Royal
Botanic Garden
Edinburgh

Biodiversity Strategy 2010 – 2015

2. Introduction

The Royal Botanic Garden Edinburgh (RBGE) is Scotland's world-renowned international centre of excellence for botanical and horticultural science and education. We are sponsored by the Scottish Government's Rural and Environmental Research and Analysis Directorate (RERAD). Our mission is:

exploring and explaining the world of plants for a better future

RBGE's strategic goal is to deliver world-class biodiversity research that:

- provides baseline taxonomic and other botanical data as a foundation science,
- investigates the evolutionary processes that have given rise to the world's botanical diversity,
- conserves plant biodiversity in the face of global environmental change and mass extinction,
- maintains and enhances our internationally important living and preserved collections, and
- communicates to society an understanding of environmental issues.

With our four outstanding gardens and education programmes for every stage of life, we use the expertise and skills of our staff, volunteers and partners to inform and influence positively the lives of our visitors.

By building public understanding, and through world class research, we champion the importance of plants as the life support system of the biosphere. By working with the Scottish Government and other research institutions in Scotland and further afield, we will maintain RBGE's place at the forefront of Scotland's international biodiversity research effort.

3. Context and Direction

The threat to global biodiversity is now more severe than at any time in human history, with consequences which threaten ecosystem function and jeopardise basic human needs. There is a social imperative to protect biodiversity, to find more sustainable ways of living and to prevent irreversible damage to our biosphere – our success in this endeavour is utterly dependent on the implementation of high quality biodiversity knowledge. Positive action to prevent biodiversity loss and sustain ecosystems is weakened by a lack of knowledge – it is thought that we have named only 10% of species that exist on our planet.

This document sets out RBGE's Strategic Plan for plant biodiversity research and communication for the period 2010-2015. It builds upon RBGE's Strategy for Science for 2004-2009, "*Delivering biodiversity science to underpin conservation*", re-enforcing and further developing the priority areas of research (see Appendix 1). It explains how RBGE's world-class science in the description and evolutionary explanation of plant biodiversity forms a platform for work that combats threats to

biodiversity and provides practical solutions in conservation and sustainable development. The first section of this Strategy explains how we will develop the organisation's successful core research programme:

Understanding our planet – contributing to the complete inventory of plant species on earth and understanding their evolution.

It then describes how this fundamental biodiversity research will enable RBGE to meet four significant **global environmental challenges**:

- **biodiversity loss** - dealing with habitat loss and fragmentation in the quest to halt species extinction,
- **climate change** - minimising plant biodiversity loss in the face of climate change and global warming,
- **sustainable use** - wise exploitation of plants so they are still available for future generations, and
- **ecosystem services** - preserving the function of Earth's biosphere and ecosystems.

Finally, it explains how we will **deliver our key goals** by optimising:

- collections,
- tools and technologies,
- communication pathways and education, and
- human resources and partnerships.

This will enable us to deliver biodiversity goals at home and to share information with countries biodiversity rich but resource poor so that they can actively contribute to the protection/research of their own biodiversity.

The strategy has been developed with input from a wide range of stakeholders and responds to recent national, international and intergovernmental reports, policies and treaties (see Appendix 2).

This Strategic Plan will influence the direction of all aspects of biodiversity research and conservation within RBGE and the messages we communicate about environmental issues to the public in Scotland and globally. Its aspirations will be reflected by operational goals laid out in RBGE's Corporate Plans and are elaborated in the Implementation Plan.

4. Understanding our Planet

Completing the global inventory of plant species and understanding their evolution is vital foundation science for biodiversity conservation and sustainable management.

Background

RBGE is Scotland's leading international player in plant biodiversity inventory and taxonomy and we contribute to the nation's role in global initiatives to describe the world's plant biodiversity. The strategic necessity to describe and explain biodiversity is deeply embedded in international, European and UK legislation and policy (Appendix 1). Accordingly, a catalogue of all species on Earth is a recognised science priority for the 21st Century, and the first target in the *Global Strategy for Plant Conservation* is a complete account of plant biodiversity. Within the over-arching framework of the *Millennium Ecosystem Assessment* the role of biodiversity and its effective conservation underpin sustainable ecosystem function and services. If we cannot identify species and do not understand their distributions, we cannot determine which species are in peril of extinction, nor can we adequately understand the basis of ecosystem function.

RBGE also has significant research programmes to investigate the evolution of plant diversity. These have been strengthened in response to strategic changes in the 2004-2009 Science Strategy, including better links with universities. These programmes include: (i) investigating evolutionary relationships of species using both molecular, morphological and cytological information, thereby contributing to global initiatives to develop a "Tree of Life"; (ii) understanding how plant species have arisen and how plants have spread across the globe and responded to past environmental changes; (iii) explaining genetic variation within and between plant species as a conservation tool and as a means of identifying species using a "DNA barcoding" approach; (iv) understanding how individual genetic changes have lead to the extraordinary diversity of plant form. Such research is not just fundamental to our understanding and appreciation of biodiversity, but it has many applications, for example in predicting how plant species will respond to future climatic changes, or in the identification of relatives of useful species as new genetic resources.

The Challenges

In the face of unprecedented habitat loss, we are the last generation with the opportunity to explore fully the diversity of life on our planet. The scale of the task is daunting – more than 30% of the large tree species in the Amazon rain forest await description. For non-flowering plants and fungi the descriptive task remains immense – new species continue to be regularly discovered in 'well-known' regions such as Europe and North America, and large areas of the world remain completely unexplored. We must speed the taxonomic process by increasing the number of working taxonomists, by harnessing new technologies, and through local, national and international collaboration.

In tandem with such fundamental taxonomic exploration, RBGE can take advantage of new technological and intellectual approaches to its evolutionary and population genetic research. The challenge is to use new approaches, that have often been applied only in the context of a few 'model' organisms, to a wider sample of global biodiversity. RBGE's future scientific impact is founded on the application of our

diverse expertise - we study plant diversity in its broadest sense from diatoms and lichens in Scotland to the trees that dominate the world's forests.

