BGjournal

Journal of Botanic Gardens Conservation International

Volume 4 • Number 2 • July 2007

Special 2007 anniversary issue

Botanic gardens and climate change

20 YEARS 1987-2007

BGCI

Editors: Etelka Leadlay and Sara Oldfield

Co-editor: Suzanne Sharrock

Cover Photo: Species such as the Quiver Tree (*Aloe dichotoma*) are under threat due to the impact of climate change (see page 36) (Photo: Nicholas Wray)

Design: John Morgan, Seascape
E-mail: studio@seascapedesign.fsnet.co.uk

Submissions for the next issue should reach the editor before 8th October, 2007. Please send text on diskette or via e-mail, as well as a hard copy. Please send photographs as original slides or prints unless scanned to a very high resolution (300 pixels/inch and 100mm in width); digital images need to be of a high resolution for printing. If you would like further information, please request *Notes for authors.*

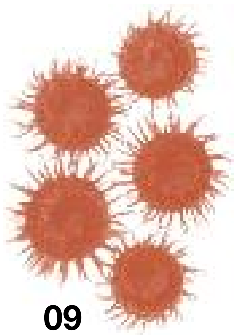
BGjournal is published by **Botanic Gardens Conservation International (BGCI)**. It is published twice a year and is sent to all BGCI members. Membership is open to all interested individuals, institutions and organisations that support the aims of BGCI (see page 32 for Membership application form).

Further details available from:
- Botanic Gardens Conservation International, Descanso House, 199 Kew Road, Richmond, Surrey TW9 3BW UK. Tel: +44 (0)20 8332 5953, Fax: +44 (0)20 8332 5956 Email: info@bgci.org, www.bgci.org
- BGCI-Russia, c/o Main Botanical Gardens, Botanicheskaya st., 4, Moscow 127276, Russia. Tel: +7 (095) 219 6160 / 5377, Fax: +7 (095) 218 0525, E-mail: seed@aha.ru, www.bgci.ru
- BGCI-Netherlands, c/o Delft University of Technology Julianalaan 67, NL-2628 BC Delft, Netherlands Tel: +31 15 278 4714 Fax: +31 15 278 2355 email: l.j.w.vandenwollenberg@tudelft.nl www.botanischetuin.tudelft.nl
- BGCI-Canarias, c/o Jardín Botánico Canario Viera y Clavijo, Apartado de Correos 14, Tafira Alta 35017, Las Palmas de Gran Canaria, Gran Canaria, Spain. Tel: +34 928 21 95 80/82/83, Fax: +34 928 21 95 81, E-mail: jmlopez@grancanaria.es
- BGCI- China, 723 Xingke Rd., Guangzhou 510650 China. Tel:(86)20-37252692. email: Xiangying.Wen@bgci.org www.bgci.org/china
- BGCI – South East Asia, c/o Registry, Singapore Botanic Gardens, 1 Cluny Road, Singapore 259569. Email: Bian.Tan @bgci.org,
- BGCI-Colombia, c/o Jardín Botánico de Bogotá, Jose Celestino Mutis, Av. No. 61-13 – A.A. 59887, Santa Fe de Bogotá, D.C., Colombia. Tel: +57 630 0949, Fax: +57 630 5075, E-mail: jardin@gaitana.interred.net.co, www.humboldt.org.co/jardinesdecolombia/html/la_red.htm
- BGCI-Deutschland, c/o Botanische Gärten der Universität Bonn, Meckenheimer Allee 171, 53115 Bonn, Germany. Tel: +49 2 2873 9055, Fax: +49 2 28731690, E-mail: biogart@uni-bonn.de

BGCI is a worldwide membership organization established in 1987. Its mission is to build a global network for plant conservation. BGCI is an independent organization registered in the United Kingdom as a charity (Charity Reg No 1098834) and a company limited by guarantee, No 4673175. BGCI is a tax-exempt (501(c)(3) non-profit organization in the USA and in Russia.

BGjournal replaces *BGCNews* and is published twice a year. *BGjournal* has been given a new name as the news section of *BGCNews* and *Roots* (Botanic Gardens Conservation International Education Review) is now contained in *Cuttings* which is published quarterly. There are 31 issues of *BGCNews* published twice yearly from 1987-2003.

Contents


09


03


22


17


26


30

Editorial - Responding to climate change

Climate change is now generally accepted to be one of the big challenges of our time. Steps to mitigate and adapt to new and often dramatic climatic conditions are being widely debated and encouraged by politicians and the media. Environmentalism is fashionable but still the value of maintaining plant diversity is not given the attention it deserves. Explaining the links between plant diversity, ecosystem functions and the global climate is a key role for botanic gardens. At the same time safeguarding plant diversity in the face of increased environmental threats is ever more important.

In this issue of *BGjournal* the impact of climate change on plant species in various parts of the world is described and the responses that can be made by botanic gardens are considered. It is vital that we act and demonstrate the actions that are being taken so that the work of botanic gardens is seen as relevant and part of the solution. BGCI is developing major initiatives in response to climate change and these are set out in our new Five Year Plan 2007-2012 (see BGCI website). Facilitating exchange of ideas and expertise between our global membership and associated botanic garden networks remains invaluable in delivering the Plan. Climate change was certainly a key topic for discussion at the highly successful 3rd Global Botanic Gardens Congress held in April this year and some of the papers presented here result from these discussions.

Provision of accurate information on the impact of climate change on wild plants will be crucial to guide and prioritise conservation action. BGCI is preparing a baseline report on this topic that will be available by the end of this year. The baseline report will be made available to policy makers and will be used to develop a response to climate change within the framework of the *Global Strategy for Plant Conservation* (GSPC).

It is likely that increasing political and popular attention will focus on biodiversity and its relationship to climate change in the run up to the 2010 Biodiversity Target, "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". We have to ensure that plant diversity is at the forefront of discussions. The successful implementation of the GSPC, building on five years of successful initiatives to promote and implement the targets, will help to ensure the security of the world's vegetation and thereby reduce the amount of carbon emissions significantly. Professor Stephen Hopper, Director of the Royal Botanic Gardens, Kew has pointed out that conserving the world's natural vegetation will reduce carbon emissions by an amount more than equivalent to those generated by the world's combined transport systems.

Using the baseline report as a starting point, BGCI is also planning a web-based information service on the impact of climate change on wild plants. This will link with our PlantSearch database, providing information on threatened plants likely to be at most urgent risk as a result of increasing temperatures, rising sea levels, altered hydrological patterns and other consequences of changing climatic conditions. The information service will be designed to provide clear messages and resources for the education and public awareness work of botanic gardens and to highlight ongoing activities around the world that people can get involved in.

There is much that we can all do to decrease our carbon footprints and BGCI is reviewing its own internal policies to make sure that we minimise our impact. We welcome suggestions and ideas to guide our review and look forward to working with all our members in addressing the challenge of climate change.

Sara Oldfield
Secretary General, BGCI

Author: David Bramwell

The response of botanic gardens to climate change

During the last 30 years or so, botanic gardens have modernized their outlook and their fundamental role to become increasingly active in the conservation of plant diversity. As a response to the biodiversity crisis as envisaged during the last two decades a considerable number of gardens have developed programmes of research, horticulture and environmental education particularly dealing with the conservation of rare and threatened species. Indeed, botanic gardens now have much to offer the conservation world not only as the principal centres for *ex situ* conservation but also as supporting institutions for the conservation of plants *in situ*. Many gardens have developed not only living collections but also important germplasm banks or seed banks for the long-term storage of threatened plants as an insurance policy against extinction.

With the development of BGCI, Botanic Gardens Conservation International, the world's botanic gardens have also become a major voice for plant conservation in the international forum. This has been demonstrated by the lead taken by botanic gardens in the development of *The Gran Canaria Declaration calling for a Global Program for Plant Conservation* (BGCI, 2000) which resulted in the *Global Strategy for Plant Conservation* (CBD, 2003). *The Global Strategy* proposed a number of conservation targets to be achieved by the year 2010. Many of which have direct relevance for botanic gardens and in many countries gardens have made a major effort to progress towards these objectives. However, there is concern that now, in the middle period for achieving the targets, a new challenge has to be faced, climate change, that was not originally a major element of the *Global Strategy*.

This new, most alarming threat to plant conservation, global climate change or more popularly "global warming" has come on to the scene since the *Global Strategy* was developed over five years ago. The world is changing and probably more quickly than at any time in human history and the most disruptive and perhaps least predictable alteration concerns the potentially disastrous effects of a rapidly changing global climate. There has been major governmental activity and alarm over the probable consequences of climate change. For instance, the *Stern Review on the Economics of Climate Change* for the British Government has really helped to focus on the need to take urgent, immediate measures (Stern, 2006). However, when the *Global Strategy* was originally developed, climate change was an issue to be resolved and reversed by the control of greenhouse gas emissions and the major emphasis was on the Kyoto Accord under which governments would take the necessary measures to limit their emissions. Over the past two or three years, however, the real extent of the problem is beginning to be understood and the fact that the weak measures that came out of Kyoto are not sufficient to prevent changes which potentially will be devastating for plant diversity and biological diversity in general. The Kyoto measures are, indeed, even if they were fully implemented, not sufficient to reverse climate change. The new challenge is, therefore, about how the *Global Strategy* and national strategies are taken forward for plant conservation in the face of such potentially devastating change.

Left: Gran Canaria Group of international experts who formulated a second *Gran Canaria Declaration on Climate Change and Plant Conservation* in Las Palmas de Gran Canaria, April, 2006

The most recent models based on a temperature rise of 2-3°C over the next 100 years suggest that up to 50% of the 400,000 or so higher plant species will be threatened with extinction. Furthermore, a recent study of six biodiversity-rich regions of the world covering 20% of the land area indicates that up to 37% of all species in these regions will be extinct by 2050 including for example up to 40% of South Africa's Proteaceae (Thomas *et al*., 2004). Models by Carlos Nobre from Brazil suggest that the wet tropical forests of the Amazon Basin will all but disappear with huge losses of biodiversity (2004). In Africa, Lovett and his fellow researchers predict that the tropical forests of west and central Africa will be seriously affected and that between 50 and 80% of species will have their range severely reduced, many to the point of extinction (Lovett *et al*., 2005; McClean *et al*., 2006). A recent report on the effects of climate change on the tropical rainforests of northern Queensland, Australia states that "the impact on biodiversity is likely to be very serious and could be catastrophic under some scenarios" (Krockenberger *et al*., 2004). It goes on to say that "Research, based on current models, shows that many species of animals and plants are at highly increased risk of extinction as a result of climate change, even under the least extreme of scenarios". Even a 1°C rise in temperature will cause a decline of 50% of the taxa in the area occupied by the highland rainforests of Queensland. The Queensland report goes on to make a very important and relevant statement for botanic gardens with respect to the conservation of biodiversity under such circumstances, "consideration of climate change may show that *ex situ* is the only realistic tool for some of the most at-risk species….". Some examples of the predicted impacts of climate change at the species level are shown in Box 1.

