in 1983 saw 50,000 visitors come to the site.

The latter part of the twentieth century saw the construction of a conservatory (opened 1989), the development of different show gardens, the initiation of education, horticultural and science programmes (in 1995 ABG became a founding member of the Georgia Plant Conservation Alliance), as well as the early stages of a dedicated tourism function with the hosting of concerts, Venus Fly Trap exhibits and the attraction of a Titan arum bloom that generated significant publicity and visitation for the fledgling institution.

Thus the stage was set for what has been dubbed the '*Ten Years of Success'* that has driven visitation of 110,000 in 2002 to over 525,000 in 2014. It appears that there were a number of sequential steps and paradigm shifts that created the success the botanic garden enjoys today:

– In 2002, the botanic garden was clearly at a level that begged the question whether it should remain a stable, static, unassuming minor attraction in the City of Atlanta or go to another level of development. This question was posed and answered by the securing for 2004 of the most prestigious exhibit in the institution's history: 'Chihuly in the Garden'. An exhibition of 50 original glass sculptures by internationally renowned glass artist Dale Chihuly that were on display from May to October, with an extended run through December. The nine-month blockbuster exhibition brought the botanic garden to the forefront of cultural tourism in the southeast of the United States. It drew some 350,000 visitors to the botanic garden and created an economic impact of USD 50 million or more.

– Rather than allowing Chihuly to define future visitation, the botanic garden followed Chihuly with an 'Orchid Days' and a 'Locomotion in the Garden' show (2005).

→→→

Tree canopy walk. (Image: Atlanta Botanical Garden)

CASE STUDY 7.5.1 (CONT.)

– From 2005 to 2009 the botanic garden featured different but equally impactful shows ('Bugs and Killer Plants', 'Sculpture in Motion', Henry Moore sculptures) to maintain the momentum that had been created.

– In 2011, two major initiatives were undertaken to develop reasons for visitation in the shoulder months of spring and winter. Accordingly, in spring 2011 'Atlanta Blooms' was introduced as a display of bulbs which in its first year attracted 60,215 visitors at a time when previously visitation had been poor. The following winter 2011-12, 'Holiday Lights', with over 1 million LED bulbs, created a festival of lights that attracted 165,000 visitors in 2014.

To suggest that for the botanic garden to go from 50,000 visitors in 1983 to 500,000 in thirty years, was solely a result of the provision of blockbuster attractions would be misleading. Behind the visitation was a philosophy, based on a mission statement, and delivered by marketing and sales, that was specifically directed at the long-term responsibility and viability of the botanic garden: '*The mission of the Atlanta Botanical Garden as a non-profit is to develop and maintain plant collections for display, education, research, conservation and enjoyment*.' To create that enjoyment, the botanic garden developed its own distinctive brand with the following marketing actions:

- Convert interest into action and inject urgency into messaging;
- Market the botanic garden as lifestyle brand;
- Change 'not enough time' perception to 'can't afford emotionally not to go';
- Inform and motivate prospects;
- Market continuously, as this is now a botanic garden for all seasons;
- Encourage viral marketing;
- Market (family) benefits aggressively, specifically to adults 45-59, women with children 35-45 and young adults 25-34;
- Leverage 'something's always in bloom' to smooth seasonal skews;
- Ask for the 'membership order' (i.e. what people want);
- Seed environmental messaging as part of the experience, but don't lead with it to drive visitation.

- **Methods to assess tourist demographics**

In assessing tourist/visitor demographics, patterns of movement, influencers, motivations and impacts, there are a number of basic but effective techniques available:

– A visitor survey conducted amongst the population at large – the potential market (by phone, mail or in-person – the last being the most effective) probing awareness of the garden;
– A visitor survey administered either at the gate upon entry/exit probing the types of questions suggested above;
– Focus groups, in which a selected group of respondents are asked questions or proffer opinions on a botanic garden's status in the marketplace;
– The 'Delphi Technique' in which the botanic garden invites recognised experts in the field of garden tourism to assess patterns, trends and postulate future influences on the botanic garden's internal and external environment;
– Economic impact studies probing the spending habits of both the botanic garden and the visitor for use in assessing economic importance of the institution to a municipality, region or country;
– Motivation studies, probing the psychographics of the visitor in which opinions and preferences are often explored by means of a graduated Likert-type scale.

The statistical outcome of these studies can take a number of forms:

– Simple frequency (percentage analysis);
– Correlation tables in which correlations between variables are charted;
– Simple mean (average), median (50% division of all cases) and mode (highest category) are stated.

These analyses are easily run, and the results obtained by use of basic statistical programmes such as IBM SPSS or SAS. They may also be used in advanced data analyses which might include:

– Simple regression (comparing one dependant variable with an independent variable for essentially prediction purposes);
– Multiple regression using a number of independent variables;
– Cluster analysis;
– Factor analysis (using multiple variables to derive underlying factors);
– Zip code or postal code mapping (the use of GIS programs to map zip/post code locations); GIS software is required and is usually only available from GIS firms or university geography departments;
– Econometric analysis of economic information to give empirical findings of these data.

- **Visitor segmentation**

Most botanic gardens appear to segment their market into:

Primary markets

1. An elderly demographic (often loosely referred to as the Baby Boomers);
2. Often or predominantly female;
3. Higher (disposable) incomes and education;
4. All age groups with an interest in gardens and gardening;
5. Usually house owners;
6. Educational groups; K-12/ kindergarten to sixth-form;
7. Tourists, both domestic and international, and day visitors.

Secondary or emerging markets

1. Millennials (those born between 1980 and 2005);
2. Propensity to visit botanic gardens as sedentary leisure-time outdoor activity;
3. New house owners usually 25 years of age and older;
4. Generation X born between 1964 and 1980. A smaller demographic, often with a garden and in need of upgrading landscape.

Historically, the application of the research showing a botanic garden's major visitor markets has been applied in the form of paid and unpaid advertising (news and press releases). However, paid advertising has only been the prerogative of larger, wealthier botanic gardens. A significant number of smaller, often not-for-profit botanic gardens or institutions governed by a Trust (Chapter 2, Section 2.2.2), are unable to dedicate large sums to paid advertising. When this is aimed at, placement in gardening and lifestyle magazines seem to provide the best return on investment. This choice is invariably borne out by consumer research. In the case of smaller botanic gardens, local community advertising may be used but more often the institution uses a steady diet of press and news releases to impart their information. Furthermore a key presence in advertising campaigns, often coordinated by the local, regional or national tourist offices, has been a major source of awareness and marketing. This has been rapidly changing with the advent and undoubted success of social media.

7.5.3 Social Media

KEY MESSAGE

Social media, without a doubt, have become botanic gardens' major public outreach conduit in the twenty first century, both as an online information exchange tool and stimulus to visit on-site.

The introduction and explosion of social media applications has also significantly changed marketing approaches by botanic gardens to tourism development. The use of social media in general and certainly for botanic gardens is now vital to enhance their visitation – there is so much 'noise' out there that social media allow individual institutions to get noticed instantly.

Firstly, social media level the playing field – if a botanic garden has great content, it can compete with the likes of top brands to rise above the marketing noise. For instance, the use of social media has been proven successful for botanic gardens participating in USA TODAY's yearly contests which ask the public to vote for their favourite botanic gardens. Those institutions making extensive use of social media are among those most highly voted for.

Secondly, social media are the first means available to botanic gardens to connect to hundreds of thousands of people in real time unlike standard print or electronic advertising. Social media have the potential to be a major force in botanic garden visitation in the twenty first century, given that close, immediate personal links are desired by all people, and furthermore that personal values, attitudes and lifestyles define visitors and their motivation to visit botanic gardens.