RBGE Activities – Past and Present

RBGE biodiversity research has been planned to maintain a critical mass of researchers whose work focuses on the diversity of biodiverse geographic regions and on a series of plant groups of economic or ecological importance, including cryptogams.

- RBGE leads in major Flora and inventory projects in areas around the world that are highly species rich but where habitats are threatened, including Nepal, Arabia, China and tropical Africa, America and Asia. In the past decade, an important element of this research has been to build the capacity of local counterparts to enable them to deliver better biodiversity research.
- Monographic taxonomic research – the study of all species in a single group - is concentrated at RBGE in cryptogams and tropical flowering plants. Cryptogams are some of the most poorly known plant groups, even in well known countries such as Scotland which is a global diversity hotspot for bryophytes and lichens. Our taxonomic research in the tropics concentrates upon families and genera that are species-rich, poorly known, or of economic and/or conservation importance.
- RBGE's research on plant evolution ranges from the population to the global scale, with a distinctive focus on diversity of species, genera and families and their evolutionary history rather than on laboratory based model organisms and systems.

RBGE Activities – Future

(i) Biodiversity inventory and taxonomy

a. **Increasing the number of taxonomic researchers and maintaining and developing our collections and library;** seeking extra resources to employ more taxonomists and continuing to invest in the collections.

b. **Improving the speed and accuracy of taxonomic research** by using new technologies for DNA sequencing and biodiversity informatics in tandem with fundamental morphological approaches.

c. **Increasing our commitment to fieldwork in collaborative inventory programmes,** using them to build capacity of local collaborators to collect, identify and classify plant species.

d. **Providing targeted authoritative information on plant biodiversity** by maintaining our focus of taxonomic and inventory research towards geographic regions and plant groups that are poorly known and are of high conservation, economic, ecological or social importance.

e. **Engaging with our user communities to** ensure that we continue to address their data needs in terms of quality and relevance, and providing information in the format they require.

f. **Taking advantage of new technologies to disseminate plant biodiversity data:** we must deliver data in appropriate electronic formats, but recognise

that printed monographs, Floras, checklists and identification guides continue to have an important role.

(ii) Evolution of plant diversity

a. **Using the latest technologies and analytical techniques to understand evolutionary relationships and speciation.** Robust hypotheses of evolutionary relationships in our study groups will enable the construction of better, more predictive taxonomies, and a clearer picture of how species have arisen and achieved their distributions. New DNA sequencing technologies can be used to investigate in detail the genetic differences between species, and shed new light on the speciation process.

b. **Aspiring to sequence short DNA regions ("barcodes") from all plants we collect in the field**. These sequences will be useful as taxonomic data and in species identification, and will form a genetic database that can eventually be used to study the evolution and distribution of genetic variability of entire floras.

c. **Moving our research in evolutionary development beyond investigating the effect of single genes**. Construction of genetic maps and the availability of breeding populations can help to pinpoint the genetic basis of a variety of morphological features.

d. **Investigating the historical construction of some of the planet's most species-rich biomes.** We will develop our successful research programme in historical biogeography more globally, taking advantage of the detailed research done on our focus taxonomic groups. We aspire to build upon approaches that use evolutionary trees for single taxonomic groups, and to investigate new approaches that examine the genetic variability and relatedness of entire floras.

5. Global Environmental Challenges

Our research on the description and evolution of plant biodiversity can have immediate impact in four priority areas:

- biodiversity loss,
- climate change,
- sustainable use,
- ecosystem function and services.

5.1 *Biodiversity Loss*

Biodiversity is inherently valuable, sustains human life and is being lost at an unprecedented rate.

Background

Biodiversity is the planet's biological wealth generated over an evolutionary time-scale of 3.8 billion years. It is measured at differing scales, comprising genetic, species and habitat diversity, and is structured into ecosystems, which can be described in terms of their function and the services they provide to humanity. Biodiversity is also deeply valued for its aesthetic quality and provides a renewable biological resource upon which the human socio-economy is ultimately dependent. Humanity is orchestrating a major global extinction event in which the current rate of biodiversity loss is estimated to be about 1000 times the 'background' level. The urgent need to halt biodiversity loss is the central theme of international conventions – for example, the 2010 Biodiversity Target - and is incorporated in national legislation.

The Challenges

The challenge of minimising biodiversity loss can be divided into two parts. The first challenge is to provide conservation assessments for species or geographical regions which are currently data deficient. The second is to develop conservation strategies to protect threatened species in the face of rapid environmental change and exploitation.

Conservation Assessments – There has previously been an imperfect link between the efforts of the taxonomic community to describe biodiversity, and the efforts of the conservation community to protect it. A current challenge is to improve these linkages and to ensure the efficient delivery of high quality distributional data and information on species diversity to support biodiversity conservation. This information flow is required to reduce the large backlog of species whose conservation status is currently unknown. Increasing the production of these conservation assessments is important as they are a prerequisite for effective conservation.

Developing Dynamic Conservation Strategies – Approaches to developing conservation strategies are shifting from an emphasis on the persistence of representative sites, to a dynamic approach which aims to conserve evolutionary and ecological processes. Protected Area Networks recognise the importance of interconnected sets of populations in the landscape. The development of Protected

Area Networks builds on species distribution data and where possible includes recognition of the biological consequences of fragmentation, the importance of adaptive variation, and the dispersal potential of species as integral components of managing biodiversity.

RBGE Activities – Past and Present

RBGE's current research to address biodiversity loss has been important in:

- Compiling information on species distributions and diversity to produce conservation assessments.
- Development of *ex situ* conservation collections and cultivation protocols, and the use of this material in restoration projects.
- Assessment of the impact of habitat fragmentation on the 'genetic health' of species, and the incorporation of genetic information into conservation programmes.
- Applying specialist identification skills towards ecological research in the response of species and communities to habitat dynamics.
- Providing recommendations for best practice *in situ* and *ex situ* conservation.