Box 1. Some examples of the predicted impacts of climate change at the species level

A European research group developed a model called "EUROMOVE" which used climate data from 1990 to 2050 as compiled from the IMAGE 2 model, and determined climate envelopes for about 1400 plant species by multiple logistic regression analysis. The climate envelopes were applied to the projected climate to obtain predictions about plant diversity and distributions by 2050. The results indicated that the species show differing responses to the forecasted climate change. For some species, their total area will increase while for other species their area will decline. Some examples include:

- *Scleranthus perennis* (Perennial Knawel), a perennial herbaceous plant of the carnation family with a European distribution will potentially undergo dramatic area reductions, with only 59% of its current distribution area remaining. The species will remain only in the centre of Central Europe, and will disappear from large parts of its distribution area in western Europe and western Russia. Its northern distribution area will slightly expand, mainly in the southern part of Finland.

- *Botrychium lunaria* (Common Moonwort), a Dutch red list species with an Atlantic and northern distribution is predicted to decrease dramatically by 2050 and it is calculated to remain in only less than half of its current area (47%). Hardly any new areas become suitable by 2050, and *Botrychium lunaria* will retreat into western Scandinavia, Iceland, Scotland, and the Alps.

- *Parietaria judaica* is a Mediterranean species growing on walls along the Atlantic and Mediterranean. Its climatically suitable area will remain largely unchanged (93%); calculations predict a potential increase of its current area (128%), primarily extending eastward into Germany and Denmark. *Parietaria judaica* is predicted to disappear from southern Portugal and Spain.

Bakkenes, M., Alkemade, J. R. M., Ihle, F., Leemans, R. and Latour, J. B., 2002. Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. *Global Change Biology* **8**: 390-407.

Thus, faced with climate change and the prospect of mass extinction of biodiversity, it is necessary to see plants not only as essential components of ecosystems but also as the most important natural resources for the future of mankind. It is necessary to face up to the major problems of conserving ecosystems in a changing environment and, at the same time make sure that the individual components of the ecosystems are not lost, that is the species. There are no ecosystems without species! Therefore, botanic gardens need to be very concerned with creating reserve collections *ex situ* as an insurance policy for facing the effects and the impacts, on local human communities of drastic environmental change and the depletion of their currently available plant resources (Bramwell, 2006).

The challenge for botanic gardens is: how do they contribute to this species-based insurance policy in the coming years and after 2010 when the *Global Strategy* achievements will be reviewed? The *Global Strategy* gives many of the guidelines needed but in the light of the new challenge of climate change the members of the Gran Canaria Group of international experts who produced the first *Gran Canaria Declaration* leading to the *Global Strategy* have formulated a second *Gran Canaria Declaration on Climate Change and Plant Conservation* and are currently engaged in preparing an action plan to facilitate the adaptation of current plant conservation policies to meet this challenge (BGCI & Cabildo de Gran Canaria, 2006). BGCI surveyed its member gardens on their response to climate change for this meeting and the main results are given in Box 2.

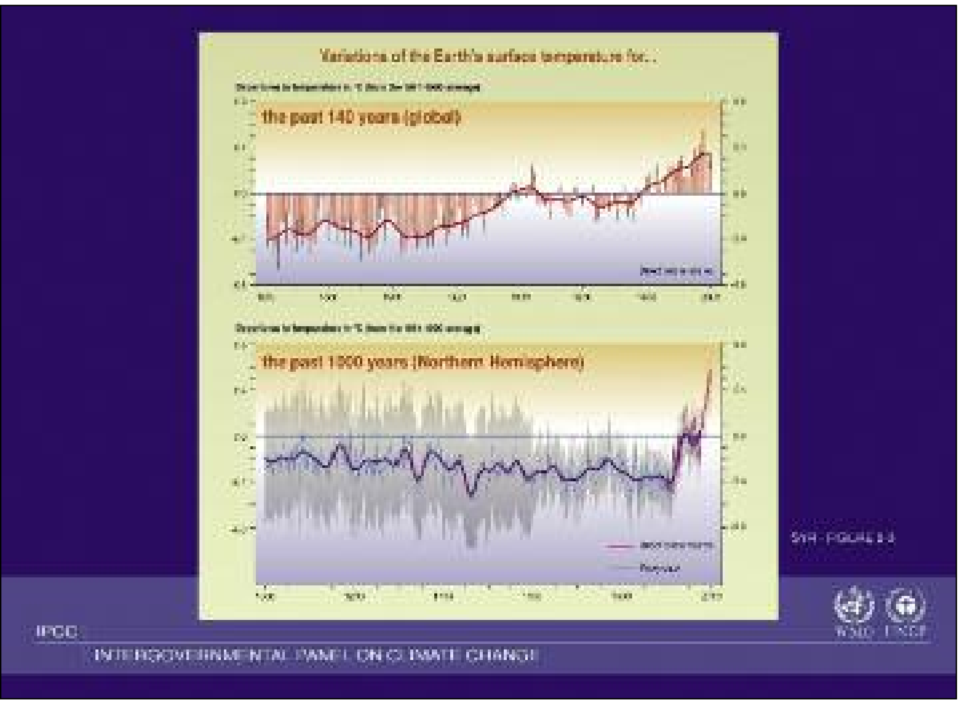
The first major step is to redefine the priorities. Current thinking on endangered species is anchored to the assignment of IUCN Red List Categories. Thus the principles for assessing the conservation status and extinction risk for species are based on past and current areas of distribution and on the fluctuation of numbers of individuals and populations. With climate change, however, plants will be faced with a whole new series of threats and current concepts of what are threatened species and how they are defined will need to be completely reconsidered and revised! Without doubt botanic gardens will have a major role in adapting both science and living collections to the new climate change situation. They form a unique international network of over 2500 plant-orientated institutions throughout most countries of the world and they have amongst their numbers some of the world's leading plant research centres, for example the Royal Botanic Gardens, Kew, UK (RBG), the Botanic Gardens Trust, Sydney, Australia and Missouri Botanical Gardens, USA.

Above: *Echium wildpretii* Barcelona Botanic Garden, Spain. Canary Island endemic (Photo: BGCI)

Many other gardens are also moving very quickly towards becoming important regional and local focal points for conservation-orientated plant research. Botanic gardens are visited by several hundred million people each year making them probably the principal public interface for connecting with plant conservation and for environmental education in general.

Climate change is taking place quickly and the recent meeting of the Gran Canaria Group, leading to the second *Gran Canaria Declaration*, calls on governments to take urgent action to protect plant diversity from the threats of climate change. The group emphasized, in its discussions and report, the increasing importance of *ex situ* conservation as a means of saving vital natural resources for the future. The role of botanic gardens as centres of *ex situ* conservation was also recognized, not only as repositories for living collections but also through their historical relationship with seed storage and exchange. Many gardens round the world have developed effective seed banks for conserving germplasm of wild plant species and the establishment of more regional and local seed banks in botanic gardens is strongly advocated. Perhaps the most important one to date is RBG's Millennium Seed Bank, a major investment for the long-term future of plant diversity (see article in this issue of *BGjournal*). However, even some smaller gardens have important regional seed banks and participate in regional programmes such as the European Native Seed Conservation Network (ENSCONET) (ENSCONET, 2007). In Spain, there are good regional examples, the Andalusian seed bank at Cordoba Botanic Garden (Hernández Bermejo & Clemente Muñoz, 1996), an inter-regional network of Mediterranean Seed Banks (GENMEDOC) (GENMEDOC, 2007) and the Macaronesian Islands Regional Seed Bank (BASEMAC) at the "Viera y Clavijo" Garden on Gran Canaria with its partner centres on Madeira and on Faial in the Azores (Roca Salinas *et al*., 2004; Bramwell, 2007). If adapting to climate change is to be successful, however, current seed-bank partnerships need to be developed into a worldwide network of seed banks with the objective of conserving the seeds of wild plants on a global scale. This would be a major contribution to conservation and the custody of natural resources in the post 2010 climate change circumstances when increasing global population and reduced available natural resources will undoubtedly sooner or later precipitate a major survival crisis for large parts of humanity. The building of such a network should be one of the major objectives between now and 2010 and then beyond.

In a future world where vegetation and whole ecosystems will be changing and will generally be depleted by climate change, such a global reserve of germplasm of wild plants will be vital for human adaptation through restoration, reintroduction and even for the total replacement of lost ecosystems. Germplasm banks will also be a source of plants and genetic diversity for the development of new crops and for the adaptation of old ones, for medicinal plants, green energy sources and other uses. If, as currently predicted, large numbers of species do become extinct in the wild then the world's seed banks, will become the only source to humankind of those species and their germplasm in the future.



Left: Variations of the Earth's surface temperature for the past 140 years (global) and the past 1000 years (Northern Hemisphere) Source: Intergovernmental Panel on Climate Change (see page 36)

There are schools of thought that consider that in some situations, the migration of plants will mitigate the effects of climate change. However, both the time scale for migration and factors such as natural barriers,

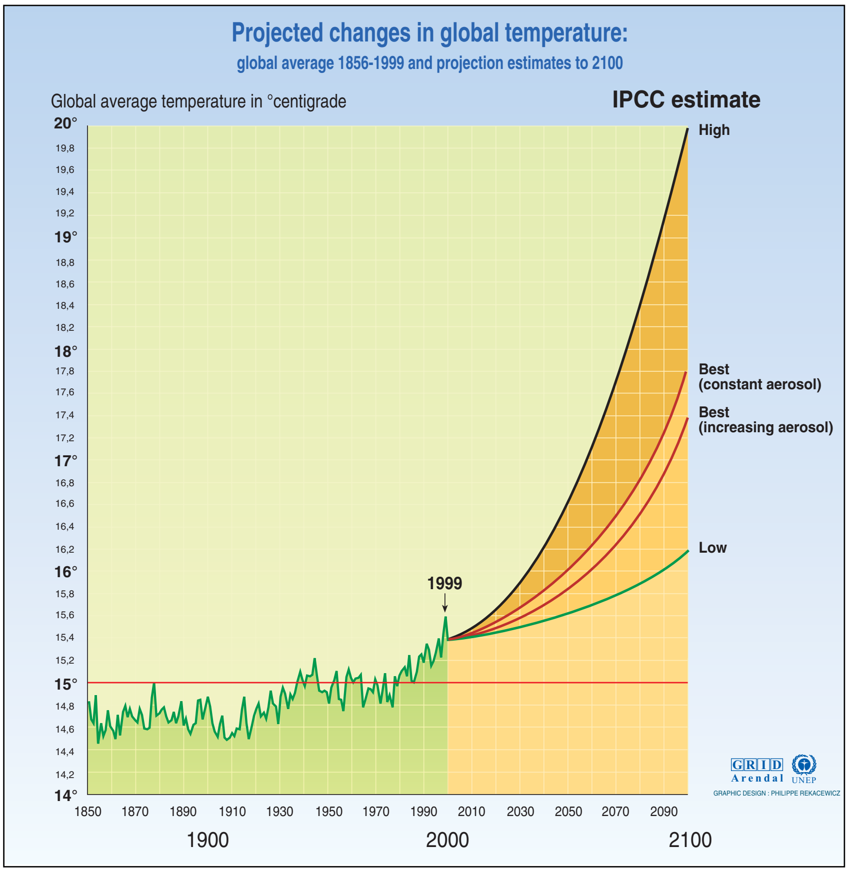
Right: Seed capsules in the seed bank of the Jardín Botánico "Viera y Clavijo" – an insurance policy for the future (Photo: BGCI)