Thirdly, social media lend themselves particularly well to botanic garden tourism and vice versa:

a) They do not require a huge investment, and numerous botanic gardens do not have significant funding for marketing.
b) Botanic gardens are visual and as many social media platforms, including Tumblr and Instagram, two of the fastest growing social platforms with highest rates of engagement, are predominately visual.
c) Social media are about telling a story, through the use of great content, and botanic gardens are replete with stories and anyone can use a smartphone to take a photo or video and publish it immediately.
d) With social media, botanic gardens can 'brand listen' using free social media tools like Hootsuite[1], and follow hashtags[2] to 'hear' what the public is saying about their botanic garden. Botanic gardens are even using social media to decide on which images to use in their calendars that will be sold in the gift shops.

The application and efficacy of social media in botanic gardens has yet to be fully defined and appreciated. It is clear that botanic gardens make use of various types of social media channels for different purposes.

Different types of social media lend themselves well to visual content in a way that is difficult to achieve through traditional promotional tools. Another attraction of social media is the immediacy of the information going out to followers; real-time updates on conditions at the botanic garden or events happening can be made available instantly. Further reasons to employ social media include the ease of use, cost effectiveness, ability to schedule and/or archival value.

Social media have the ability to share content with other tourist and business organizations in a collaborative fashion for post exposure to a wider potential market. The image or post may tell little about the specific botanic garden. However, as Case study 7.5.2 points out, because visitors on average stay for less than two hours on site, they can find the details they are looking for about the region where the botanic garden is located, whilst they may also gain the sort of ancillary but pertinent information about the botanic garden of interest. Social media are very much a reciprocal business – formally called 'building social capital' in the social media world. However, while many social media users gauge success on the number of likes or followers, it should be noted that this does not equate to return on investment.

Not only can botanic gardens reply to people's comments, they can do so at any time and they are notified, allowing a conversation to begin. Others might join in too. People enjoy personalised responses, especially from brands (see also Case study 7.5.1 regarding the importance of branding botanic gardens), and it makes them much more likely to have that brand at the top of mind when considering a botanic garden as a tourism and recreation option.

[1] HootSuite is a social media management tool that allows users to schedule and post updates to any pages or profiles for Facebook, Twitter, Instagram, etc. – the HootSuite dashboard. Upon signing up, a dashboard with tabs organizing all the social profiles connected to HootSuite are being provided. It also allows users to follow and respond to conversations about the botanic garden across social media platforms.

[2] A hashtag is a word or an unspaced phrase prefixed with the hash character (or number sign) – # – to form a label. It is a type of metadata tag. Words or phrases in messages on microblogging and social networking services such as Facebook, Google+, Instagram, Twitter, etc. may be tagged by entering # before them, either as they appear in a sentence, e.g. 'New artists announced for #SXSW2014 Music Festival' or appended to it. The term hashtag can also refer to the hash symbol itself when used in the context of a hashtag. A hashtag allows grouping of similarly tagged messages, and also allows an electronic search to return all messages that contain it.

CASE STUDY 7.5.2

Tourism at Royal Botanic Garden Edinburgh, Scotland

Richard Benfield, New Britain, Connecticut

The Royal Botanic Garden Edinburgh (RBGE) has a long and distinguished history. Established in 1670 as a 'Garden of Signatures' for medicinal purposes, in the following centuries it would become a repository for some of the most important plants discovered by plant hunters for commerce, research and exhibition. Additional sites were acquired and run by the RBGE starting in 1929 such that today there are three regional gardens administered by RBGE at Benmore, Logan and Dawyk. In 1858, the tallest conservatory in Britain was opened for palm display and today all eleven glass houses are linked as a complete visitor package. In 2013, 679,756 visitors came to RBGE making it one of the top three tourist destinations in Edinburgh. Of those 679,000 visitors, approximately 80% are Scottish residents (66% Edinburgh residents, 33% outside Greater Edinburgh), 10% English and 10% international visitors. The desire was to significantly increase the latter two market segments.

At the basis of a new marketing strategy was the need to know the customer. The Insight Department of VisitScotland, Scotland's National Tourist Organization, researched the overseas market to gauge the propensity of holiday visitors coming to the gardens. Botanic garden visiting of all overseas residents to the United Kingdom is third in popularity, 56%, after 'Castles' and 'Famous monuments'.

Much like RBGE, 44% of all Scottish botanic garden visitors are locals, 26% Scottish, 25% other United Kingdom (mostly England) and 6% overseas. For United Kingdom visitors in particular over 40% have never been to Scotland and get their information on Scotland from online travel sites (53%), guidebooks and brochures (43%), the national tourism website (42%) and other travel websites and blogs (34%). Thus it appears that the English tourist is heavily influenced by computer-based information. This is borne out by data that finds 43% of English visitors spend over 20 hours a week on the internet and that 69% are active on Facebook, 29% Twitter and 25% Instagram. At least 70% go on Facebook daily and 50% to Twitter. Finally, of the English botanic garden visitors, they are predominantly male (59%), usually without children (66%) and highly educated. Perhaps most surprisingly, of those English visitors, aged 25-34, 37% say the botanic garden is the main purpose of their visit (as opposed to 17% of all tourists), suggesting that garden visitation is not just for elderly females. Similarly for those aged 55 and older, 22% say visiting a botanic garden is the main purpose of their trip, again higher than the percentage for total British tourism.

From an understanding of the demographic characteristics of the visitor, the botanic garden can now segment the market they wish to address. VisitScotland had undertaken a segmentation study of the English market: *'Traditional tools often define consumers purely by demographic or life stage variables that assumes everyone in one age group acts in a similar way. Segmentation offers the chance to research … the wants and needs of consumers as well as their specific behaviours, alongside demographic and life stage information … VisitScotland's segmentation model is based on a behavioural approach based on … motivations, and behaviours, attitudes toward Scotland … and their use of media channels'.*

From this research, five tourist segments presented themselves and the RBGE has seized on two, 'Engaged Sightseers' and 'Natural Advocates', to address in their marketing. The study indicates their level and type of social media participation (generally 'followers' rather than innovators), the major print media they use (usually gardening magazines) and the challenges and obstacles to greater garden visitation (potentially due to issues of signage, distance or information dissemination). This research of potential visitors can be compared with survey studies undertaken in and by the botanic garden to compare and contrast its current visitation. In RBGE, visitors are predominantly female (60%), over 50% were over 45, and 10% identified themselves as being disabled. Again, while the national data showed 42% of English visitors had never been to Scotland, only 20% of RBGE visitors were first-time visitors suggesting a new potential market of first-time visitors to Scotland and thus the botanic garden. Finally, tourists spend on average some two hours in the botanic garden, and thus by extension after that leave and visit another location. The fact that RBGE is a founding member of a new national collaborative group called 'Discover Scottish Gardens' set up in 2015 to raise the profile of Scotland's gardens and its outstanding horticultural offering suggests a wise development in Scottish garden marketing with around 300 garden institutions in Scotland being open to the public; as members of a new network, they will also create a collective voice for botanic garden tourism in Scotland.

Logan Botanic Garden, United Kingdom. (Image: BGCI)

Selected social media platforms

Social media have been experiencing an unprecedented speed of development in recent years. While the types selected below were among the most commonly used in 2016, the list is by no means comprehensive.

- **Facebook**

Facebook is one of the most popular social media platforms, with 1.86 billion monthly active users in 2016. It is widely used across most age demographics and cultures, especially in the major tourism markets of Canada, United States, United Kingdom, Japan and Australia. It allows for paid targeting of users – geographically, demographically and by interest. However, it is a 'closed garden' – a term used on the internet to label content that is not universally accessible or searchable. For members of the public who do not have a Facebook account, not all content is available to them.

Most botanic gardens use Facebook to broadcast events, photos and videos – mostly to great acclaim. In turn, they obtain valuable feedback in terms of likes, shares and comments from around the world in real time. Similarly, the botanic garden can engage followers in real time and in the follower's own language as there is a translation function embedded. An institution can test ideas and photos for traditional marketing on Facebook to get feedback and ask those most interested in the garden experience what they think about ideas or plans that are being considered. This can be a very valuable feedback mechanism. However, the average Facebook post has a lifespan of three hours before the internet forgets about it – it is still there, but few will be engaging with it.