RBGE Activities – Future

a. Conservation Assessments. Protocols will be further developed to improve the flow of data from field-recording, through herbarium curation and digitisation, to data analysis and conservation assessment. Such protocols will lead to more efficient conservation assessment for diverse taxonomic groups in the many countries in which we work. In turn, the resulting database of conservation assesments can form the basis for analyses of the importance of geographic distribution, life-history traits, evolutionary relationships, population size and genetic structure in the development of general conservation principles.

b. Protected Area Networks. RBGE's specimen and field-inventory data will be applied in the design of Protected Area Networks. New methods will be developed to improve site prioritisation, drawing on large-scale floristic data sets and where possible incorporating information on species dispersal characteristics and adaptive potential. Within sites, the response of biodiversity to habitat dynamics will form the basis for recommendations in conservation management.

c. Restoration. RBGE will work to improve restoration protocols, making the persistence of evolutionary and population processes a priority. The aim is to shift remedial conservation from a state of intensive management towards self-sustaining ecological systems. To have maximum impact, this approach will be accompanied by partnerships with major conservation organisations to deliver large scale practical restoration projects.

5.2 *Climate Change*

Human-induced global warming is regarded as one of the greatest threats to biodiversity.

Background

There is a scientific consensus that human activities are causing warming of our planet. Important questions remain about the magnitude and spatial pattern of future climate trends. Thus, climate change adds complexity in understanding the response of biodiversity to a range of environmental drivers (e.g. habitat loss, pollution). The science behind climate-impacts analysis is a rapidly developing field. It is imperative that the highest quality scientific data are used to under-pin effective conservation, aiming to off-set climate change impacts on biodiversity.

The Challenges

The key challenge is to provide a scientific evidence base that can be used to protect biodiversity in the face of climate change. There are at least four important barriers to achieving this goal.

First, data quality must be reliable – while uncertainty in climate change scenarios must be incorporated into the assessment of threat, it is critically important that biodiversity data used to assess this threat are taxonomically robust, accurately geo-referenced, and collected in a manner that is appropriate to scientific analysis. No matter how robust the analytical framework, climate-impacts analysis will be only as accurate as the field-data upon which it is based.

Second, previous attempts to understand the response of species to climate change have been limited in taxonomic scope, and are prone to important ecological uncertainty, e.g. in dispersal rates, the capacity for *in situ* adaptation, or species interactions. Improved quantification of these uncertainties has the potential to change fundamentally the conclusions of climate-impacts analysis.

Third, it may be recognised that climate change is not a threat to biodiversity *per se* (e.g. it may be considered an evolutionary driver of biodiversity). It is the interaction of rapid human-induced climate warming with additional drivers (e.g. pollution, habitat loss) which causes an unprecedented large-scale biodiversity threat. This interaction between multiple drivers increases complexity in understanding the threat of climate change, and would benefit from down-scaling to regional or local settings.

Fourth, committed investment in long-term monitoring, although unpopular in the current funding-climate, is nevertheless essential to confirm, refute and recalibrate the results of predictive and experimental models. Monitoring is a rate-limiting step towards confidence in scientific results, and remains the only way to measure with certainty the biological response to environmental change.

RBGE Activities – Past and Present

RBGE's current research examining climate change has been important in three areas:

- Extending the taxonomic scope in climate-impacts analysis - using high quality data to examine diverse though neglected biological groups, particularly where these are of special concern to Scottish and UK conservation.

- Engaging in climate-impacts analysis to examine how the species-response to climate change might be dependent on multiple landscape-scale variables.
- Investing in long-term monitoring studies in natural habitats and under cultivation, to provide informative datasets that can be used to confirm or refute important areas of threat and/or uncertainty.

RBGE Activities – Future

a. **Recording high quality taxonomic data for modelling climate change.** RBGE's gathering of taxonomic data appropriate to climate- impacts analysis will focus on data-poor regions of conservation concern. This will provide novel datasets for systems that have proven difficult to model. Our research will also critically investigate the limitations of these data, and, considering the data properties, how they can best be analysed and improved at the collection stage.

b. **Providing species distribution data for Earth system science.** It is vital to model how species distributions will alter with changing climate because modified ecosystems will impact in different ways to global climate. Such bioclimatic modelling has enjoyed a very high profile in recent years and is currently experiencing substantial development, but, especially in species diverse regions, requires a much better underpinning from taxonomic science.

c. **Facilitating opportunities for targeted long-term monitoring.** RBGE will continue to invest in targeted long-term monitoring. Monitoring programmes cannot be realised through short-term grant-funded research (e.g. university funding structures), though are suited to Government investment in RBGE's grant-in-aid structure. Such data provide extremely important added value and fundamental support to predictive and experimental research.

d. **Analysis of multiple drivers**. Our research will adopt an holistic view of climate change threat, integrating multiple drivers where these have important implications for the species-response. This will be achieved through both the improvement of statistical models and by a down-scaling of research focus, to examine regional and local scenarios. Avoiding a 'one size fits all' solution, this approach will shift our impacts-analysis from a general framework towards studies that are targeted on specific conservation priorities.

e. **Providing an evolutionary framework for climate change science**. Studies in evolutionary and population genetics will include research focussing on adaptive genetic and life-history traits, dispersal and gene-flow between populations. As the conservation agenda is shifting towards a dynamic landscape-scale perspective, this work will be critical for assessing the long-term evolutionary impacts for biodiversity.

f. **Functional species response.** Assessments of climate change impacts will be improved through functional response models based not only on distribution data (correlative) but also on an improved understanding of species biology. This will be achieved by coupling information on biogeography with data from phenology monitoring and experimentation. RBGE will continue to promote opportunities for collaborative experimental work in this field by linking science and horticultural expertise and facilities.