Far right: Botanic gardens, the main interface between plants and the public (Photo: David Bramwell)

dispersal mechanisms, absence of pollinators, absence of available area for colonization, sea level rise as well as man-made barriers such as agricultural zones and urban sprawl as poor people migrate to the cities will put severe limitations on both the natural movement of plant communities and on the creation of major migratory corridors. The movement of seed and living plants through seed banks and botanic gardens has the potential however, to become one of the most important man-made "migratory corridors" for the re-establishment of plant communities in the future (termed an *assisted migration* process by the author). In many cases it will probably be the only way of moving even the most basic set of species for any community restoration and as a source of natural resources for adaptation to new circumstances. Certainly the experience and skills that botanic gardens staff have acquired over several centuries of growing both native and exotic plant species will be of vital importance if assisted migrations are to succeed.

A second area in which botanic gardens can play a major role is in the local monitoring of the effects of climate change. Many gardens have, over the years, accumulated a considerable amount of information about their local or regional floras. This information will become increasingly valuable as the local effects of rising temperatures are observed and, if possible protective measures initiated. Species distribution, vegetation maps and plant community data can all play a major role in monitoring change. As more and more research potential and economic resources at universities are taken up by molecular studies and biochemistry, botanic gardens are becoming the only sources (even the last bastions) of whole plant biologists, taxonomists and field ecologists for the future. This lack of foresight by universities and research councils in the majority of developed countries can only become an acute problem in the years to come. Currently, molecular biology might seem a more exciting area for research and it doubtless has a value in the advancement of science, but its emphasis, even its hegemony to the detriment of whole-plant science, taxonomy and field ecology, will not contribute to the practical future of humanity in the face of global climate change.

However, much more accurate and refined climate change models on a local or regional scale will be needed because corrective measures for the conservation of floras and ecosystems will have to be taken at these levels. This implies that the role of botanic garden taxonomists and field botanists will become more and more important for monitoring changes in vegetation distribution, species composition in



Right: Projected Changes in global temperature: global average 1856-1999 and projection estimates to 2100 Source: Climatic Research Unit, University of East Anglia, Norwich, UK. Projections: IPCC report 95 (see page 36)

Box 2. Climate change: the botanic garden response

BGCI undertook a survey of its members in November 2005. The following questions were asked:

- Does your institution maintain meterological or phenological records?
- Is your garden involved in any research on plants and the impact of climate change?
- Have you modified your planting schemes in response to climate change?
- Is your garden involved in any public awareness or education activities on this topic?
- Are you undertaking any steps to reduce or off-set carbon dioxide emissions?

A more recent survey (2007) has indicated that 88% of gardens responding are taking, or plan to take action related to climate change.

Summary of results

Maintenance of meteorological or phenological records and monitoring

Phenological records are being collected by botanic gardens around the world, including gardens in Europe, North America, China, Kazakhstan, Bangladesh, Indonesia, Mexico, Malaysia and Russia. Many gardens also maintain meteorological records, often going back over long periods of time. For example, Bogor Botanic Garden in Indonesia has kept records for more than 30 years as has the Botanic Garden of the Institute of Crop Botany in Bangladesh. In Austria, the University Botanic Garden, Innsbruck has kept meteorological records at its main Botanic Garden (600m) since 1995 and at the Alpine Garden (1950m) since 1994. Furthermore, the Landesmuseum Kärnten in Austria stores a series of photos of the Carinthian Alps mountain tops, which clearly shows glaciers receding. In addition, the Regional Botanic Garden of *Cadereyta* in Mexico has observed its local alpine region getting warmer and drier. For example, the cactus *Thelocactus leucacanthus* was previously reported as occurring at a maximum height of 1900m, but has recently been recorded at 2600m. Similarly, the Botanic Garden at Syktyvkar, Russia, has noted a change in tree development and life history that was previously constrained by the long period of extreme cold e.g. *Quercus robur* usually bears fruits only once every 4-5 years, but this recently occurred in both 2004 & 2005.

Research

Many examples were cited, including:

- The Argotti Gardens in Malta is involved in research on the drought resistant conifer *Tetraclinis articulata*.
- Kings Park and Botanic Garden, Australia are carrying out research on the drought tolerance of rare and threatened plants.
- The Forest Research Institute, Malaysia is assessing the carbon stocks and sequestration potential of the natural and plantation forest in Malaysia.
- Olso University Botanic Garden, Norway is predicting future plant immigrations and vegetation changes in Svalbard due to global warming.
- The Royal Botanic Gardens (RBG), Melbourne, Australia is involved with the management of weeds, biosecurity and pest management in relation to climate change - the tropical palm disease “pink rot” has made an appearance in the last two years in their gardens, growing on the indigenous *Archontophoenix* spp.
- Xishuangbanna Tropical Botanical Garden, China has carried out research on microclimate changes in the tropical rainforest fragments of the region.
- The National Botanic Garden of Wales, UK has a 3 year study of the potential evolutionary changes of *Senecio cambrensis* induced by climate change.

Modified planting schemes

Many gardens (approximately one third of respondents) reported changes in the plants they grow in their gardens, with for example, gardens now growing palms outside which could previously only be grown in greenhouses. The Diomides Botanic Garden in Greece has stopped cultivating some species requiring exposure to low temperatures and Mediterranean rather than alpine plants now thrive at the Landesmuseum Kärnten in Austria. RBG Melbourne is planning its planting and management for reduced water availability, including C4 grasses for turf while the Georgetown Botanic Gardens in Guyana stated “we have done a complete new scheme to cater for our climate change”. In a related response to climate change, Oxford University Botanic Garden has extended its opening season from May 20-Oct 31 to April 1-Nov 30, in response to earlier flowering of bluebells, and later autumn colours.

Education and public awareness

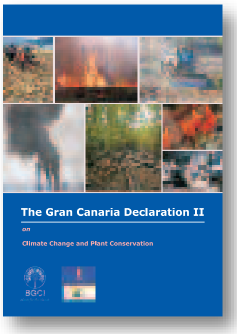
About one third of respondents had education resources focused on climate change. Some gardens had static exhibits on the subject, but many undertook lectures to visiting school children, or to the general public. These gardens ranged from those in the UK (EdenProject, Oxford, Wales), to those in Georgia, USA and Bangladesh.

Reducing carbon emissions

About one third of respondents noted measures for improved efficiency, such as better boilers and reducing fossil fuel use. Some gardens noted that they used electric carts in the garden, and others suggested that their plantings contributed to offsetting carbon. Chester Zoological and Botanical Garden, UK offset carbon emissions of air travel and the Eden Project offers a reduced admission rate for public transport users.

---

plant communities and species distribution on a local scale. This will provide better data about climatic effects on local plants and communities for modelling the future and also by functioning as a plants threat early warning system. Furthermore, botanic gardens have a wealth of data on how plants can tolerate different climatic regimes through garden records and observations and the experience of growing plants including exotics. In northern Europe tropical plants are not grown under exactly the same conditions as in their native habitats but in rather varying greenhouse conditions that mimic different climate regimes. This is especially true for temperature tolerance, rainfall (watering regimes) and atmospheric humidity so that by studying garden records and calling on the wisdom accumulated by the gardeners, an estimate can be made of the tolerance range of the species grown and of what might happen to them in their natural habitat during global climate change. Such estimates of species tolerance can contribute important hard data both to climate change modelling, ecosystem management and to the selection of specifically vulnerable species for use in monitoring climate change effects.



Above: Cover of *The Gran Canary Declaration II on Climate Change and Plant Conservation*

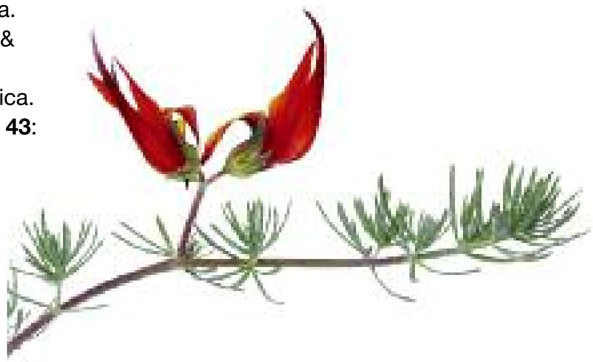
So where does this lead in defining the role of botanic gardens in relation to climate change? The recent realization at a political level, of the importance of the effects of global climate change on the world’s economy and on biological diversity will mean that a major international effort will be made over the next 20 years or so to conserve natural resources and minimize potential biodiversity loss due to global warming. From a plants point of view the *Global Strategy* will need to be adjusted and its terms of reference extended well beyond the initial proposal of 2010. The role of botanic gardens will become increasingly important in the period after 2010 because the effects of climate change will be seen on an increasing scale. The changing nature of threats and the large numbers of endangered species including many not currently considered to be threatened will be increasingly apparent. Those gardens participating in the international network of seed banks will be aiming at new targets for the long-term storage of seed collected from the wild and concentrating on saving plant resources for the future. The same will apply to living collections, especially in the case of species with recalcitrant seeds. These are predominant in some of the humid, tropical ecosystems which will, according to the models, be under severe threat from climate change. The future of many such species will probably depend on what botanic gardens can do for them in terms of cultivation (field gene banks) and even the possibility of assisted migration provided that new habitats are available.