As an example of the power of Facebook, The Butchart Gardens in Victoria, British Columbia, Canada, created a post in 2013 that went viral unexpectedly. Initially, people and then radio and TV stations were asking for photos of a rare snowfall that had fallen on December 5, 2013. The garden subsequently posted a photo of snow in the garden. The reach of this single photo was 75,000 people, with ~7,000 likes, comments and shares and 6,500 actual post clicks. To give perspective, the largest local paper in Victoria has a circulation of 58,000. A myriad of conversations came out of this single post, keeping the Gardens top of mind for the day and the weeks after. It is apparent that in rare instances, a fledgling brand, can rise up above the 'noise and chatter' on social media. The Butchart Gardens make extensive use of hashtags, both to index posts and to get noticed by people outside their social media channels. They use three 'branded' tags: #butchartgardens, #butchartchristmas and #butcharttraffic (to give real-time traffic updates to people waiting in line for special events and on high volume days) among many others. This approach gets like-minded individuals together into a conversation, so, in the same vein in the gardening world, #gardens, #gardening and #gardenchat are very popular hashtags.

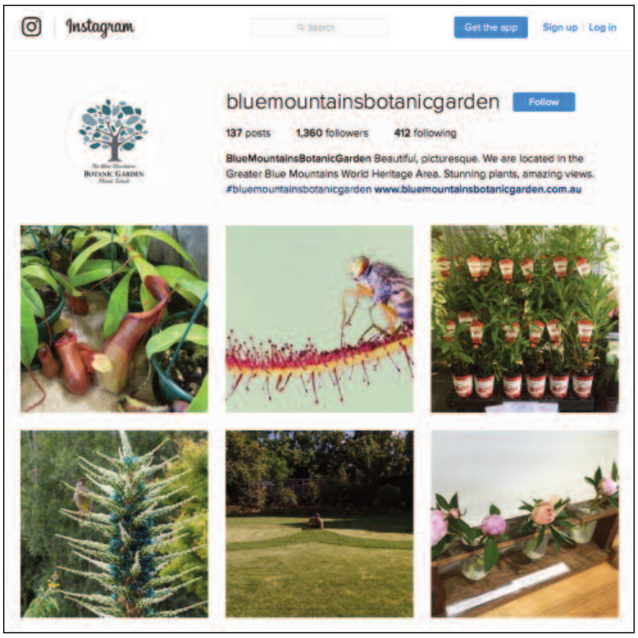
- **Twitter**

There are over 317 million monthly active Twitter users. Botanic gardens make use of Twitter mainly for broadcasting information regarding an event, a change in hours, to engage followers. Twitter messages, or tweets, have a limit of 140 characters, encouraging concise messaging.

The average Tweet has a lifespan of a few minutes unless it gets retweeted a lot or unless it is pinned (only one allowed) to the top of the page.

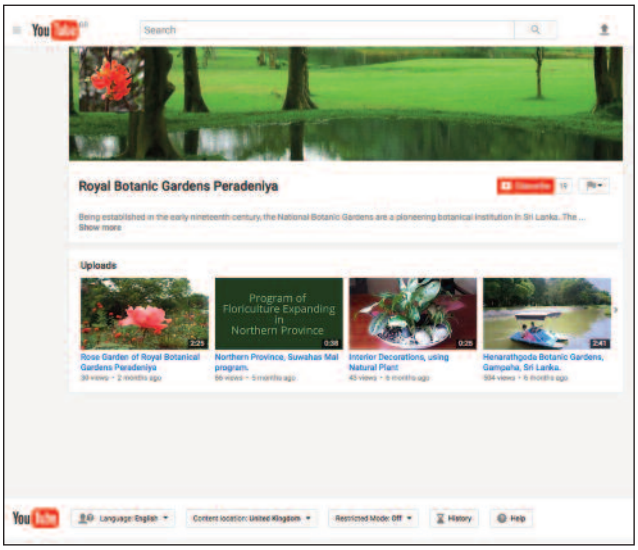
- **Instagram**

Instagram is one of the fastest growing social media platforms. By its very nature as a photo-sharing app, this highly visual social media platform is also of great relevance to botanic gardens. The majority of the users of Instagram are young people. The use of hashtags # with keywords is also an important element of this platform. The average post has a lifespan of several hours, mostly because of hashtag searches which are popular on Instagram.



- **YouTube**

While YouTube has not been used extensively by botanic gardens to date, the scope for use is tremendous, as botanic gardens and their activities are uniquely suited to video. Most videos are shot by traditional media and then can be uploaded onto a botanic garden's YouTube channel and then shared through other social networks as a conversation starter. Demographics widely vary however clearly they are very subject dependent.



- **Pinterest**

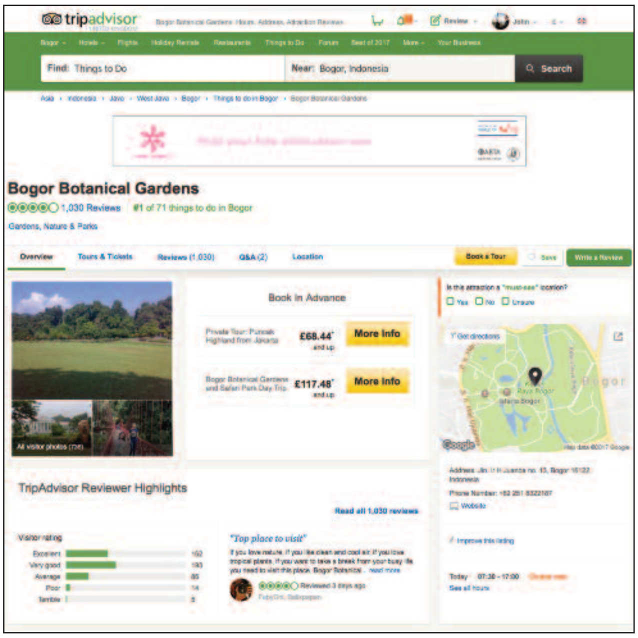
Pinterest is used to highlight important branded accounts or regionally significant accounts. As with Instagram, Pinterest is highly visual and offers a great outreach platform for botanic gardens. They can use it to drive web traffic while highlighting blooms, nature, weddings, travel and more, and can also feature other botanic gardens and sites.

- **Blogs**

Blogs offer long-form text posts but can also incorporate photos and videos. The lifespan of blogs is much longer than the social media mentioned above, and allows for archiving of content. Blogs are a useful channel for botanic gardens to provide updates and news or to go into more detail about their work.

- **TripAdvisor**

Not a social media as such, TripAdvisor is a consumer review site that is integral to the marketing of many botanic gardens. People may often view the site to study previous visitor reviews and to ask questions before deciding on a potential visit. Regular reviews from visitors can encourage footfall to the botanic garden. In order to capitalize on this, botanic gardens should interact with Tripadvisor users.



7.5.4 Conclusion

Tourism to botanic gardens for many years was rather unappreciated and unnoticed. This began to change around the turn of the century as botanic gardens became more relevant probably owing to the desire of the public for conservation, sustainability and a realisation of the socio-cultural value of gardens and gardening. More recently the academic world, governments and the tourism industry have begun to investigate botanic gardens visiting and gardening as actual and potential tourist attractions. It might be concluded that botanic garden visitation is on the threshold of becoming a major component of twenty first century tourism, and that much of this growth may be enabled by the linkage of social media and botanic gardens. Decisions have to be made on how botanic gardens might go to the next level of development to fully and sustainably capitalise on their potential as tourist destinations.