5.3 *Sustainable Use*

Wise exploitation of plants for future generations.

Background

Plants are an essential resource for humanity, but the speed of expansion of the global human population has led to a significant increase in biodiversity depletion and destruction. Many people in developing countries depend on their local plants for their livelihoods but burgeoning international markets are driving excessive collection, which puts pressure on wild populations, resulting in over-exploitation of trees and plants that have commercial value. Plant resources provided by the natural world cannot be renewed if they are over exploited.

The Challenges

Developing strategies for sustainable use of plants requires characterising species that are useful to humankind, identifying related species that have potential benefit, and optimising strategies for sustainable exploitation.

RBGE activities – past and present

RBGE's scientists and horticulturists record and document plant species biodiversity, develop protocols for their successful propagation and cultivation and work with partners to ensure implementation of good practice, e.g.

- The RBGE International Conifer Conservation Programme is engaged in *in situ* and *ex situ* conservation of threatened conifers worldwide.
- The Jade Dragon Field Station in Yunnan, China, is a focus for *in situ* and *ex situ* conservation of Chinese native plants from the Yulong Xue Shan that are used in Traditional Chinese Medicine.
- Research to support agroforestry in Peru.
- User-friendly field guides to tropical trees: *Sangha Trees- an illustrated identification manual*.
- Developed standard tests to screen populations of bluebell for purity prior to sustainable harvesting of seed.

RBGE activities - future

a. **Increase our collection and documentation of useful plant species, and provide tools to identify them.** We will make special efforts to tailor identification tools to their users, where necessary making them non-technical and exploiting appropriate technologies. We will also target taxonomic research on plant groups with economic uses, for example our taxonomic research on the tropical family Sapotaceae, a source of valuable timber.

b. **Building more partnerships with organisations who work to improve livelihoods via sustainable use of plant species.** For example, with organisations working in agroforestry in the tropics who need information on how to identify useful tree species in a diverse flora; through collaboration with ethnobotanists and social anthropologists.

c. **Developing further practical horticulture training programmes and delivering information about the propagation and cultivation of important species,** e.g. threatened British natives**.**

d. **Continue to link best scientific practice in conservation and sustainable use with horticultural expertise** for *in situ* and *ex situ* management.

e. **Promote further the Garden's sustainable development policy and environmental management systems within our organisation;** sustainable use to be an importance element of our education and communication programmes.

5.4 *Ecosystem Services*

The continued function of Earth's life support systems.

Background

The ability of the Earth's ecosystems to sustain future generations can no longer be taken for granted. 'Ecosystem services' represent the planet's life support systems, and include nutrient cycling, soil production and stabilisation, clean water provision, energy exchange and climate regulation. The Millennium Ecosystem assessment made clear that the last 50 years have witnessed an unprecedented degradation of natural ecosystems. Not only has this led to substantial loss of species, but also to the degradation or loss of the services ecosystems provide to us, such as clean water and food. The loss or degradation of the services provided to society by the biophysical functioning of natural ecosystems is seen as a major barrier to meeting the Millennium Development Goals, and hence is of central interest to the mission of RBGE.

The Challenges

The challenge is to slow or reverse the degradation of natural ecosystems. Our ability to do this is hampered by incomplete knowledge of individual species or species groups, and of the functional properties of those groups that contribute most to the maintenance of key ecosystem services. A major science goal underlying this challenge is the quantitative and qualitative understanding of the importance of biodiversity for maintaining various ecosystem functions, including bioclimatic and biogeochemical processes.

RBGE's taxonomic botanists already provide key baseline data such as geo-referenced herbarium records and tools to identify plants in the field without which few ecological or economic studies can proceed. However, what is required is more information and for it to be made freely available on-line. Many of the ecosystems of most interest to the Earth system science community are selected because of their large extent and high metabolic activity. Such ecosystems are also amongst the mostly poorly known taxonomically, yet RBGE has a world-class reputation and expertise in inventory and taxonomy in many of these biomes and regions.

RBGE Activities - Past and Present

Collaboration with Earth system scientists will be a new venture for RBGE. However, it represents a logical extension of our past collaborations with ecologists both in the UK and overseas.

RBGE Activities - Future

a. **Building stronger collaborative links with Earth system scientists, ecosystem scientists and social scientists** in Scotland, the UK and worldwide. Scientific links are needed so that we can maximise the impact of our existing research and living collections and develop new patterns of science through a two-way interaction, based on mutual interest. Collaboration with social scientists will enable our research programmes to address more effectively the linkages between biodiversity and ecosystem services and society, and how society can adapt to environmental change.

b. **Providing species identifications for Earth system science**. The assessment of biodiversity - in terms of genetic and species diversity and distribution - is a key element that contributes to the valuation of ecosystem services. Furthermore, all plant scientists need to know the identity of the species upon which individual measurements are made. Indeed, even the simplified process understanding embedded in current large scale vegetation-climate models is based on original species-level understanding of plant physiology. We will seek opportunities to develop identification tools for plant species in biodiverse ecosystems that are a key focus for Earth system science. This knowledge, and the methods by which it is obtained, are required to advance process-level ecological understanding of species and to inform the wider goal of understanding the role of biodiversity in the functioning of the world's most diverse ecosystems.

c. **Providing species trait information for Earth system science**. Plant functional types, which group together species based upon morphological and physiological traits, are used to understand how complex, biodiverse ecosystems are functioning in different places. We aim to collect trait data such as leaf mass per unit area, leaf thickness, and wood density, and to collect dried leaf samples for subsequent nutrient analysis as part of our field research in selected ecosystems.

d. **Use of our Living Collections as a source of functional traits and ecophysiological information.** As part of developing new collaborations with Earth system scientists and ecologists, we believe that our living collection will have wider use, for example in understanding trait plasticity under different environmental regimes, or the reflectance of different leaf types.