Climate change will open up further fields for research such as reproductive biology, molecular population genetics, the ecology of colonization of new habitats but they must not be embraced to the detriment of classical taxonomy. Inventories and classification will still be needed if knowledge about biodiversity is to be learnt before it is too late. Therefore, the capacity for botanical exploration must be increased and the skills required for taxonomic revision and the description of new species developed. From a biodiversity point of view, it has been said that Linnaeus described about 9000 species. Currently, the same number are being described each year but in order to finish the catalogue, of even the most conservative estimates of the total biodiversity of the planet, 400 and 500 years will be needed. The enormity of this task should be appreciated and, in the face of a new phase of rapid mass extinction brought on by climate change, scientists should urge politicians to provide sufficient resources to attend to cataloguing and conserving biodiversity. Indeed, there should be a major UN-led programme to do this but it will be up to the scientific community to propose it perhaps through the climate change action plan for plants proposed by the Gran Canaria Group. Botanic gardens, as a major world network for plant conservation, can, if they are given sufficient resources in the period coming up to 2010 and then beyond, be important contributors to such a programme and have a major role in fulfilling the task of understanding and conserving the biological diversity of the planet in the face of climate change.

References

- BGCI, 2000. *The Gran Canary Declaration* calling for a *Global Program for Plant Conservation*. BGCI, London, UK.
- BGCI & Cabildo de Gran Canaria, 2006. *The Gran Canary Declaration II on Climate Change and Plant Conservation*. BGCI, London, UK & Cabildo de Gran Canaria, Las Palmas de Gran Canaria, Spain.
- Bramwell, D., 2006. Los Jardines Botánicos y el reto del cambio climático. *Rincones del Atlantico* **3**: 244-249. http://www.rinconesdelatlantico.com/num3/botanicos.html accessed 25th June, 2007.
- Bramwell, D., 2007. The role of botanic gardens and seed banks in biodiversity conservation after 2010. *Ensconet Bulletin* in press.
- CBD Secretariat, 2003. *Global Strategy for Plant Conservation*. CBD Secretariat, Montreal, Canada. http://www.cbd.int/programmes/cross-cutting/plant/default.asp accessed 4th July, 2007.
- ENSCONET, 2007 http://www.ensconet.com/ accessed 25th June, 2007.
- GENMEDOC, 2007. An inter-regional network of Mediterranean seed banks. http://www.genmedoc.org/default.htm accessed 25th June, 2007.
- Hernández Bermejo, J.E. & Clemente Muñoz, M., 1996. Strategies and *ex situ* Conservation Techniques in the Cordoba Botanic Garden: the Germplasm Bank. In *Proceedings of the Third International Botanic Gardens Conservation Congress*, Hobson, C. (ed.). http://www.bgci.org/congress/congress_rio_1992/bermejo.html accessed 25th June, 2007.
- Krockenberger A.K., Kitching R.L. & Turton S.M. (eds.). 2004. *Environmental crisis, Climate Change and Terrestrial Biodiversity in Queensland*. Report 28. Rainforest CRC, James Cook University, Cairns, Australia.
- Lovett, J.C., Midgley, G.F. & Barnard, P., 2005. Climate change and ecology in Africa. *African Journal of Ecology* **43**: 167-169.
- McClean, C.J., Doswald, N., Küper, W. et al., 2006. Potential impacts of climate change on Sub-Saharan African plant priority area selection. *Diversity and Distributions* **12**: 645-655.
- Nobre, C. A., 2004. *Climate Change Scenarios and Impacts on the Biomes of South America*. WWW.aiaccproject.org/meetings/Buenos_Aires/Nobre accessed 25th June, 2007
- Roca Salinas, A., Vilches Navarrete, B., Jardim, *et al*., 2004. The Macaronesian Seed Bank (BASEMAC). A programme for rational conservation of plant diversity. In *2nd World Botanic Gardens Congress, Barcelona 2004*. http://www.bcn.es/medciencies/botanicgardens2004/abstracts/pdf_abstracts/Alicia_Roca_final.pdf accessed 25th June, 2007 http://www.bgci.org/barcelona04/postcongress/oral.html accessed 25th June, 2007
- Stern, N., 2006. The Stern Review on the Economics of Climate Change. Cabinet Office, HM Treasury, UK Government. http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm accessed 25th June, 2007.
- Thomas, C.D., Cameron, A., Green, R.E., *et al*., 2004. Extinction risk from climate change. *Nature* **427**:145-148. http://stephenschnieder.stanford.edu/Publications/PDF_Papers/ThomasEtAl2004.pdf, accessed 25th June, 2007.

David Bramwell
Jardín Botánico "Viera y Clavijo"
Cabildo de Gran Canaria, El Palmeral 15
Tafira Alta, 35017
Las Palmas de Gran Canaria
Canary Islands, Spain
E-mail: dbramwell@grancanaria.com
Internet: http://www.step.es/jardcan/



Right: *Lotus berthelotii* (Lobster Claw) Jardín Botánico "Viera y Clavijo" Canary Island endemic (Photo: BGCI)

Authors: Paul P. Smith, Clare Trivedi, Anne Cochrane, Andrew Crawford and Michael Way

The Millennium Seed Bank Project delivering Target 8 of the *Global Strategy for Plant Conservation*

Introduction

The Millennium Seed Bank Project (MSBP) International Programme is a ten year global conservation programme (2000-2010), conceived and managed by the Seed Conservation Department at the Royal Botanic Gardens, Kew (Smith *et al*., 1998). The two principal aims of the Project are to:

- Collect and conserve 10% of the world's wild seed-bearing flora, principally from the drylands, by the year 2010.
- Develop bilateral research, training and capacity-building relationships worldwide in order to support and to advance the seed conservation effort

The MSBP currently works with partners in around 50 countries across five continents, and its main outputs and activities are: effective partnerships, high quality collections; removing researchable constraints; technology transfer and public awareness.

The focus of the seed collecting and conservation programmes in partner countries depends on national and institutional priorities. In many cases the emphasis is on the collection of rare and threatened species towards achieving Target 8 of the *Global Strategy for Plant Conservation: '60 per cent of threatened plant species in accessible* ex situ *collections, preferably in the country of origin, and 10 per cent of them included in recovery and restoration programmes.'*

This paper represents a progress report, including up to date statistics on seed banking of threatened species, problems encountered in achieving this target, and case studies of how such collections are being used for conservation purposes.

Progress towards Target 8 amongst MSBP partners

Table 1 shows progress towards achieving Target 8 of the GSPC amongst MSBP partner institutions where collection and reintroduction of threatened species is a central aim of the country programme.

For the purposes of this analysis, threatened species include extinct in the wild, critically endangered, endangered, vulnerable, near threatened and data deficient taxa, or categories equivalent to these. Least concern species are not included in the analysis.

Western Australia is the only state/country to have achieved Target 8 at the time of writing, with both 70% of threatened species conserved, and 13% of threatened species reintroduced. The United Kingdom has achieved the threatened species conserved target (78%), but not the reintroduction target. MSBP partner countries that are likely to have conserved more than 60% of their threatened flora ex situ by 2010 are

Left: Millennium Seed Bank scientist at work

Right: Seed of *Medicago polymorpha*

Botswana, Namibia and South Australia. Most countries are unlikely to achieve the second part of the Target - 10% of threatened species in recovery and restoration programmes. The reasons for this are discussed below.

The seed conservation programme with INIA Chile is typical of an MSBP partnership. This programme has successfully made over 700 collections of seed, of which over 70% of the taxa are endemic to Chile. Amongst the collections is *Menodora linoides* (Oleaceae), a shrub which was considered extinct, but was recently rediscovered in the wild (see picture, below).

Other endangered species from which seed has been collected include *Dalea azurea* (Critically Endangered); *Placea lutea* (Rare); *Tigridia phillipiana* (Rare); *Adesmina resinosa* (Vulnerable); and *A. balsamica* (Rare). Reproductive biology trials of *Dalea azurea* are currently underway to ensure that adequate numbers of seedlings can be re-introduced to the wild in coordination with local authorities.

Problems encountered in achieving Target 8

Absence of a red list or up to date, accurate information on threatened species

In MSBP partner countries such as Burkina Faso, Mali, Lebanon and Jordan no national red list of plants is available to our institutional partners. In other countries, such as Madagascar, Kenya, Botswana and Malawi, existing red lists have deficiencies.

For example, Of the 43 taxa on the Botswana red list (Golding, 2002) 22 are data deficient, 13 have misspelled author's or species names, and 10 names are either out of date or have ambiguous taxonomies (Smith & Balding, 2007). In addition, 14 rare, endemic taxa are not on the red list.

The MSBP has tackled this problem by employing a team of 12 people in Kew Herbarium, comprising specimen digitisers, literature researchers, Geographical Information System (GIS) specialists and conservation assessment officers. This team, working with in-country partners, digitises specimen information where no up to date red list assessments are available in order to produce preliminary conservation assessments. In this methodology specimen data from rare or threatened taxa are mapped in a GIS and used to calculate extent of occurrence and area of occupancy. From this a preliminary red list assessment is calculated using a simple algorithm. Where possible, other information is taken into account, such as habitat intactness estimated from satellite imagery, number of populations inside or outside protected areas etc. In addition, where species are designated data deficient or there are taxonomic problems, the team is able to add new information. To date the MSBP herbarium team and partners have produced 4500 preliminary conservation assessments (Target 2 of the *Global Strategy*) in 10 countries. The taxa that this analysis identifies as most threatened are prioritised by MSBP seed collection teams

Absence of accessible data on the locality, phenology and identification of threatened species

Knowing the names of your threatened species doesn't necessarily make it easy to find and collect seed from

Table 1: Progress towards Target 8 amongst Millennium Seed Bank Project institutional partners, where threatened species are the focus of seed collecting programmes

Country/state	Species focus*	No. of threatened species from which seed collected	Total no. of threatened species on list	Percentage of threatened species collected	No. of species reintroduced
Australia -Northern Territory	R,T	5	1191	0.5	1
China	R,T	2	234	1	0
Australia-Tasmania	R,T	23	734	3	0
Austalia-Victoria	R,T	39	967	4	5
South Africa	R,T,U	147	2683	5.5	4
Georgia	R,T,U	15	156	10	0
Australia-New South Wales	R,T	56	572	10	2
Chile	R,T	64	402	16	3
Malawi	R,T,U	33	206	16	1
South Australia	R,T	61	356	17	17
Namibia	R,T,U	8	24	33	7
Botswana	R,T,U	14	39	36	0
Western Australia	R,T	259 815	372** 2618***	70 31	48
United Kingdom	R,T	219	282	78	5

* R= rare; T= threatened; U= utilitarian ** Declared Rare Flora *** Declared Rare and Priority Flora.

them. Seed collectors need accurate locality and phenology information, and they need plant descriptions and images in order to recognise the plant when they are in the field. To this end, the same specimen information that is used to produce preliminary conservation assessments can be used to locate and identify species in the field. The MSBP herbarium team have produced 26 collection guides covering 2255 taxa from 10 countries to date. For each taxon covered in a collecting guide there is detailed locality data, a phenology chart showing when the plant is likely to be in seed, a detailed description of the taxon, and at least one image. These guides enable our seed collectors to be in the right place at the right time and able to identify the target plant.