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D Botanic Gardens as Models of Environmental Sustainability

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Part D: Botanic Gardens as Models of Environmental Sustainability

Contents

CHAPTER 8: MANAGING ENVIRONMENTAL SUSTAINABILITY IN TIMES OF RAPID GLOBAL CHANGE

Chapter 8:
Managing Environmental Sustainability in Times of Rapid Global Change

Mark Richardson, Botanical Consultant; Kevin Frediani, The National Trust for Scotland; Keith Manger, Royal Botanic Gardens Kew; Richard Piacentini, Phipps Conservatory and Botanical Gardens; Paul Smith, Botanic Gardens Conservation International

8.0 DEFINITION

Environmental sustainability: Used often synonymously with *sustainable development* which is defined as meeting *'the needs of the present without compromising the ability of future generations to meet their own needs.'* World Commission on Environment and Development (1987).

8.1 INTRODUCTION

Climate change, loss of habitats and biodiversity are a symptom of humanity's unsustainable use of natural resources, particularly in the developed parts of the world. Conventional ways of building and operating will not solve this problem. We need a major paradigm shift in the way we live and operate to reduce the risk of serious climate change and environmental degradation.

Botanic gardens have a strong role to play in promoting environmental sustainability through their own management practices and by engaging and inspiring their visitors, staff and funders to understand the critical role that plants play in supporting life on our planet. This is especially important in times of rapid global change.

KEY MESSAGE

Environmental sustainability has economic, moral, legal and many more benefits for botanic gardens.

8.2 HOW CAN BOTANIC GARDENS DELIVER ENVIRONMENTAL SUSTAINABILITY?

There are many considerations when looking at delivering environmental sustainability in all its forms. An Environmental Management System (EMS) is a framework that can help a botanic garden to achieve its environmental goals through consistent control of its operations. The assumption is that this increased control will improve the environmental performance of the organisation. The EMS itself does not dictate a level of environmental performance that must be achieved – each organisation's EMS is tailored to its business and goals. However, the EMS pulls together documents such as Environmental Policy, Legal Register, Impacts and Aspects Register and Objectives into a logical system.

8.3 ENVIRONMENTAL STANDARDS AND SCHEMES

KEY MESSAGE

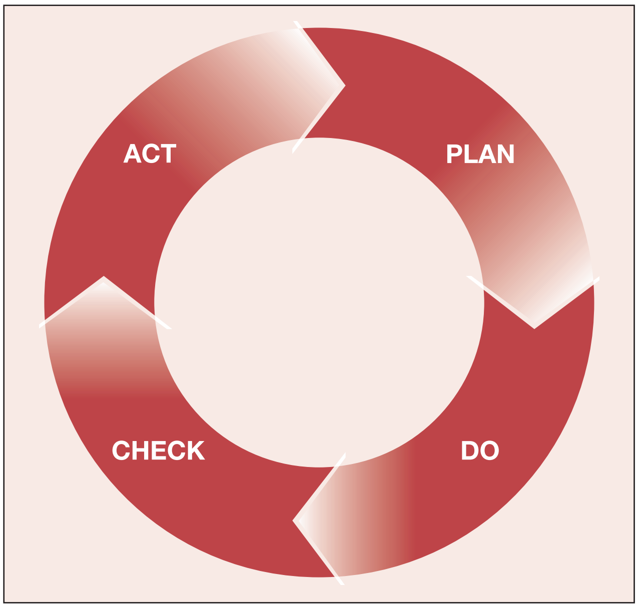
There is a wide range of environmental standards and schemes that botanic gardens can choose from.

ISO 14001 Environmental Management Standard – ISO 14001 is perhaps the best known environmental standard. This internationally recognised system requires, as a minimum, legal compliance with relevant environmental legislation and year-on-year continual improvement. This is demonstrated by means of an annual, external audit of the EMS and its implementation.

Although there is an annual cost associated with ISO 14001 compliance, adherence to the thorough systems allows for comprehensive delivery of environmental sustainability and usually delivers significantly more savings than costs. The annual external audit, combined with the discipline required to maintain the standard, helps to maintain focus and momentum within an organisation.

By application of the management cycle (Figure 8.1), the EMS can be reviewed and any issues can be documented and reported upon.

Figure 8.1 Management cycle



For example, since 2008, Paignton Zoo's Botanic Garden in the United Kingdom has implemented and managed an EMS that has reduced waste and pollution, reduced utility consumption, and positively reported on its conservation work in terms of its impact on the wider environment (Peter Morgan, pers. comm.).

Organisational carbon footprint – Emissions from all the activities across a botanic garden, including energy consumption, industrial processes and travel, can be used to help create a baseline against which total greenhouse gas emissions caused directly and indirectly by a person, organisation, event or product can be monitored and managed (see for instance Carbon Trust Guide).

A carbon footprint is measured in tonnes of carbon dioxide equivalent (tCO_2e). The carbon dioxide equivalent (CO_2e) allows the different greenhouse gases to be compared on a like-for-like basis relative to one unit of carbon dioxide. A carbon footprint considers all six of the Kyoto Protocol greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). CO_2e is calculated by multiplying the emissions of each of the six greenhouse gases by its 100 year Global Warming Potential (GWP). A botanic garden may need the assistance of a consultant in order to calculate its carbon footprint.

In 2009, the Royal Botanic Garden Edinburgh began the process of writing and then implementing a carbon management plan. It was partly motivated by the need to be able to quantify its carbon footprint and to allow for monitoring future emission reduction initiatives, but also provided the means to establish a robust and clear carbon management plan in line with the ISO 14001 EMS standard (Case study 8.1).

Living Building Challenge (LBC) – This is an international building certification programme, advocacy tool and philosophy that defines the most advanced measure of sustainability in the built environment possible today and acts to rapidly diminish the gap between current limits and the end-game positive solutions we seek. It is the built environment's most rigorous performance standard. It calls for the creation of building projects at all scales that operate as cleanly, beautifully and efficiently as nature's architecture. To be certified under the Challenge, projects must meet a series of ambitious performance requirements including net-zero energy and water over a minimum of 12 months of continuous occupancy. The Challenge is comprised of seven performance categories called Petals: Place, Water, Energy, Health and Happiness, Materials, Equity and Beauty. Phipps Conservatory's Center for Sustainable Landscapes (Case study 8.5) demonstrates the collaboration of an entire planning team from the start of development through completion by using design charrettes that provided a holistic perspective.

Leadership in Energy and Environmental Design (LEED) – LEED is an international rating system for the design, construction, operation, and maintenance of green buildings. Two botanic gardens using LEED are the Phipps Conservatory and Botanical Gardens tropical forest conservatory and the Brooklyn Botanic Garden Visitor Center, while the Oman Botanic Garden in Muscat aims for LEED certification and has embedded sustainability in all aspects of design and operations.

Ontario EcoCentres Network – The aim of the Ontario Ecocentres Network is to assist learning centres (including botanic gardens) in the process of leading by example and reducing their environmental impact. The Network also provides staff and students with a framework to address sustainability, including energy and water conservation, the enhancement of biodiversity and the pursuit of carbon neutrality. Like LEED, the Ontario EcoCentres Network has different levels of achievement.

Public Gardens Sustainability Index – Maintained by the American Public Gardens Association, the purpose of the Public Gardens Sustainability Index is '*to define and promote leading environmental stewardship practices, and drive innovation and continual improvement in the sustainability performance of the public gardens sector.*'

Sustainable SITES Initiative (US Botanic Garden, Lady Bird Johnson Wildflower Center, American Society of Landscape Architects, ASLA) – This is a set of voluntary guidelines and a rating system for sustainable landscapes, with or without buildings. Examples of botanic gardens using the SITES system are Bartholdi Park and the Phipps Conservatory, the latter with the highest 4 star rating under this scheme.

YOUtopia – The American Public Gardens Association (APGA) also has the YOUtopia programme that aims to increase leadership among cultural institutions and inspire millions of Americans to engage in climate change solutions. Through this program, public gardens lead by example, taking climate change impact reduction measures that affect a wide array of garden operations. Public gardens have unique credibility as trusted sources of non-partisan, highly effective science and conservation information. From designing and building sustainable landscapes and buildings to reducing non-renewable energy consumption, YOUtopia gardens are committed to educate and engage garden visitors, volunteers, staff, and communities to address climate impacts and develop sustainable solutions. The impacts of these actions are monitored, reported, and shared with the public. YOUtopia reporting is designed to utilize the Sustainability Index for North American Public Gardens standards while remaining flexible to individual garden goals and accomplishments.