6. Delivering our Key Goals

Delivering this strategic plan will require investment in people, 21st Century tools and technology, and the development of new partnerships in Scotland and around the world. Communicating its relevance to policy makers, explaining our research to a wide audience, and training new practitioners will be a key focus of RBGE's communication and education programmes.

We will make the best use of RBGE's assets and resources to deliver high quality biodiversity science. In addition to continued investment in the research facilities and institutional infrastructure, the following four areas are identified as essential to the successful delivery of the key goals of our Biodiversity Strategy.

6.1 *Collections*

Conserving and developing our collections to meet the needs of biodiversity research

Background

Scotland's national collections at RBGE - the living and preserved collections, library and archives - are part of a world wide network of collections that hold critical information and resources for global biodiversity research. They are also essential tools for the delivery of this Biodiversity Strategy. Only through continued conservation of these resources and appropriate investment to develop them further and make them widely accessible, will these national collections continue to meet the needs of RBGE, science and society.

The content and management of the Living Collection is governed by the 'Collection Policy for the Living Collection' that is closely aligned to the Biodiversity Strategy. The Policy includes targets to improve the quality of the Collection and lays out standards of delivery to ensure it meets the needs of all users, but especially for research and conservation.

The main driver for the herbarium collections is identification. Identification of plants has always been a crucial requirement for humans. In the 21st century the need for identification of plants is just as crucial to our future as it has been in the past. The most important part of the identification process carried out in the herbarium is in the production of Floras, taxonomic revisions and monographs. These works cannot be produced without well curated specimens. They are the fundamental work of an institution like RBGE and they support all aspects of plant science. Herbarium collections and their associated data are of immense value to the scientific research community.

The Challenges

To gain continued support for investment in the collections we will demonstrate the critical role that the collections play in biodiversity science. By using the collections as an integral part of our education and knowledge exchange activities, we can demonstrate their value to science and society.

Herbaria have to adopt, adapt and develop new techniques and tools, such as the internet, high quality digital images and databases, to continue their fundamental centuries-old service. The data collected with herbarium specimens vary historically and the requirements of other scientists also change over time with differing research priorities - the challenge is to deliver information for these new priorities of climate change, sustainable use and ecosystem function.

We aspire to be the best interpreted botanic garden, and the quality of our collections and their interpretation are critical to this goal.

RBGE Activities - future

a. **Raising the profile of the collections among scientists and society** by developing appropriate tools and technologies to deliver information on the collections in appropriate format to meet their needs. This will include increasing the number of herbarium specimen images and associated data available on-line.
b. **Georeferencing of specimens** to ensure that co-ordinates associated with on-line images are accurate and presented in a format suitable for end users, working with ecologists, climate change scientists and molecular biologists to allow new specimens to be added in a way that maximises their requirements, continuing the cross-referencing of herbarium specimens and literature to increase the value of both.
c. **Maximising the quality of our horticulture and the plants cultivated**, matched with effective presentation, record keeping (including documentation in the cultivated herbarium), and standards of information and interpretation.
d. **Upgrading glasshouses in order to reduce energy use and provide improved facilities to maintain these important collections.**
e. **Further developing the genetic collections,**
f. **Continuing to develop and conserve our library collections, digital images and archives.**
g. **Making best use of all our collections as resources** to train the next generation of taxonomists and horticulturists as well as students of any of the huge diversity of disciplines that rely on plants.

6.2 *Tools & Technologies*

Increasing the pace of biodiversity science by development and application of tools and technologies

Background

The immediate requirement for high-quality biodiversity information to inform conservation planning precludes small-scale piece-meal approaches to biodiversity science. Instead it favours the development of rapid, high-throughput systems. Developments in molecular genetics, imaging systems and bioinformatics all represent opportunities to increase the pace of the acquisition, synthesis and delivery of plant biodiversity science.

The Challenges

There are several challenges involved in moving towards industrial scale delivery of biodiversity information. The first is to have sufficient staffing levels to undertake the collection of high quality field data and material in order to provide the samples which are the basic unit of biodiversity data. We also need to ensure that there is appropriate expertise for project design and data analysis. The second challenge is to develop efficient work flows to optimise data collection. Finally, there is a need for the development and refinement of more efficient systems in the handling and analysis of data, and subsequent automation of their delivery to users in forms tailored to their needs.

RBGE Activities – Past and Present

- Development of biodiversity database systems and informatics tools for managing taxonomic information and its subsequent delivery to end-users in various electronic and analogue forms.
- Development of user-friendly on-line identification systems.
- Research and development into novel taxonomic database systems integrated into taxonomic working practices and user interface development.
- Development and application of image capture systems for scanning herbarium specimens and valuable botanical texts to provide on-line access to our collections.
- Participation in international collaborations to develop data exchange standards and global initiatives to facilitate public access to biodiversity information.
- Making efficient use of existing laboratory facilities for the generation of molecular genetic, cytological and anatomical data.

RBGE Activities – Future

a. **Investing in high-capacity information technology systems and biodiversity informatics**. We will increase our investment in biodiversity informatics to make efficient use of the increasing volume of data produced both internally and externally. This will involve the handling of fieldwork data, collection management data, sequence data, digital images of scanned herbarium specimens, and the retrieval and management of data from on-line resources. We will continue our commitment to provide identification tools in user-friendly electronic media.

b. **Mobilise our biodiversity data for internal and external use**. We will continue to develop systems that enable rapid delivery of our biodiversity data from the point of collection to the full range of potential users. Systems will be established that enable the collection of specimen-level data and options for serving these as base-line data or synthesised reports. We will actively participate in global initiatives seeking to provide biodiversity data, and ensure that we remain aligned with future developments. Given the immediate threats to biodiversity we will seek to release data at the earliest opportunity.

c. **Developing the capacity for high-throughput sequencing**. We will capitalise on decreasing costs and increasing throughput of sequencing

technologies to routinely sequence all plant specimens collected as part of RBGE fieldwork programmes. This will involve a combination of in-house robotics for sample preparation, and external sequencing facilities. We will make sequence data available on-line to support global initiatives (e.g. the International Barcode of Life Project and the Assembling the Tree of Life Project) and enable use by our in-country partners. We will use next-generation sequencing technologies for evolutionary research, and will develop appropriate partnerships to handle the avalanche of data these technologies produce.