Absence of infrastructure for processing and storage of seed

Seed storage for orthodox species (about 90% of plant species) is not a high technology procedure. Seeds need to be dried down to 5-7% moisture content then stored in a cold room, usually at 4°C for short term storage or -20°C for long term storage. The drying stage is particularly critical because if a seed is not dry when frozen it will be killed. The MSBP has provided drying and freezer facilities to ca. 30 partner institutions over the past seven years. Advice has been provided on seed bank design to 19 institutions in 10 countries worldwide.

Absence of skills enabling collection, handling and storage of seed

Having good facilities and equipment is pointless unless you know how to use them. For this reason, the MSBP has expended a considerable amount of time, effort and money on training people in seed conservation techniques. This training has comprised formal courses delivered at the MSB and regionally, exchange technical visits to the MSB and informal training on the job. The main focus areas for training have been seed collecting, seed handling, seed germination and seed storage. To date, the MSBP has trained 1181 people in seed conservation techniques, including 64 exchange visits and 31 PhD programmes.

Constraints associated with using seed in reintroduction programmes

The major challenge associated with Target 8 is species reintroduction. Few countries carry out species reintroduction programmes. This is partly because reintroductions are seen as a last resort, but also because they can be expensive and may fail for a wide number of reasons (see below). The first step towards using seeds for reintroduction is successful germination. The MSB currently carries out more than 10,000 germination tests a year. Every collection of over 500 seeds that is accessioned into the bank is tested for germinability. However, achieving germination is not always straightforward. For most of the species accessioned into the MSB nobody has tried to germinate them before. In addition, some taxa exhibit dormancy mechanisms that need to be overcome if successful germination is to result. Dormancy may be physical, morphological or physiological, and not only does the mechanism have to be elucidated, but procedures for breaking it have to be developed before germination can be achieved in the laboratory or nursery (Baskin & Baskin, 1998).

If germination can be achieved, successful establishment *in situ* does not always follow. There are many reasons for this. Using appropriate ecotypes of the right provenance or ensuring adequate genetic diversity in reintroduced populations may be crucial (e.g. see Vilas *et al*., 2006). Microbial symbionts, such as rhizobial bacteria or mycorrhizal fungi may be important, as will pollinators, seed dispersers and associated plant species. Alternatively, natural attrition through disease, predation or drought may be enough to knock out small populations of reintroduced species in the process of acclimation.

Western Australia's Department of Environment and Conservation (DEC) Threatened Flora Seed Centre (TFSC) currently holds 815 (or 31%) of the extant taxa on Western Australia's 2006 Declared Rare and Priority Flora list (see Table 1 above). This includes 70% of the extant taxa on the Declared Rare Flora list. These collections have been made over a 14 year period from late 1992 to the present. The MSB partnership has enabled the Threatened Flora Seed Centre to accession 474 of these 815 conservation-listed taxa. Since 1998 DEC has established 48 threatened (DRF) plant reintroductions. Thirty-three of these have utilised seed from the Threatened Flora Seed Centre. This amounts to 13% of the Declared Rare Flora being used in recovery. Although TFSC collections of DRF taxa exceed Target 8 of the Global Strategy

Below: Millennium Seed Bank scientist at work

for Plant Conservation, many of the existing TFSC conservation collections are small, and do not adequately represent the diversity of the taxon. In addition, collections are of insufficient size to meet recovery efforts. Further collection is needed for ongoing conservation, maintenance, duplication, distribution and recovery.

Conclusions

The examples above show that Target 8 is achievable. The strength of the MSBP network is in the diversity of experience and expertise of the partners. From the increasing number of examples of reintroduction programmes in the literature, it is clear that for reintroductions to be successful, a multidisciplinary approach needs to be employed, using molecular, ecological and horticultural knowledge to maximise survival and long term establishment. In most of the MSBP partner countries, this kind of expertise and experience is in short supply. The rationale going forward is to use the expertise that does exist in places like Australia to promote best practice throughout the network.

This paper has concentrated on the technical challenges associated with achieving Target 8. As has been shown, these are surmountable. The biggest constraints to success remain lack of political will and funding. A technical network such as the Millennium Seed Bank Project partnership comes at a cost - £50 million to secure 10% of the world's flora in safe storage in 10 years. The model is proven, but further funding will be needed to extend the network further, and to start to tackle the technical challenges associated with species reintroductions and habitat restoration. The CBD and its signatory governments need to enable the technicians to get on and achieve the targets that the CBD has set. The GSPC is a test of credibility for the CBD – will it ever actually achieve anything useful, or will it remain an expensive talking shop?

Right: Collecting *Ecballium elaterium*, Lebanon

References

- Baskin C.C. & Baskin J.M., 1998. *Seeds: ecology, biogeography and evolution of dormancy and germination*. Academic Press, San Diego/London.
- Golding J.S. (ed.), 2002. *Southern African Plant Red Data List*. Southern African Botanical Diversity Network Report Series No. 14. pp. 135-156. National Botanical Institute, Pretoria, South Africa.
- Smith P. P. & Balding S., 2007. The taxonomic impediment to conservation of biodiversity: an example from Botswana. In prep.
- Smith, R.D, Linington S.H. & Wechsberg G.E., 1998. The Millennium Seed Bank, the Convention on Biological Diversity and the dry tropics. In: H.D.V. Prendergast, N.L. Etkin, D.R. Harris & P.J. Houghton (eds), *Plants for food and medicine*, pp 251-261. Royal Botanic Gardens, Kew.
- Vilas C., San Miguel E., Amaro R. & Garcia C., 2006. Relative contribution of inbreeding depression and eroded adaptive diversify to extinction risk in small populations of shore Campion. Conservation Biology **20(1)**: 229-238.

Paul P. Smith, Clare Trivedi, Anne Cochrane, Andrew Crawford and Michael Way
Seed Conservation Department
Royal Botanic Gardens, Kew
Wakehurst Place, Ardingly
West Sussex, RH17 6TN UK
E-mail: P.smith@kew.org
Internet: http://www.kew.org/msbp/

Editor's Note: This paper was given at the 3rd Global Botanic Garden Congress (3GBGC) held in Wuhan, China in April, 2007.

Authors: Kayri Havens, Pati Vitt, Jennifer Schwarz, Barron Orr and Theresa Crimmins

Chicago Botanic Garden's conservation and outreach efforts on climate change

On January 4, 2007, giant snowdrops (Galanthus elwesii) bloomed at the Chicago Botanic Garden (CBG). This broke the previous record for earliest snowdrop bloom date, set in 2006, by 25 days. Hundreds of calls were logged at CBG's Plant Information Service regarding the anomalous bloom time. Ten reporters from local television, radio and newspapers questioned Garden staff about the relationship between global climate change and bloom times. The significant public response to this event underscores the interest in, and need for, public education on our changing climate and its impact on natural systems.

Ecological changes connected with trends in increasing temperatures and the earlier onset of spring are well documented across the globe using plant phenology data (Schwartz and Reiter, 2000, Abu-Asab *et al*., 2001, Cayan *et al*., 2001, Schwartz, 2003). These data are observations of phenological events (e.g. leaf emergence, first flower, peak flowering) recorded each year over an extended period of time. Phenological observations are highly intuitive from both interpretation and data collection standpoints and are therefore accessible to the general public. Nature and science museums, science centres, and botanic gardens and arboreta are well suited to deliver critical science and environmental content in an informal, self-directed manner. US botanic gardens, often with associated natural areas, enjoy a broad public audience (50 million visitors per year) and are particularly appropriate to connect global climate change concepts to potential impacts on plant species and ecosystems.

The Chicago Botanic Garden has several programmes underway or in development to introduce the public to climate change issues and to engage them in collecting data relevant to predicting plant responses to climate change. As illustrated by the snowdrop example, the public is often aware of climate effects, but individuals may not consider their observations scientifically valuable. The Garden's projects will capture the public's observations and provide further opportunities to engage in citizen science. While data collection activities in this project are primarily designed to educate and involve learners, the data will also contribute to critical climate change research and prediction tools. There is precedence for the efficacy of citizen collected data in several very valuable phenology and plant distribution datasets that are the result of hobby or volunteer observations (e.g., Beaubien & Johnson, 1994, Bradley *et al*., 1999, Fitter & Fitter, 2002, Wolfe *et al*., 2005, Vitt *et al*., in review) and each has furthered scientific understanding of the natural world.

Project Budburst

Piloted in 2007, this national project is a collaborative effort developed by several organizations, including Chicago Botanic Garden, and

Above: *Tetraneuris herbacea*. Species monitored by Plants of Concern programme (Photo: Carol Freeman)

Left: Susanne Masi (left), manager of Plants of Concern programme with a volunteer monitor (Photo: Robin Carlson) universities that are members of the US National Phenology Network (NPN). The NPN is a network of scientists and educators that collaborate to facilitate collection and dissemination of phenological data to support global change research. Project Budburst engages citizen scientists, including youth, to record phenological observations, such as first flower, first leaf, peak flower and others, on a website (www.budburst.org). About 60 native wildflowers, shrubs and trees, from Eastern Columbine (*Aquilegia canadensis*) to California Poppy (*Eschscholzia californica*), were targeted in the pilot campaign, but people can submit information on any plant species. A few commonly used landscape species, such as Forsythia (*Forsythia x intermedia*) and Lilac (*Syringa vulgaris*) and two weeds, Dandelion (*Taraxacum officinale*) and White Clover (*Trifolium repens*) are also included, so people could participate even if they could not get out to a natural area. In the first year, nearly 900 observations from 38 states were received, the majority submitted by children under 12. Next year, it is planned to expand the website to accept historical datasets (since many citizen scientists have volunteered to donate their datasets going back decades in some cases) and allow data submission year round.