WELL Building Standard – This international standard is based on creating buildings and building practices that are not only better for the planet, but also for people. It is the first standard of its kind that focuses solely on the health and wellness of building occupants. It identifies 100 performance metrics, design strategies, and policies related to air, water, nourishment, light, fitness, comfort and mind, that can be implemented by the owners, designers, engineers, contractors, users and operators of a building. The standard is based on a thorough review of the existing research on the effects of spaces on individuals and has been advanced through a thorough scientific and technical review. In order to achieve the certification requirements, the space must undergo a process that includes an on-site assessment and performance testing by a third party.

CASE STUDY 8.1

Carbon Management Plan at the Royal Botanic Garden Edinburgh

Mark Richardson, Adelaide, South Australia

The Royal Botanic Garden Edinburgh (RBGE) was founded in the 17th century as a physic garden and now extends over four botanic gardens in Scotland. It is a world-renowned centre for plant science and education.

In order to achieve an environmentally sustainable workplace, the RBGE made a commitment to achieve the international environmental standard ISO 14001. As a part of this, the RBGE joined the Scottish National Heritage Carbon Management-Lite Programme and, in 2009, began the process of writing and implementing a Carbon Management Plan. Since then, the plan has been developed to reduce carbon emissions throughout the organisation's buildings, activities and sites including the three regional gardens at Dawyck, Logan and Benmore.

The purpose of the RBGE Carbon Management Plan has been to lay out the scope, issues, methods, people, paperwork and techniques necessary for RBGE to reduce its energy usage and therefore its carbon emissions. It has done this by calculating the organisation's baseline of annual carbon emissions and then setting targets to reduce these.

The project has not only been found to have financial advantages but other benefits that include:

- contributing towards achieving the ISO 14001 standard;
- quantifying RBGE's carbon footprint;
- monitoring future emission reduction initiatives;
- facilitating change in work culture to increase environmental consideration and reduce wastage;
- increasing opportunities to communicate with the public and other stakeholders;
- increasing evidence of environmental stewardship that RBGE could communicate to funders and principle financial awarding agencies.

The original target was for the RBGE to reduce CO2 emissions from its activities by 13% from the 2008 baseline by March 2015. It was estimated that this could be increased to 43% if key structures and heating systems were replaced. Carbon emissions for 2013/14 were 187 tonnes less than the previous year, which is a reduction of 5% of the emissions for 2012/13. This reduction was largely attributed to the replacement of heating equipment in the main building with a new and highly efficient combination of water heater and central heating boiler.

To further reduce emissions, the RBGE has installed air source heat pumps and solar photovoltaic panels to heat the new conservatory at Logan Botanic Garden. This was the first public greenhouse in the United Kingdom to be powered by green energy.

A current issue for the RBGE in relation to the Carbon Management Plan has been the energy inefficiency associated with RBGE's large and outdated glasshouses. However, the planned replacement of these structures and the incorporation of sustainable features into the modern buildings will result in significantly reduced energy use in the long-term. When complete, this major capital project should greatly reduce RBGE's carbon emissions.

The John Hope Gateway, the Royal Botanic Garden Edinburgh's new biodiversity and information centre, is a shining example of green construction: sustainability aspects have been included very early on during the design stage. (Image: Annette Patzelt)

8.4 KEY AREAS OF ENVIRONMENTAL MANAGEMENT

KEY MESSAGE

Improvements in energy, water and waste management can save significant amounts of money, while upgrades in the sustainability of buildings can have significant health benefits for visitors and staff.

8.4.1 Pollution Control

An important element of protecting the environment is pollution control. This pollution includes that of the air, land and water.

Pollution of air includes discharge from boilers, incinerators, exhausts and ventilation systems; leaks from refrigeration systems; and microbial aerosols such as Legionella and fungal spores from composting. Pollution of water can arise from discharge from sewers, drains, compost areas and septic tanks; it also includes fertilizer and pesticide run-off. Pollution of ground soil can stem from leakage from pipes, compost areas and fuel tanks.

Any environmentally hazardous materials should be stored and used appropriately, with relevant safety and environmental information readily available. Dangerous substances include fuels, asbestos, pesticides and herbicides. Safer alternatives should be used where possible, including biological control and insect traps. Appropriate spillage kits and procedures, can mitigate against accidents involving hazardous substances.

Control of pollution relates to thorough maintenance of mechanical and engineering infrastructure, regular inspections and replacement of failing assets.

8.4.2 Building Design

Designing sustainable solutions for new buildings or alterations to existing facilities can dramatically improve a building's environmental performance. For instance, the visitor reception centre of the Australian Arid Lands Botanic Garden in South Australia implemented the following sustainability features:

- The building is oriented to maximize passive heating and cooling;
- Most walls are of rammed earth construction with excellent thermal properties, using soil from site;
- There is a large rain water tank beneath the building;
- All rainwater from the roof is collected and stored in the underground tank for use in the kitchen, cafe and toilets;
- Only plantation timber was used in the construction of the building
- A passive evaporative air conditioning (AC) system is used – the AC plant is away from the building, screened by plants and the cooled air is drawn into the building through large underground pipes, aiding the cooling process;

Biochar makers – a stainable way of recycling, turning organic waste into charcoal. (Image: Kadoorie Farm & Botanic Garden)

- There is a large bank of solar panels on the roof with further expansion planned – providing power for both the building and garden;
- Verandas and awnings provide shaded areas.

8.4.3 Waste Management

Waste management can be encapsulated by three R's: Refrain - buy only what you need; Re-use - wherever possible; and Recycle.

All sources of waste should be monitored and these items recycled wherever possible. It is important to engage with suppliers to reduce and/or recycle packaging. Some waste can become income-generating. Bailing cardboard, paper, plastic and aluminum cans may allow resale for profit.

Wherever possible, sending waste to landfill should be avoided. Organic waste stemming from plant, food and manure can be composted or be anaerobically digested to produce energy. Such green waste processing is illustrated by Shanghai Botanical Garden in Case study 8.2. While composting can emit green house gases, it has been found that a significant reduction of gases such as methane can be achieved by improved compost management for instance by regular watering and turning.

8.4.4 Energy Management

All energy including electricity, oil and gas should be monitored using accurate metering. In some cases metering of individual items of equipment may be possible. Monitoring should be at least every month because this will allow for seasonal and annual comparisons. Annual energy use should be calculated and expressed in terms of cost, kWh and CO_2 equivalents.

More advanced real time monitoring using data loggers or a Building Management System (BMS) can allow for detailed control of energy including alarm notification if issues occur. Careful management of buildings, including glasshouses, can save large amounts of energy. Simple measures such as ensuring glasshouse windows and doors are shut when heating is applied, can be highly effective.

Key savings will be made through good building design (Section 8.4.2) especially relating to insulation and double glazing, measures that can create significant energy savings.

CASE STUDY 8.2

Green waste processing at Shanghai Botanical Garden

Feng Shucheng, Shanghai, China

The Shanghai Botanical Garden was established in 1974 and is one of the largest municipal botanic gardens in China. An important activity that the Shanghai Botanical Garden undertakes for both itself and surrounding districts is the processing of green waste and production of compost.

The green waste processing plant which is located in the northwest corner of the Garden, has four crushing machines and covers an area of 60,000 m^2. As such, it is the largest processing plant in Shanghai. The plant processes 40,000 tonnes of green waste annually, with the waste coming from the botanic gardens as well as from the Xuhui, Changning, Minhang and Huangpu districts every day.