6.3 *Communicating and Educating*

Putting knowledge to work and training others - Knowledge exchange.

Background

We live in an information age where people have ever-increasing access to knowledge in print and electronic forms. Despite this, effective planning in biodiversity management and conservation is frequently hampered by a lack of accurate information on what plant species exist, what their names are, where they are found, in what habitats they grow, and how they can be cultivated. We recognise the importance of providing such authoritative biodiversity information and independent advice to the biodiversity community, policy makers and to a broad range of end users, and the need to work closely with end users to ensure that our outputs have maximum value. The lack of information about species, and limited access to professional training in taxonomy, identification and horticulture, are also limiting factors in the race to conserve the world's plant biodiversity. RBGE undertakes many activities in this area, both formal and informal: lectures, workshops, and other training events, tertiary education and adult classes. Effective communication is crucial to all that we do and we aspire to project our science into society both at home and internationally.

The Challenges

The better informed the public are on the major environmental challenges, the more they will support the goals of RBGE, and increase our ability to address these challenges. The way that RBGE addresses these will be an essential element of our education programmes. Our exhibitions, interpretation, events, media activities and marketing will reflect our strategic goals, and seek to engage audiences with the natural world.

There are also growing needs for access to reliable biodiversity data, and we will be at the forefront of information delivery. We will tailor our knowledge dissemination to meet the needs of governments, policy makers, and conservationists to ensure that society can ultimately reap the benefits of advances in plant biodiversity research.

RBGE activities - future

a. **Working closely with partners to meet their requirements**. To broaden the application of our research and ensure that our outputs make an effective contribution.

b. **Engage with end-users to meet their requirements**. To ensure that we respond to the needs of specialists and the general public, and deliver our data and research efficiently and in the most appropriate formats.

c. **Effective use of media for promotion -** highlight our biodiversity activities that meet the major environmental challenges, with special promotion of a selection of 'flagship' projects with particular public interest.

d. **Embed the communication of taxonomy, conservation and biodiversity within all of our education programmes** - focussing on the work directed towards sustaining biodiversity.

e. **Continue to develop and promote our practical training programmes** for outreach in the UK and capacity building overseas, maintaining our status as one of the world's leading trainers in horticulture and botany.

f. **Effective use of our publications for communicating biodiversity issues** and the work that we are directing towards these.

g. **Maximise our visitor experience and effective use of interpretation** for the promotion of our responses to the Global Environmental Challenges.

h. **Concerted effort to increase the number of overseas participants in education activities.**

6.4 *People*

Investing in people to deliver world class biodiversity research

Background

We will maintain and seek to increase staff numbers to deliver key goals and will develop the skills of our expert staff within RBGE so that they are empowered to deliver the highest quality biodiversity research and communication. RBGE plays a crucial role in the development of the next generation of biodiversity workers in science and horticulture, especially through its acclaimed BSc, MSc and PhD programmes.

The Challenges

We will provide staff with appropriate training and career structure to help them grow in their roles. RBGE is often praised for its close links between Horticulture, Science and Education, and we must continue to promote this broad way of working and develop opportunities for interdisciplinary research across the organisation. Opportunities to appoint new staff are rare, and it is vital that these are used wisely. New posts need to be directed towards identified knowledge or skills gaps in strategically important research areas, and we must attract the best people. Key to this are competitive terms and conditions and excellent career development. A priority is the development of sustainable research teams within RBGE. Continuity planning is needed to maintain key areas of expertise that may be lost through retirement. Other elements concerned with Human Resources, Health and Safety etc., are covered in the Corporate Plan.

RBGE activities - future

a. **Retaining our focus in Investors in People.**
b. **Reviewing staff training provision -** to ensure that people have the skills base to meet our needs and increase opportunities for career development.
c. **Continuity planning for staff members retiring within the next five years** where their areas of expertise are critical to delivering the strategic goals.
d. **Promotion of cross divisional collaboration of staff**.
e. **Development of graduate and postgraduate research through BSc, MSc and PhD students.** Working in collaboration with University of Edinburgh, and other UK and international universities.
f. **Enthusing the public about taxonomy and biodiversity and training the next generation of practitioners via our communication, education and volunteer programmes.**

6.5 *Partnerships*

New and stronger local, national and global collaborations.

Background

The global environmental challenges that threaten planet Earth are complex and solving them will require multi-disciplinary, international studies. Partnerships are not restricted to scientific research links, but also encompass engaging with governments and the public. It is only by working in partnership with our wider audience that we can earn their support, meet their needs, communicate effectively and ultimately be successful in our goals.

The Challenges

RBGE recognises its key skills in biodiversity research as a major contribution to collaborative projects and initiatives addressing global environmental challenges. However, resources will limit what we can achieve and we must prioritise our work towards our strategic goals if we are to be successful. We remain committed to strengthening our links with our many stakeholders, promoting communications and open dialogue to help inform our research. Partners should be involved at all stages, from project formulation to completion. Participation in national and international review panels and advisory boards is important for raising our profile, but also ensures that our research and expertise are used at the highest decision-making level.