Above: Card of Project Budburst

Right: *Sisyrhinchium montanum.* Species monitored by Plants of Concern programme (Photo: Carol Freeman)

Global Climate Change Monitoring Gardens

This project, under development for a 2008 launch, consists of "global climate change monitoring gardens" which will be planted at 13 botanic gardens (Table 1), thus creating a nationwide "ecological antenna" where citizen scientists record climate data and a standard set of phenological events. After piloting the monitoring gardens at the 13 botanic gardens, monitoring gardens will be provided to community organizations working with urban and underserved youth audiences. The monitoring gardens are designed to hold genetic variance constant and standardize growing conditions. Environmental response variables – to be measured by participating community youth, garden visitors, and scientists – will include: date of first open flower, peak flowering, first fruit ripened, last fruit ripened, total flowering period, and fecundity. Each garden will contain genetically-identical cloned plants which will act like a network of climate sensors or "phytometers." The Global Climate Change Monitoring (GCCM) gardens will include native species that are long-lived and exhibit a variety of breeding systems. Gardens will also include both a C3 and a C4 grass; these contrasting photosynthetic pathways are expected to respond differently to elevated CO_2 levels. Target species, including False Indigo (*Baptisia australis*), Summer Phlox (*Phlox paniculata*), Bee Balm (*Monarda fistulosa*), Indian Grass, a C4 grass (*Sorghastrum nutans*), and Western Wheatgrass, a C3 grass (*Pascopyrum smithii*), have wide geographic ranges, which allow them to be planted at the participating gardens; have flowering times that are initiated by temperature, as opposed to daylength; are easy to clone; and are attractive in a garden setting. Plant responses to the different climates of the 13 participating

Right: *Platanthera leucophaea*, Species monitored by Plants of Concern volunteers

gardens will allow inferences about how the species might respond to future climate change. Repeat photos will be displayed on a project website, enabling website visitors to see phenological changes and patterns through time, as well as spatially across all participating sites. This "ecological antenna" will allow the following conservation research questions to be addressed: (1) How do clones respond phenologically to various bioclimatic zones? (2) Is phenologic behaviour different across bioclimatic zones? (3) Can observations be related to future climatic shifts in the region? and, (4) Over time, how do the cloned plants respond phenologically to the changing climate in each of the bioclimatic zones where they are located?

At eight of the 13 gardens, climate and phenological observations in the gardens will be interpreted in a regional and national context at an accompanying public access computer kiosk and display, as well as on the project website available to all. Display of these products will be accompanied by additional evidence that represents the current understanding of how climate is changing globally. Figure 1 illustrates the relationships between the climate change gardens at botanic gardens, at associated community organizations and the programming team at University of Arizona.

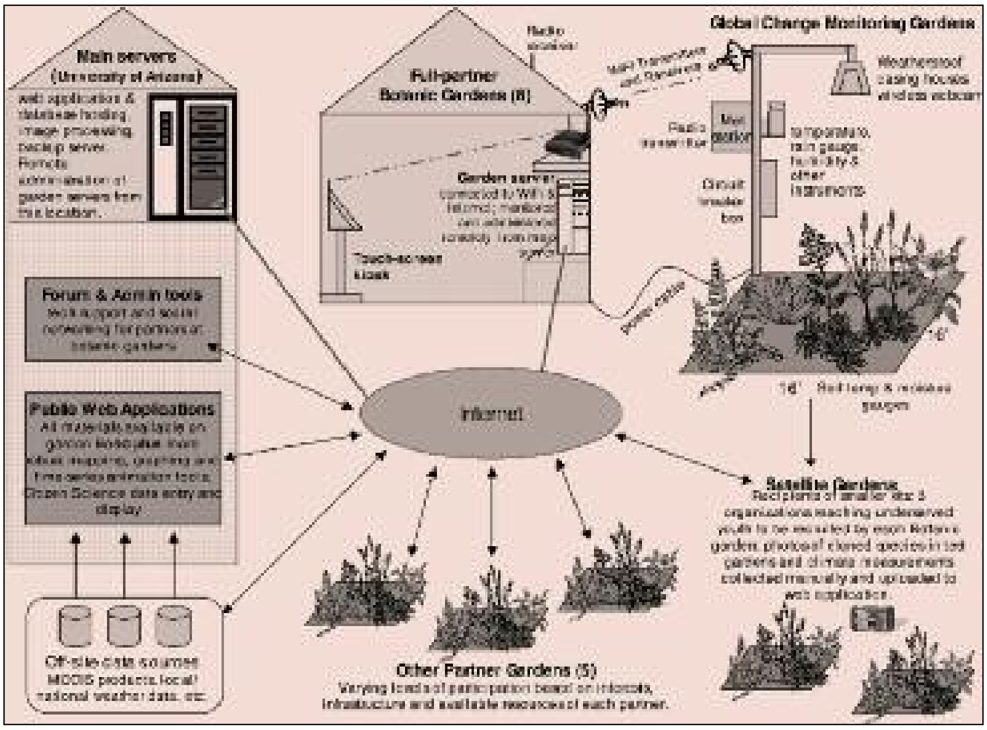


Figure 1. Schematic design of relationships and linkages between monitoring gardens, kiosks, servers, data and the University of Arizona programming team (Diagram: Anne Thwaits, University of Arizona).

Plants of Concern

The global climate change monitoring gardens will provide information on the response of plants in a controlled design to different environments nationally. It is alos interesting to find out how rare and invasive plant species respond, both phenologically and demographically, over time in the wild. Plants of Concern (POC), founded in 2001, is a citizen-science monitoring programme designed to collect these types of data on rare plants in the northeastern Illinois region. To date over 300 volunteers have monitored over 400 rare plant populations representing 145 species. The volunteer retention rate over the life of the programme is quite high (61%). Volunteer data quality has been verified experimentally, and there were no significant differences between staff and volunteer collected data (Vitt, unpublished data).

In 2008, it is planned to expand the programme, both geographically and conceptually, to include invasive plant monitoring. Of the many factors involved in the endangerment of native plants, invasive species rank second only to habitat loss, and issues such as native plant rarity, invasive species, and habitat destruction are entwined. Many invasive species thrive in disturbed ecosystems, and climate change is one type of disturbance that is predicted to increase for the foreseeable future. Thus continued invasion may be favoured by climate change (Dukes & Mooney, 1999), while rare species are more likely to be negatively impacted.

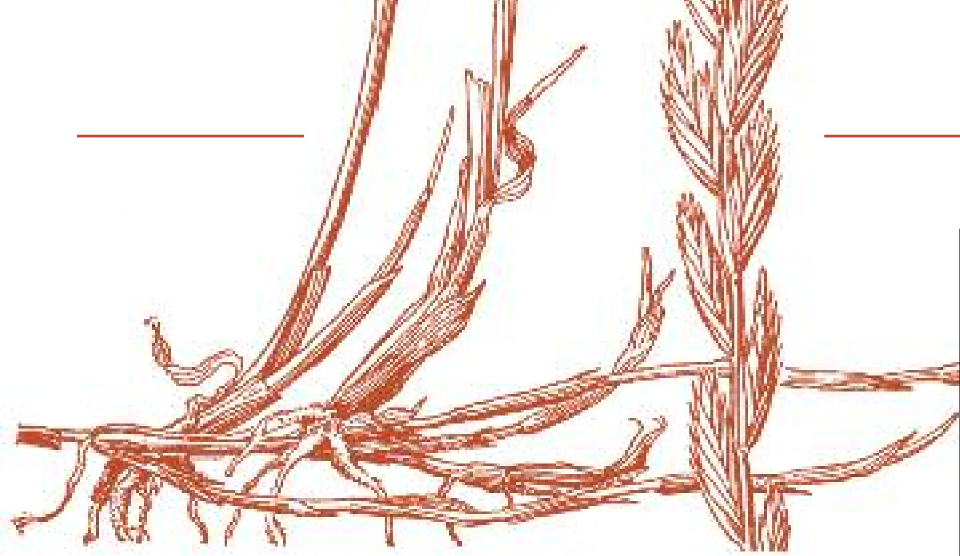
For the invasive species monitoring component, data on all fields in the North American Weed Management Association (NAWMA, 2007) standards will be collected, as well as additional phenological (flowering and fruiting times) and demographic (percent of plants flowering and fruiting, seedling recruitment, senescence, etc.) data. Species selected for this study include well-established regional invasives and incipient invasives popular in horticulture. Aggregate report data will allow conservation biology researchers to answer questions such as: How fast do these emerging invasive species spread, and does rate of spread change as climate changes? Which non-native species are becoming invasive? Do certain regions (such as urban areas) serve as refugia for emerging invasive species?

Are there certain population characteristics that could help identify emerging species?

Taken together, these projects lead learners through one or more, loosely, yet systematically, linked informal education opportunities toward an increasing awareness of how individual behaviour can affect climate change. Ultimately, it is hoped that individual behaviour will be influenced to reflect both an understanding of climate change and to create awareness that

Far left and left: *Sorghastrum nutans* (Indian Grass) a C4 grass and target species for the Global Climate Change Monitoring Gardens Project

Far left: Taken from Hitchcock, A.S., 1950. *Manual of the grasses of the United States.* USDA Misc. Publ. No. 200 Left: Taken from R.H. Mohlenbrock, USDA SCS. 1991. *Southern wetland flora: Field office guide to plant species.* South National Technical Center, Fort Worth. (Courtesy of USDA NRCS Wetland Science Institute



Above and far right: *Pascopyrum smithii* (Western Wheatgrass) a C3 grass and target species for the Global Climate Change Monitoring Gardens Project

Above: Taken from Hitchcock, A.S., 1950. *Manual of the grasses of the United States.* USDA Misc. Publ. No. 200) Far right: Taken from R.H. Mohlenbrock, USDA SCS. 1989. *Midwest wetland flora: Field office illustrated guide to plant species.* Midwest National Technical Center, Lincoln (Courtesy of USDA NRCS Wetland Science Institute)

individuals can positively affect this environmental issue. In addition, these projects provide valuable data that the Garden and others will use to improve predictions about how plant species will respond as the climate changes.