Since 2006, the Shanghai Botanical Gardens has invested approximately RMB 20 million (USD 3 million) in green waste processing. There are 15 staff working on this project, and they can crush the waste and gather it for composting on the same day it was delivered. After crushing, they add nitrogen fertilizer and microbes to compost the material in 30-40 days. The compost is used on-site at the botanic garden with the remainder being packaged and sold. The kind of compost produced plays an important role in soil improvement, can save energy and reduce emissions. The project continues to develop with government support.

Compost management at Shanghai Botanical Garden. (Image: Feng Shucheng)

If possible, renewable energy sources should be used rather than those derived from fossil fuels. Massive advances have been made in the generation of renewable energy in the last 30 years. Electricity can be generated by photovoltaic panels, wind turbines and water turbines (hydro-electric power). Hot water can be produced by solar panels and biomass boilers can be used to produce heat by direct burning or by production of gas from anaerobic digestion. Combined heat and power (CHP) generation can make more efficient use of energy. A gas fired CHP plant produces electricity via a generator with waste heat recovered and used for heating. The gas can also be from renewable sources such as anaerobic digestion of waste. Heat pump technology has been used for decades and has huge potential. Heat pumps are efficient, electrically driven, they extract heat from air, soil or water. Typically 3 to 5 kWh of heat is generated from each kWh of electricity used.

LED lights have revolutionized the lighting industry and retrospective conversions of existing fluorescent lights to LED ones can make energy savings in excess of 50%. There are significantly greater savings when halogen or incandescent fittings are replaced. The reliability and life of LED lights reduce maintenance costs as well.

Finally, education and behavioral change can prevent energy wastage. Turning off all lights and appliances when not in use saves energy.

An example of a botanic garden energy policy is given in Case study 8.3, while sustainable energy usage is illustrated in Case studies 8.4 and 8.5.

CASE STUDY 8.3

Eden Project Energy Policy 2013

Mark Richardson, Adelaide, South Australia

In an energy policy released in 2013, the Eden Project is working towards sourcing 100% of their energy needs from renewable sources by 2020 and will continue to work in a collaborative way, seeking best practice from a wide variety of stakeholders. The objective of the policy is '*to reduce the environmental impacts of our energy use by driving down consumption and investigating alternative energy sources, communicating the success of low carbon initiatives, and stimulating direct change by increasing the awareness and skills of our visitors, staff and community.*' They seek to reduce their emissions by pursuing on-site geothermal investigations and large-scale solar arrays, purchasing locally-sourced wood-chip and managing energy using the best technologies. For more information see http://www.edenproject.com/eden-story/behind-the-scenes/cutting-energy-and-carbon-at-eden

The Eden Project, continuously working to enhance environmental sustainability. (Image: The Eden Project)

CASE STUDY 8.4

Sustainable energy use at Cairns Botanic Gardens

Mark Richardson, Adelaide, South Australia

The Cairns Botanic Gardens visitor centre, servicing the Cairns Botanic Gardens and Tanks Arts Centre, has been built with sustainability in mind:

The building generates renewable energy with 104 solar panels on the roof of the structure. This 20 kW system generates the equivalent energy usage of five to six average homes a day. Excess energy is fed back into the electricity grid, providing clean energy.

The visitor centre building also has a rainwater catchment system, and the water collected is used in the building for flushing toilets and other non-potable uses. Recycled water from Council's sewerage treatment plant is used for irrigation of the Gardens.

The building design reduces the need for air-conditioning through use of louvers and fans to control air flow in each room.

Solar panels generating renewable energy. (Image: Cairns Botanic Gardens)

CASE STUDY 8.5

Using multiple certifications for the building, landscape and human health: Phipps Conservatory and Botanical Gardens

Richard V. Piacentini, Pittsburgh, Pennsylvania

Phipps Conservatory and Botanical Gardens is located in Pittsburgh, USA and was founded in 1893 by Henry Phipps as a gift to the City of Pittsburgh.

The Phipps Center for Sustainable Landscapes (CSL) was designed to be one of the most environmentally sustainable buildings in the world. It is the only building to have ever met the Living Building Challenge, LEED Platinum, 4 Stars Sustainable SITES and Platinum WELL Building certification. To achieve this, the CSL uses a range of technologies and strategies including:

Energy
- The building emphasizes passive energy-saving strategies and uses 70% less energy than a typical office building. It is long and narrow and faces south to maximize natural daylighting and ventilation.
- Strategic window placement and light shelves that direct the sun's rays and reflective ceiling material all allow daylight to naturally illuminate the interior 80 percent of the time. This reduces the need for energy-intensive artificial lighting. A green roof, high performance insulation and triple-pane, low energy windows help keep heat inside during the winter and outside during the summer.
- Onsite 125 KW photovoltaic solar panels produce more energy than the building uses on an annual basis.
- A vertical axis wind turbine, the first to be commissioned in the City of Pittsburgh, produces energy with winds as low as 6.8 kph.
- A series of six geothermal wells buried 500 feet below ground are used to capture heating and cooling temperatures.

Storm Water
- The building captures and treats all storm water (12.3 million litres) that lands on the site using the following strategies:
- A former Public Works and brownfield site. Over 2 acres of asphalt was removed and replaced with a landscape entirely made up of 100 species of plants native to within 320 kilometres of Pittsburgh.
- A green roof on the CSL captures rainwater. It also is accessible to the public and is part of the visitor experience.
- Five raingardens, strategically located, capture surface runoff from the landscape and roads.
- Permeable asphalt allows storm water to directly infiltrate into the ground.
- Excess water from the green roof and gardens is stored in a lagoon, which is also an important visitor amenity.
- If the lagoon overflows, excess water is captured in a 302,000 litre underground rain tank. That water can either be used for irrigation or infiltrated into the ground.

Phipps Center for Sustainable Landscapes. (Image: Denmarsh Photography Inc)

Sanitary Water
- All 300,000 litres of sanitary water from the CSL is treated on site.
- The initial water, and make up water, for the toilets is captured from a conservatory roof and stored in a 6,400 litre cistern.
- Water from the toilets and sinks is treated on site for reuse in flushing the toilets using a constructed wetland, sand filters and UV sterilization.
- Two 45,400 litre fuel tanks were repurposed to capture sanitary water overflow until it can be treated on-site.

Materials
- All buildings materials are Red List toxin free.
- All heavy building materials are sourced from within 800 kilometres to reduce the energy costs associated with transportation.

Human Health
- The building is WELL Building Platinum certified. This programme requires strategies to address how the built environment effects human health in seven critical areas: Air, Water, Nourishment, Light, Fitness, Comfort and Mind.

Education
- The green roof, landscape and atrium of the building is accessible to all 450,000 of Phipps' annual visitors.
- Educational signage and docent led tours help interpret how the building works for the public.
- The primary classroom for children's programmes is located in the CSL.
- A Biophilic Art programme helps interpret why connections to nature are important for human and environmental health.

In producing all of its own renewable energy, the CSL has achieved the Living Building Challenge, Net Zero Energy, LEED Platinum, 4 Stars Sustainable SITES and Platinum WELL Building certification.

CSL serves as a key part of the botanic gardens visitor experience as well as being a facility that houses administrative offices as well as groundbreaking sustainability research and science education programmes.

8.4.5 Water Management

Water is frequently the forgotten utility. Drinking water is a finite, valuable resource with significant financial cost. It is advisable to monitor drinking water use via accurate metering and sub-metering. Waste water (sewage) charges are sometimes based on a proportion of the drinking water usage. Reduction in drinking water use therefore reduces charges for both water and waste water.

Reducing the use of drinkable water for irrigation has probably been one of the Royal Botanic Gardens Victoria's most significant environmental challenges. Through a range of approaches such as staff training, research programmes, irrigation efficiency measures and managing irrigation demand, over 50% reduction in annual drinkable water use for irrigation has been achieved since the early 1990s.

A number of other approaches to careful water management are presented below:

Use of drought tolerant plants – By using the drought-tolerant flora of arid central Australia in its collections, the Alice Springs Desert Park is a very efficient water user. They use on average 2 mega-litres/ha/year. This is well below industry standard usage and better than other local park areas.