RBGE future activities

a. **Strengthen our partnerships at home** through the Scottish Biodiversity Strategy with government organisations, scientific institutes and NGOs (e.g. SNH, SEPA, MRPs, RERAD, DEFRA, DFID, NERC, BBSRC, EU); through partnership we will seek to influence the strategic direction of funding bodies.
b. **Strengthen our partnerships abroad** through formal memoranda of understanding with government organisations and scientific institutes. Through

partnership we will seek to influence practical outcomes for policies on conservation and sustainable development.

c. **Improving collaborative links with scientists in the UK and overseas.** Including understanding their research better and how we can link with this. Early stage interaction at the formulation stage of new research projects.

d. **Participation on review panels and advisory boards.** Membership of high-level groups and contributing to international reports and agreements (e.g. SBSSTA, GSPC, UK BRAG, research council panels and advisory groups), and peer review.

e. **Participation on international journal and Flora editorial boards.**

f. **Engaging more closely with the public** through the quality of the horticulture on display, the range of plants cultivated, the quality of the visitor experience, the quality of the exhibitions and interpretation and the quality of educational programmes on offer.

Appendix 1. Priority areas of research for RBGE

The Strategy for Science for 2004-2009, "*Delivering biodiversity science to underpin conservation*" set out three over-arching strategic objectives:

- Conserving plant biodiversity in the face of global environmental change and mass extinction,
- Provision of baseline taxonomic/botanical data as a foundation science,
- Understanding the evolutionary processes that have given rise to the world's botanical diversity.

It identified five cross-cutting research themes:

- Describing the biodiversity of species and habitats within important ecosystems and contributing towards completion of the inventory of life on earth,Evaluating the major threats to biodiversity and undertaking research to provide authoritative data to underpin and determine optimal conservation strategies,
- Developing methodologies to synthesize biodiversity knowledge and transfer it to a broad range of technical and non-specialist end users,
- Reconstructing phylogenetic histories of species to establish the patterns and processes responsible for the evolution of plant biodiversity,Evaluating the conditions under which population divergence and speciation occurs;

and it defined four major research programmes with defined priorities (Figs 1 & 2 below), ensuring complementarity with other UK taxonomic institutes. The priority research areas will be the framework for delivery of the Biodiversity Strategy 2010-2015.

Programme 1: Major Floras
Aim: To undertake floristic studies of botanically important regions in Asia and develop innovative bioinformatics methods of dissemination of floristic information to a range of end-users, including other taxonomists, ecologists and conservationists, and especially national governments to assist them in meeting targets derived from the CBD.

Programme 2: Tropical Diversity
Aim: To describe biodiversity in the tropics concentrating on widely distributed and species-rich genera and high priority conservation areas, and to elucidate the evolutionary processes giving rise to this biodiversity.

Programme 3: Cryptogamic Plants and Fungi
Aim: To describe the biodiversity of cryptogamic plants and fungi, to elucidate the evolutionary processes giving rise to this biodiversity, and assess threats and devise strategies for conservation.

Programme 4: Genetics and Conservation
Aim: To elucidate the population genetic processes underlying the evolution of plant biodiversity in high conservation priority groups and to devise practical strategies to contribute towards their conservation.