Acknowledgements

The authors would like to thank the collaborators and funders on all of these projects. Project Budburst collaborators include Sandra Henderson and Kirsten Meymaris (National Center for Atmospheric Research), Carol Brewer and Brooke McBride (University of Montana), Susan Mazer and Brian Haggerty (University of California-Santa Barbara), Sarah Wright (University of Wisconsin) and other members of the National Phenology Network. Project Budburst was funded in 2007 by the Bureau of Land Management and Plant Conservation Alliance. Global Change Monitoring Garden collaborators include Jim Ault and Laura Altergott at Chicago Botanic Garden and Stuart Marsh, Wim van Leeuwen, Michael Crimmins, Wolfgang Grunberg, and Anne Thwaits at the University of Arizona and participating gardens (see Table 1). Plants of Concern is managed by Susanne Masi at Chicago Botanic Garden and funded by Chicago Wilderness, State of Illinois

Table 1 Global Climate Change Monitoring Garden project partners

Arboretum at Flagstaff
Berry Botanic Garden
Chicago Botanic Garden
Cincinnati Zoo & Botanic Garden
Cornell Plantations
Denver Botanic Garden
Holden Arboretum
Missouri Botanical Garden
The Morton Arboretum
New England Wild Flower Society at Garden in the Woods
North Carolina Botanical Garden
Santa Barbara Botanic Garden
University of Washington Botanic Garden

References

- Abu-Asab M, Peterson, P.M., Shetler, S.G. & Orli, S.S., 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC area. *Biodiversity and Conservation* **10(4)**:597-612.
- Beaubien, E.G. & Johnson. D.L.,1994. Flowering plant phenology and weather in Alberta, Canada. *International Journal of Biometeorology* **38(1)**: 23-27.
- Bradley, N.L., Leopold, A.C., Ross, J. & Huffaker. W.,1999. Phenological changes reflect climate change in Wisconsin. *Proceedings of the National Academy of Sciences of the United States of America* **96(17)**: 9701-9704.
- Cayan, D.R., Kammerdiener, S.A., Dettinger, M.D., Caprio, J.M & Peterson, D.H., 2001. Changes in the onset of spring in the western United States. *Bulletin of the American Meteorological Society* **82(3)**: 399-415.
- Dukes, J.S. & Mooney, H.A., 1999. Does global change increase the success of biological invaders? *Trends in Ecology and Evolution* **14(4)**: 135-139. http://globalecology.stanford.edu/DGE/Dukes/Dukes_TREE1.pdf accessed 26th June, 2007.
- Fitter, A.H. & Fitter R.S.R., 2002. Rapid changes in flowering time in British plants. *Science* **296:** 1689-1691.
- NAWMA, 2007. North American Weed Management Association. http://www.nawma.org/ accessed 26 June, 2007.
- Schwartz, M. D. (ed.), 2003. *Phenology: An Integrative Environmental Science*. Springer, New York, USA.
- Schwartz, M.D. & Reiter, B.E., 2000. Changes in North American spring. *International Journal of Climatology* **20:** 929-932.
- Vitt, P, Havens, K., Kendall, B.E. & Knight T.M., in review. Community-level management increases the viability of *Tomanthera auriculata*, a Rare Prairie Annual. *Ecological Applications*.
- Wolfe, D.W., Schwartz, M.D. Lakso, A.N. et al., 2005. Climate change and shifts in spring phenology. *International Journal of Biometeorology* **49:** 303-309.

Kayri Havens, Pati Vitt and Jennifer Schwarz
Institute for Plant Biology and Conservation
Chicago Botanic Garden
1000 Lake Cook Road
Glencoe, IL 60022
Email:
khavens@chicagobotanic.org
Internet:
http://www.chicagobotanic.org/
and
Barron Orr and Theresa Crimmins
University of Arizona

Authors: O. Téllez, P. Dávila, M. Ayala,
K. Gutiérrez & I. Melchor

Case studies on the effect of climate change on the flora of Mexico

Above: *Mammillaria napina* in the Tehuacan-Cuicatlán Biosphere Reserve (Photo: Oswaldo Téllez-Valdés)

Mexico belongs to a natural biological region that extends from southern USA to northern Central America. This region is called ¨MegaMexico 3¨ (Rzedowski, 1993). It is characterized by rich biological diversity, which is mainly restricted to the Mexican territory. Mexico is considered a megadiverse country, and is probably third in the world with 8-12% of the global biodiversity (Caldecott *et al*., 1996; Mittermeier & Mittermeier, 1992). With regard to reptiles, Mexico has the most species in the world, with 717 species (Flores, 1993), with regard to mammals, Mexico takes second place, with 456 species and fourth place with regard to amphibians, with 285 species. Finally, Mexico has approximately 25,000 plant species (Rzedowski, 1993; Villaseñor, 2003). In addition, the endemism rate in different plant groups is usually high. For example, of the 900 Cactaceae species found in Mexico, 687 are endemic. In the Compositae (>3,000 species), the endemism rate is above 50% (Turner & Nesom, 1997; Villaseñor *et al*., 1998) and in the Leguminosae (>2,200 species), the endemism rate is also more than 50% (Sousa & Delgado, 1993).

Left: *Ferocactus haematacanthus* in theTehuacan-Cuicatlán Biosphere Reserve (Photo: Oswaldo Téllez-Valdés)

Unfortunately, this unique biodiversity is rapidly being lost. Official reports point out that more than 500,000 hectares of natural forest are being lost or severely degraded every year, especially in the S-SE of Mexico. Other assessments state that the annual deforestation rate in the country has reached 1.5 million ha (CCE, 2007) or even 75,000 to 2 million hectares per year (Lund *et al*., 2002). The FAO assessments, since the 80's estimated the loss of 350,000 to 650,000 ha a year. A recent assessment of the deforestation in Mexico indicates that from 1976 to 1993, 29,765 km^2 of forest was lost and from 1993 to 2000, about 54,306 km^2 disappeared. Therefore, the annual deforestation rate has increased from 175,000 to 775,800 ha (Velásquez *et al*., 2002).

The National Commission of Biodiversity of Mexico (CONABIO) has made important efforts to build a system of Priority Conservation Terrestrial Regions (RTPs) in the country (Arriaga *et al*., 2000), including 151 areas that cover about 500,000 km^2. However, its biological and environmental richness representation is inadequate (Cantú *et al*., 2004).

So far, the efforts undertaken regarding biodiversity conservation, with a few exceptions, have not considered the effects of global climate change, especially regarding plants. It is only recently that research projects have tried to assess the effects of different environmental conditions caused by global climate change on the current distribution patterns of plant groups.

Since 2003, the Facultad de Estudios Superiores Iztacala (FES, Iztacala), Universidad Nacional Autónoma

Right: *Mammillaria crucigera* in the Tehuacan-Cuicatlán Biosphere Reserve (Photo: Ulises Guzman)

México (UNAM) have undertaken projects related to the conservation of the natural resources of the arid and semi-arid regions of Mexico. The efforts include *in situ* and *ex situ* conservation and incorporate the goal of assessing the effects of global climate change, as a long-term conservation criterion (Téllez-Valdés & Dávila-Aranda, 2003; Villaseñor & Téllez-Valdés, 2004; Téllez-Valdés *et al*., 2006). Accordingly, three main projects are currently being developed: 1) Sustainable management and human development; 2) *Ex situ* conservation of the natural resources of the arid and semi-arid regions of Mexico; 3) Conservation assessments.

These projects target different aspects related to the conservation of natural resources. In particular conservation assessments aim to assess different future climate scenarios, based on the use of ecological niche models in which the bioclimatic information is the main source of information. Thus, the idea is to evaluate the consequences of future climate change on the conservation of the flora and to analyze the role that the RTPs and the Natural Protected Areas of Mexico are playing to conserve its future biodiversity.

Due to the uncertain magnitude of climate change, a comprehensive study was undertaken to include various proposals that suggest different scenarios. In particular, the model includes information which emerged from the IPCC studies (Canziani & Diaz, 1998; Giorgi *et al*., 1998; Karl, 1998; Neilson, 1998) and the Canadian general models of circulation (HadCM2 and HadCM2a). A conservative scenario (HHGSDX50), assumes a CO_2 increment of 0.5% per year, whereas the most drastic one (HHGGAX50) proposes a CO_2 increment of 1% each year. With this information it is possible to generate different scenarios in the country between 2030 and 2100. For instance, 1) a conservative scenario that considers an increment of 0.5°C and annual precipitation reduction of 10%; (2) an intermediate scenario with a temperature increment of 1-1.5°C and an annual precipitation reduction of 10%; and 3) a drastic scenario with a temperature increment of 2-2.5°C and an annual precipitation reduction of 10%.

One of the most important *in situ* projects is the assessment of the conservation status of endangered or threatened Cactaceae of the Tehuacan-Cuicatlán Biosphere Reserve. In this project, the distribution patterns and reproductive capacity of these species are being evaluated and their habitat and the effects of land use are also being studied. Finally, the effects of climate change on their survival and future distribution patterns, especially those species that are more sensitive to climate conditions, are being assessed. This Reserve is unique as it represents the southernmost semi-arid region of North America and is one of the most diverse areas, with almost 3,000 vascular species in an area of 10,000 km². As part of this project, a database of 5,000 records of 82 Cactaceae species growing in the reserve, including 21 that are endemic is being analyzed.

The possible future distribution of the Cactaceae species in response to global climate change has been evaluated. The distribution of the 82 species of Cactaceae show different responses to climate change, both increase and reduction (Figures 1 & 2). In general terms, only a few species extend their distribution area under climate change. In fact, almost 95% of species drastically reduce their areas and 50% seem to have no distribution possibly because they will be extinct by 2100. It is clear also, that most of the habitats associated with the latter species will also be lost. However, in

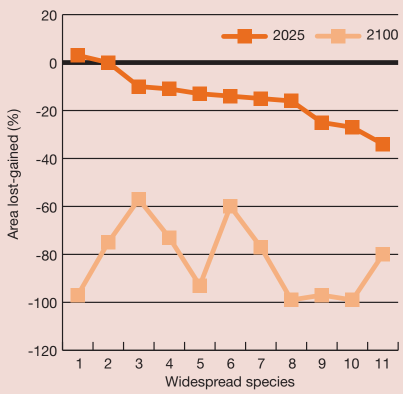


Figure 1. Changes in potential distribution after climate change scenarios for different widespread species of Cactaceae in the Tehuacan-Cuicatlán biosphere reserve

Taxa from left to right:
1. *Pachycereus grandis*, 2. *Hylocereus undatus*,
3. *Opuntia tomentosa*, 4. *Opuntia pubescens*,
5. *Stenocactus crispatus*, 6. *Pachycereus marginatus*,
7. *Pachycereus weberi*, 8. *Cylindropuntia kleiniae*,
9. *Neobuxbaumia mezcalaensis*,
10. *Cylindropuntia leptocaulis*, 11. *Opuntia decumbens*

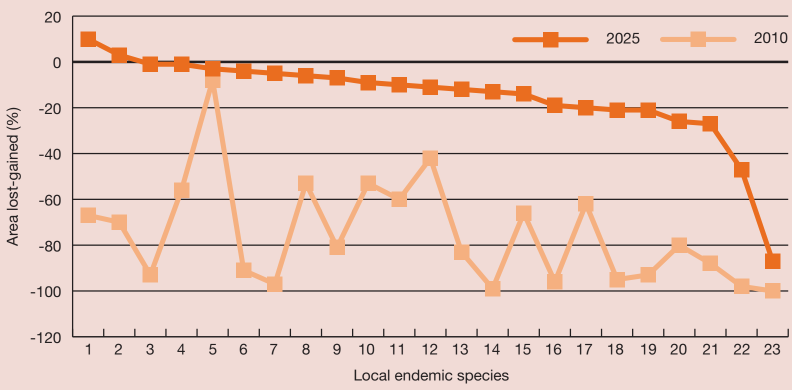


Figure 2. Changes in potential distribution after climate change scenarios for different local and regional endemic species of Cactaceae in the Tehuacan-Cuicatlán Biosphere Reserve

Taxa from left to right: 1. *Cephalocereus columna-trajani*, 2. *Coryphantha pycncantha*, 3. *Mammillaria kraehenbuehlii*, 4. *Neobuxbaumia macrocephala*, 5. *Ferocactus haematacanthus*, 6. *Mammillaria pectinifera*, 7. *Mammillaria napina*, 8. *Polaskia chende*, 9. *Mitrocereus fulviceps*, 10. *Ferocactus recurvus*, 11. *Mammillaria supertexta*, 12. *Echinocactus platyacanthus*, 13. *Polaskia chichipe*, 14. *Mammillaria crucigera*, 15. *Ferocactus robustus*, 16. *Ferocactus flavovirens*, 17. *Mammillaria discolor*, 18. *Mammillaria huitzilopochtli*, 19. *Pachycereus hollianus*, 20. *Neobuxbaumia tetetzo*, 21. *Opuntia parviclada*, 22. *Mammillaria oteroi*, 23. *Opuntia tehuacana*

other cases, the area appears to occupy a more protected region at higher altitudes, where the species can find a refuge in the Reserve. This effect might already have occurred in the Cuicatlán Canyon, where the distribution of many columnar Cactaceae and their pollinators coincides very well.