Use of young plants – Starting with young plants and growing them 'hard' in their early period of establishment has been shown to pay dividends when they eventually establish and grow on. Trees that are planted as young whips often establish faster (acclimation) and then grow on to out-perform larger root balled plants. Large plants often struggle to establish (called 'planting shock'), exhibit smaller leaves, have fewer roots extending into wider soil horizons and require substantially more nutrient and water use in the first three years of establishment.

Use of storm water and sustainable urban drainage systems within the botanic garden – Wherever possible, direct downspouts toward plants, trees and shrubs and use porous materials for walkways and driveways. It is helpful to develop rain gardens in natural or man-made depressions in the landscape to capture and soak up runoff from rooftops, driveways and walkways. Similarly, green walls and living roofs reduce rapid run-off of rainwater (Case studies 8.5, 8.6 and 8.7).

Irrigation systems – Low pressure or low volume systems such as drip irrigation or soaker hoses should be used, not oscillating sprayers. This allows for less evaporation and more direct watering of the root area. Systems with rain sensors prevent unnecessary watering and checking of the system for overspray keeps water loss at a minimum.

Correct management of lawns – Grasses compete for water in the top 5 cm of the soil and have a large water demand that often outcompetes other plants to their detriment. Removal or reduction of the lawn area should be considered along with selection of grasses that require less moisture. Moisture can be retained by raising mower height to ensure survival during drought or extreme heat and by leaving clippings on the lawn. Allowing the lawn to go dormant during mid-summer is another way to ensure survival of cool season grasses. Finally, lawns should be watered when evaporation is at a minimum.

Mulching and compost – Mulch should be applied around plants to aid moisture retention and to reduce surface evaporation. It is important to select a type of mulch that is best suited to different plants and to mulch in late winter to 'lock in' soil moisture and help prevent weeds growing in spring. Compost should be used as part of the refill when planting, to provide additional water-holding organic matter.

Containers – Container gardening can also be a good method which uses less water provided the species grown and container sizes are appropriate. Saucers under containers prevent water running away and can help reduce the time spent watering. Water-storing crystals in the potting mix reduce the amount of watering needed. Finally, limit the use of hanging baskets.

Maintenance – Irrigation, hoses and outside taps need to be checked regularly for leaks with repairs carried out as needed. Similarly, the programming on irrigation systems needs to be checked regularly.

Irrigate appropriately – Use of excessive amounts of water which simply drains away should be avoided as should insufficient water which just wets the soil's surface and evaporates. Watering should be carried out at dawn or dusk to minimise evaporative losses and reduce the visitor impression that water is being wasted.

Rainwater capture – Rainwater from buildings or hard surfaces may be used as irrigation for plants. If stored, this water should be kept cool and dark to prevent it deteriorating in quality due to growth of micro-organisms including algae (see Case study 8.6).

Extraction – Water may be extracted from boreholes (wells) subject to local regulations. Water extracted from lakes, ponds or rivers is likely to contain suspended solids which may block pumps and nozzles. It may also be nutrient rich leading to quality deterioration and anaerobic conditions as it is likely to contain significant microbiological contamination, some of which may be harmful such as *Legionella* or *Leptospirosis*. Consideration should be given to treating this water prior to use. Treatments could include filtration, UV sterilisation and aeration.

8.4.6 Travel

Travel by staff, visitors and contractors contributes to energy consumption and related pollution. This should be monitored and reduced where possible.

Use of low energy vehicles including electric or hybrid technology can reduce carbon emissions and save money. Encouraging car sharing by staff and reducing unnecessary deliveries are also beneficial. Although monitoring travel-related energy use and carbon production can be challenging, it is necessary to calculate environmental impacts. There are various tools for measuring your carbon emissions on line, for example myclimate.org

For overseas travel, especially flights, consideration could be given to carbon 'off setting' via appropriate schemes. The Eden Project offers a 'Green Travel Discount' to visitors who travel to the garden by foot, bicycle or bus rather than by car.

CASE STUDY 8.6

Sustainable Rainwater Management at the Auckland Botanic Gardens

Jack Hobbs, Auckland, New Zealand

Typically, rainwater is collected by drains and piped away to be released untreated into streams, waterways and the sea. Auckland Botanic Gardens now incorporates sustainable rainwater management wherever possible. The rainwater management includes:

- **Nursery:** Nursery rainwater (and irrigation) run-off is collected in a 30,000 litre underground tank and is pumped back through sprinklers to water the plants. The nutrients that have washed out of the potting mix are reapplied with each watering.
- **Visitor centre:** Rainwater is collected from the visitor centre roof and stored in an underground tank. It is then used to run a water feature at the entrance to the centre and to flush the toilets.
- **Children's garden:** Rainwater collected from the roof of the large shelter in the Potter Children's Garden is stored in a tank that is used for irrigation to demonstrate water re-use in education programmes.
- **Rain gardens:** Rain gardens have been established at the carpark where contaminants such as heavy metals and oil wash off vehicles. As this is at the highest point of the Auckland Botanic Gardens, the rain garden captures and treats this water before it flows into the botanic garden. The water pools for up to 24 hours in the rain garden, allowing sediment and other contaminants to settle into the soil, or be absorbed by plants. The water then slowly seeps through the growing medium and restocks ground water, with excess ground water draining into a stream.

Living roof with native plants at Auckland Botanic Gardens. (Image: Jack Hobbs)

- **Living roofs:** Living roofs act as a trap for rainwater, decreasing the rainwater volume flowing off it by up to 65% and slowing the water speed down to a trickle. The native living roof, on the Potter Children's Garden toilet block, is a trial and is testing many different native species for New Zealand roofs.
- **Riparian planting:** A large number of New Zealand's native species are planted around the lakes and along streams in the gardens. These plants continue to clean the water as well as slow the rainwater flow, reducing the risk of bank erosion. Trees also provide cooling shade, discouraging algae growth in the water.
- **Swales:** Swales are suitable for many situations where rainwater needs to be slowed and moved to be further treated. They are commonly seen alongside car parks, roads and motorways. Conditions vary from very dry to very wet, so the plants need to be hardy. One of the swales at the Auckland Botanic Gardens is used to move the rainwater from the visitor car park, paths and nursery overflow down to the sediment.
- **Permeable surfaces:** Permeable surfaces allow rainwater to flow right through them and gravel, sand and crushed shells are permeable surfaces often used for garden paths and driveways. In areas where harder more robust surfaces are needed, porous pavers can be used.
- **Rainwater tree pits:** Rainwater tree pits are designed to treat large volumes of rainwater from roads and car parks. Under light rain conditions the plants and the planting medium within the tree pit act as a biological filter to treat and slow rainwater. When heavy downpours create large volumes of rainwater, the water overflows from the planted area into underground filter chambers (beneath the green mesh cover). The filter chambers use chemical processes to remove pollutants from the water including hydrocarbons.
- **Planter boxes:** Planter boxes have also been used to treat rainwater. At the Potter Children's Garden, water flows in to two planter boxes, fed by rain falling on the roof of the Education Centre roof. A perforated pipe disperses water across the surface of the planter boxes, where it slowly seeps down through the soil mix. The boxes are completely lined so water won't seep into the ground and around building foundations. Any water that eventually flows out from a drainage pipe at the base of the planter boxes is directed through further treatments and finally to the gardens wetland area.
- **Infiltration trenching:** The use infiltration trench has also provided rainwater treatment. Water is held within the trench slowly absorbing into the surrounding soil. This re-stocks groundwater, which is beneficial to surrounding trees. Sediment and other contaminants carried in by the water settle to the bottom of the trench. The trench is 10 metres long, by 1 metre deep and is filled with small porous rocks. The infiltration trench is part of a 'treatment train', where a series of rainwater treatments are linked together.
- **Wetland area:** The wetland naturally collects surface run-off and ground seepage from the surrounding lawns and gardens. Wetlands effectively treat the collected rainwater, trapping sediment and other contaminants, and correcting the water's pH and temperature levels. Over long periods of time they also help store carbon.
- **Areas outside the botanic garden:** Pipes also deliver rainwater into the gardens from the surrounding suburb and roads. It is first collected and treated in a sediment reservoir.