Fig. 1 **SCIENCE RESEACH OVERVIEW**

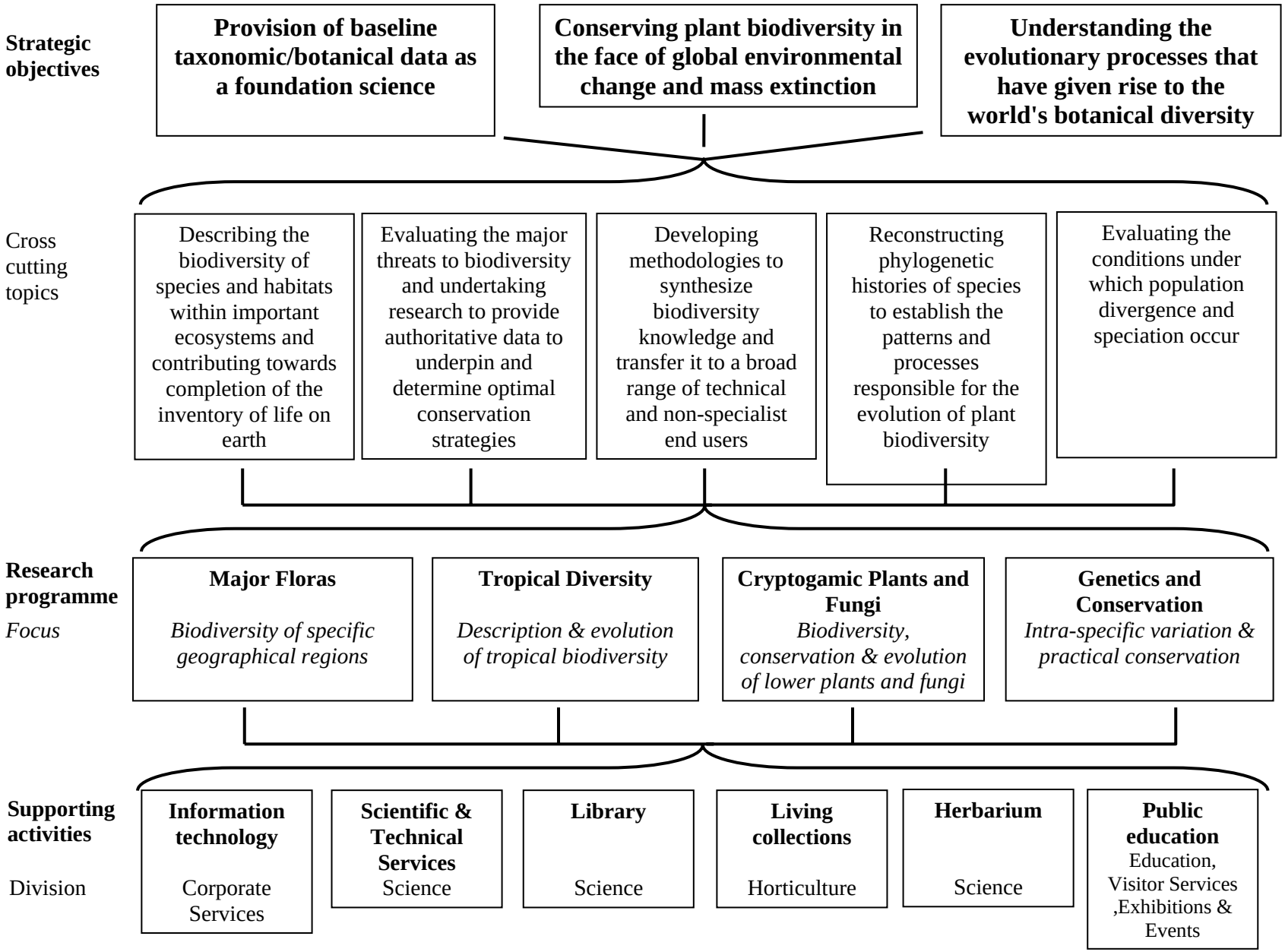

Fig. 2. **RESEARCH PRIORITIES**

Programme	**Major Floras**	**Tropical Diversity**	**Cryptogamic Plants and Fungi**	**Genetics and Conservation**
Focus	*Biodiversity of specific geographical regions*	*Description and evolution of tropical biodiversity*	*Biodiversity, conservation and evolution of lower plants and fungi*	*Intra-specific variation and practical conservation*
Priority Projects	• Floristic research in Nepal • Floristic research in SW Asia • Biodiversity informatics • Herbarium and Archive Collections of India	• Inventory research in threatened areas • Monographic and phylogenetic research on key families (*Begoniaceae*, *Gesneriaceae*, *Sapotaceae*, *Zingiberaceae*) • Environmental change and biogeography • Evolutionary development	• Scottish/UK cryptogamic biodiversity, and conservation biology • Taxonomy and floristics of cryptogamic plants and fungi • Phylogeny and speciation in cryptogamic plants and fungi	• Molecular ecology • Conservation and ecology • International conifer conservation programme

Appendix 2. National, international and intergovernmental reviews, policies and treaties that drive RBGE's biodiversity research

1. The Convention on Biological Diversity (CBD) (1992) is an international treaty to sustain the diversity of life on Earth and is dedicated to promoting sustainable development. It addresses a range of cross-cutting issues and a thematic programmes that a relevant to the work of RBGE. Key cross cutting issues include:

a. *Global Strategy for Plant Conservation (GSPC) 2002*

RBGE was a partner in the development of the GSPC through *The Gran Canaria Declaration* (2000) and is actively contributing to 12 of the 16 targets for conservation, both in the UK and internationally. The targets fall into three main categories:

i. Understanding and documenting plant diversity,
ii. Conserving plant diversity,
iii. Using plant diversity sustainably,
iv. Promoting education and awareness about plant diversity,
v. Building capacity for the conservation of plant diversity.

More recently RBGE has contributed to the development of *The Gran Canaria Declaration II* (2006) on climate change and plant conservation.

b. *The 2010 Biodiversity Target (2002)*

The Parties to the Convention committed themselves **to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth.**

c. *Global Taxonomy Initiative*, *c*onfronting the taxonomic impediment to biodiversity conservation.

d. *The ecosystem approach*, a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

Specific themes include *Island biodiversity* and *Mountain biodiversity*.

The CBD informs policy at both the international level and national level. In response to the CBD the UK Government, in consultation with conservation bodies, developed *UK Biodiversity Action Plans* (UK BAPs) (mid 1990s) and *Plant Diversity Challenge* (2004) – the UK's response to the Global Strategy for Plant Conservation. With devolution, RBGE has contributed to the development of and helps deliver the *Scottish Biodiversity Strategy, 'It's in your hands'* (2004). A report of progress was published in 2007 (*Scottish Biodiversity Strategy, 'It's in your hands'. A progress report 2005-2007*).

2. House of Lords Reports: Science and Technology Committee

'*Systematics and Taxonomy: Follow-up*' (2008)
'*What on Earth? The threat to the science underpinning conservation*' (2002)

'Systematic Biology Research'. -the 'Dainton Report' (1992)

The 2008 report follows two earlier reports in 1992 and 2002 that have all addressed the issue of taxonomy and systematics in the UK, and the ability of the UK to deliver national and international biodiversity targets on conservation despite loss of expertise through retirement, little recruitment, and the loss of this discipline across the university sector. The taxonomic institutes, and particularly RBGE, play a key role in this area.

3. The Millennium Ecosystem Assessment (2005) and particularly the Biodiversity Synthesis Report provides a valuable resource for putting biodiversity conservation into practice.

4. Climate change

The impact of climate change on biodiversity has been recognised to be of great relevance to CBD targets, including the effect on 2010 targets, both at the local scale and internationally, and recognising that the greatest impacts of climate change will fall on those least able to deal with them.

The following reviews and reports have relevance for RBGE's work:

2006 Stern Review on the Economics of Climate Change

2007 Intergovernmental Panel on Climate Change (IPCC), 4th Assessment Report

2006 *The Gran Canaria Declaration II* on climate change and plant conservation(as discussed above)

5. Within Scotland, our work addresses:

Scottish Government Strategic Objectives* - particularly 'Smarter' and 'Greener'

Scottish Government National Outcomes* - particularly 'Research and Innovation' and 'Environment'

Scottish Government 'A Framework for Science in Scotland', 2008

A Coordinated Agenda for Marine, Environment and Rural Affairs Science (CAMERAS) (2011-2016)

Strategic Research for SEERAD, Environment, Biology and Agriculture 2005 – 2010

RBGE is a partner in the delivery of Programme 3: *Environment, land use and rural stewardship*, contributes to the cross cutting themes of *Climate Change* and *Protecting Biodiversity*, and is the sole contributor to the *International Biodiversity* programme.

Scottish Government's Ministerial Priorities for RBGE*

National Heritage (Scotland) Act, 1985*

Nature Conservation (Scotland) Act, 2004

2007-2017 Living With Environmental Change (LWEC)

Scottish Biodiversity Strategy (see 1. above)

*for details see RBGE's Corporate Plan