CASE STUDY 8.7

Changing to non-potable water for irrigation at Adelaide Botanic Garden

Sam Phillips, Adelaide, South Australia

The Adelaide Botanic Garden in South Australia was officially opened in 1857. It occupies 51 hectares of land and is part of the South Australian government's Department of Environment, Water and Natural Resources.

Of all the Australian capital cities, Adelaide is the driest, receiving an average of 545mm of rain per year. The rainfall is unreliable, light and infrequent throughout the summer. Temperatures are high in Adelaide, and irrigation has always been important for the botanic garden's living collections, which have used the city's potable water since it was available. To address this, the Adelaide Botanic Garden created First Creek Wetland, officially opened in 2013, to replace the use of potable water for irrigation of the botanic garden with stormwater from the wetland.

First Creek Wetland at Adelaide Botanic Garden. (Image: Jake Dean)

The stormwater is collected during winter, stored in the aquifer below and then recovered for botanic garden irrigation use in summer. To achieve this, a small amount of stormwater is diverted from First Creek as it enters the botanic garden, where a pollutant trap removes litter and improves the quality of the water. In the wetland, a sedimentation pond removes the silt from the water. Plants in the main wetland pond remove heavy metals and other contaminants, cleaning the water so that it can be stored in an underground aquifer for later use. Within about eight years from its construction, the wetland is expected to be able to recover enough water to sustainably irrigate the entire Adelaide Botanic Garden. Key design features include, a sedimentation pond to limit the quantity of sediment entering the macrophyte zone which is planted with wetland plants to improve the quality of water prior to injection into the aquifer, a mechanical filtration system to further improve water quality, a storage pond to provide storage of water retrieved from the aquifer for irrigation and an irrigation pump station to deliver water into the existing irrigation network.

The First Creek Wetland also complements the Adelaide Botanic Garden's goal of connecting people with plants, and shows visitors a function of plants which they may never have considered - cleaning water. The project has been developed as an important educational facility to help the community understand the role of wetlands, especially in an urban environment. The wetland features pathways and viewing platforms, as well as educational signs to explain the aquifer system and the importance of wetlands to the 1.6 million annual visitors to Adelaide Botanic Garden, including 50,000 school students.

8.4.7 Procurement

Sustainable procurement can have huge benefits, ensuring that the suppliers of goods and services are also minimising environmental impact by reducing energy, waste and pollution. The 'full life costing' model considers energy and water efficiency, waste costs, building quality as well as the initial purchase price over a defined period. This inclusive system supports environmental sustainability.

For example, the Eden Project has an ethical procurement policy for its catering and the products it sells in its shop – *Ethical buying at Eden*. This includes purchasing locally produced goods, things that are made from plants, products that promote sustainable living, fairly traded goods and recycled products.

8.4.8 Biodiversity

The very nature of a botanic garden's business can have a positive environmental impact including increase in biodiversity and carbon sequestration via living collections, reintroductions and support to restoration projects (Chapter 7, Section 7.1.1).

Selection of plant collections – Showcasing local plants (Case study 8.8) can help encourage the community to use plants that are well adapted to the local environment with concomitant reduction in water and other inputs. In many cases this approach has resulted in whole gardens becoming devoted to the local or regional flora. For example, by using only local plants in Barossa Bushgardens Regional Native Flora Centre in Nuriootpa, South Australia, the garden is not only reducing water use, it is also helping to increase local biodiversity, as the local flora is the preferred habitat for the local fauna. This approach is seen as effectively working with the local environment and not against it (Chris Hall, pers. comm.).

Careful consideration should be applied to which exotic species are grown and, where possible, plants requiring excessive water or energy inputs, should be avoided. Transfer of such material to better suited gardens should be considered. For instance, Asian species considered to be at threat from climate change in the Royal Botanic Gardens Victoria living collection near the centre of Melbourne, South Australia, have been re-located to a higher elevation at the Dandenong Ranges Gardens east of Melbourne which is likely to be much better suited now and into the future.

8.5 EDUCATION AND COMMUNICATION

KEY MESSAGE

Visitors are increasingly expecting botanic gardens to demonstrate leadership in environmental sustainability.

There is increasing evidence that visitors are expecting conservation and education organisations, like botanic gardens, to address sustainability and related issues. Botanic gardens have a huge opportunity to engage and inspire their visitors and staff on environmental sustainability by embedding it throughout their range of activities. Not only can visitors see sustainability in operation but there are rich opportunities to showcase it in outreach projects in communities, local schools, colleges and universities (Chapter 7, Sections 7.2, 7.3, 7.4 and 7.5). There are also opportunities to link up with local businesses or industries with corporate social responsibility programmes.

8.6 CONCLUSION

Successful environmental sustainability must have 'buy in' from all levels of the botanic garden and particularly that of management. In turn, managers need to make sufficient people and financial resources available. Initially, botanic gardens may find it helpful to enlist the services of a competent environmental adviser/consultant to help establish the system and provide sound advice. As financial savings from lower energy or water use are made, managers should consider re-investing them in further environmental sustainability measures.

Good communication within the organization and to its stakeholders and visitors is essential. This needs to not only detail the organisation's commitment to environmental sustainability, but publish its annual progress and celebrate its successes.

Finally, it is important to ensure that the sustainability 'ethos' is supported by all staff, who will be crucial to its achievement. The staff team will be the force that transforms policies and our environmental rhetoric into the practical action that will deliver the model of sustainability that we all wish to achieve for our institutions.
Wyse Jackson (2009)

CASE STUDY 8.8

Growing, conserving and promoting the native flora at the Royal Botanic Garden of Jordan

Tariq Abu Taleb, Amman, Jordan

The Royal Botanic Garden (RBG) is located in Tel Al-Rumman, Jordan, about 25 km north of Amman and beside the King Talal Dam. The botanic garden was founded in 2005 as a non-government, non-profit entity. Its role is to conserve the flora and biodiversity of Jordan by propagating and displaying native plants, rehabilitating habitats, conducting research, demonstrating sustainable practices and sharing information.

Native plants are being propagated in the RBG's nursery to enable the re-creation of authentic Jordanian habitats for research, display and educational purposes. A seed bank is being developed to save the seeds of Jordan's native plants and crop wild relatives. At the RBG herbarium, dried specimens of Jordan's plants are being preserved.

Display gardens will follow specific themes while highlighting the practicality of using native dryland plants, which are best adapted to Jordan's arid climate. Five typical Jordanian habitats are being re-created on the site: deciduous oak-, pine- and juniper forests, riparian freshwater as well as Jordan Valley and Dead Sea habitats.

The RBG works closely with people in the nearby village and region. The Garden consults and cooperates with the community in its work through initiatives like the Community-Based Rangeland Rehabilitation programme and teaches best practice and sustainable living skills to pastoralists, farmers and families. As a result, local employment rates are on the rise, individual and regional capacities are being built, and the native flora is better protected. These positive effects are already measurable and sustainable.

Native plants garden, Royal Botanic Garden, Jordan. (Image: Tariq Abu Taleb)

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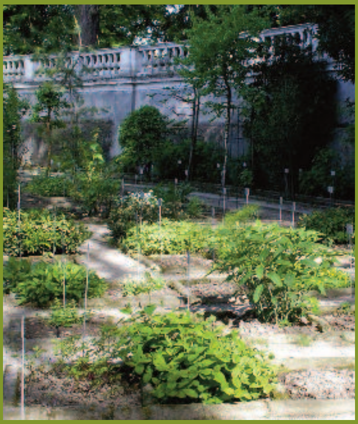

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