The differential response to global climate change shows interesting results. There are various species (*Mammillaria crucigera, M. huitzilopochtli, M. kraehenbuellii, M. napina* and *M. pectinifera*) with current restricted distribution patterns that seem to be less sensitive to climate change by showing lower reduction rates, than those with wider patterns such as *Cephalocereus columna-trajani* and *Neobuxbaumia tetetzo*, which in theory have a higher genetic diversity and can occupy various habitats with different environmental conditions (unpublished Thesis).

There is also information about the behaviour of other endemic cacti species with less than 10 currently known populations (*Ferocactus haematacanthus, F. macrodiscus, Mammillaria huitzilopochtli, M. kraehenbuellii, M. napina, M. pectinifera* and *Stenocactus crispatus*). In these cases the effects of climate change are also very interesting. For instance, *Mammillaria kraehenbuellii, M. napina* and *Ferocactus haematacanthus*, have high habitat specificity and very restricted distribution patterns; the two species of *Mammillaria* showed an increase in their distribution while *F. haematacanthus*, even in the drastic scenario, only seemed to have a slight reduction (see Figure 3).

In the future, it is hoped to include data relating to the dispersion rate of the species, as an indicator of their "escaping capacity" to find new and more adequate habitats, under the pressure of global climate change.
In general, the Cactaceae are characterized by producing fleshy fruits that are dispersed by animals (especially insects, birds and bats), which could play an important role for the dispersion of the seeds to other areas, where they could probably establish and grow.

In addition, there is a current project which aims to regionalize the flora of the Baja California Peninsula, on the basis of the climate and conservation status of the species. This Peninsula is located in northwest Mexico and represents an arid region with 0-22 mm of precipitation. In this project priority areas for conservation using bioclimatic models are being selected that enable the incorporation of climate-change scenarios, as an important tool to assess its long-term conservation value. Within the framework of this project two databases have been analyzed.
One includes 40,000 records with information on about 3,000 vascular plant species. The second has 6,000 records of 500 endemic species.

Considering possible future scenarios in different timeframes based on an increase in temperature from 0.9-1.2°C and 1.5-2°C and decrease in precipitation of about 5-10%, the species show different responses to these changes. However, in general terms, most of the species seem to show a drastic reduction of their distribution (Figure 4).

Above and left: *Mammillaria pectinifera* in the Tehuacan-Cuicatlán Biosphere Reserve (Photo: Irving Rosas-Ruiz)

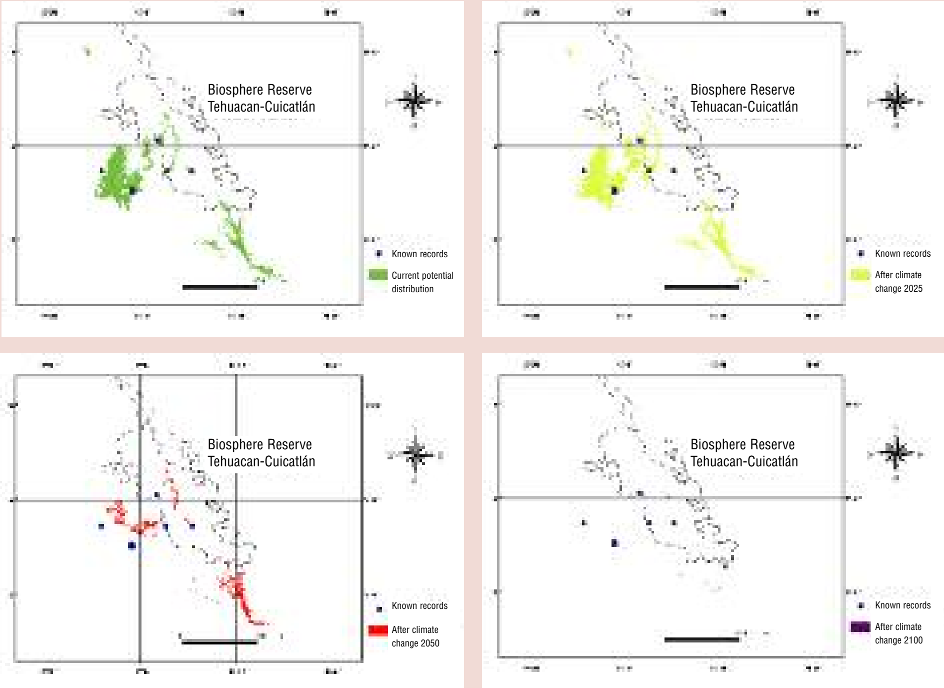


Figure 3. Maps showing the known and potential distribution of *Mammillaria kraehenbuellii* in and adjacent to the Tehuacan-Cuicatlán Biosphere Reserve, and its distribution after several scenaria of climate change between 2025-2100.

For example, a group of species from the temperate areas of the Peninsula show an increase in distribution (*Agave deserti, Astragalus orcuttianus, Eriogonum elongatum, Eriogonum hastatum, Garrya grisea, Ipomopsis effusa, Ipomopsis guttata, Nolina palmeri* and *Quercus peninsularis*). However, others that currently have a wider distribution that partially enter the drier zones show a reduction and under a drastic scenario can even disappear.

The effects that climate change will have on the plant species of the drier areas of the Baja California Peninsula are diverse, due to the fact that most of the habitats in which they currently live will change. Some groups of species will have a reduced distribution or disappear, even in the less drastic future scenarios. However, those species inhabiting more temperate areas will probably be less affected. For instance, it seems that the wetter pine and oak forests, will contract more gradually than the dry habitats.

In summary, it is recognized that most species have only a few alternatives in the face of climate change. For instance, they can 1) migrate to appropriate environmental conditions; 2) adapt to the new environmental conditions; or 3) become extinct. Evidently, it is expected that the intrinsic capacity of each taxon or group of taxa to respond to these climate changes, will result in different behaviours that can probably be assessed by bioclimatic modeling. Consequently, the results obtained so far show that the effects of climate change on the flora of Mexico, although different, is in general terms negative to the survival of numerous taxa inhabiting different habitats.

It is evident that in most cases, the areas where plant species are currently living will change latitudinally and altitudinally or the species will even disappear. Consequently, these models can help to propose future in situ and ex situ conservation strategies that assess the long-term role of the protected areas.

Future projects for 2008

In 2008, the effect of global climate change on the areas and distribution patterns of wild relatives of cultivated plants will be assessed. Mexico is the centre of origin of several plant species that have been domesticated and played an important role as main food crops for humans. Wild species of some families such as the Cucurbitaceae and Gramineae will be studied in order to propose strategies that can mitigate the reduction of their distribution or avoid extinction by ex situ conservation.

In addition, conservation priority areas of the drylands of Mexico will be studied and selected. In this project, FES Iztacala, UNAM will collaborate with the Royal Botanic Gardens, Kew, UK through the Millennium Seed Bank. This will assess the effects that global climate change will have on the distribution of species that inhabit Mexican drylands and the role that natural protected areas can play for their long-term conservation. The role of the Seed Bank of Mexico located at the FES-Iztacala in the conservation of the plant species of the country will also be evaluated.

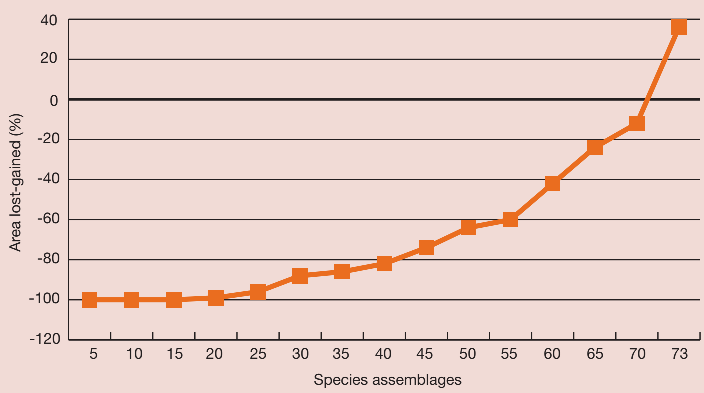


Figure 4. Percentage ranges of change in potential distribution after climate change scenaria on different assemblages of species in Baja California, Mexico (numbers refer to assemblages of species).

Finally, it is worth mentioning the increased concern of society and the academic world in relationship to environmental issues, including global climate change. In many ways they have been supportive and have financed research activities that are needed to provide the necessary information. For example, most of this work has been supported (2007-2008) by the FES, Iztacala, other UNAM institutions, the automotive company Volkswagen which through its programme 'For love of the Planet' has granted US$ 100,000 and the Royal Botanic Gardens, Kew contributed US$ 50,000.00. Evidently, due to the large size of Mexico, more funds are needed for research to understand and if it is possible, to protect the 25,000-30,000 Mexican plant species from global climate change.

References

- Arriaga L., Espinoza, J.M., Aguilar, C. *et al*. (Coordinadores), 2000. *Regiones Terrestres Prioritarias de México*. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México.
- Caldecott, J.O., Jenkins, M.D., Johnson, T.H. & Groombridge, B., 1996. Priorities for Conserving Global Species Richness and Endemism. *Biod. and Cons*. **5:** 699-727.
- Cantú, C., Wright, R.G., Scott, J.M. & Strand, E., 2003. Assessment of current proposed nature reserves of Mexico based on their capacity to protect geophysical features and biodiversity. *Biol. Cons.* **115:** 411-417.
- Canziani, O.F. & Diaz, S., 1998. *Latin America*. Pages 187–230 In: R.T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken (eds.). *The regional impacts of climate change: an assessment of vulnerability*. Special report of the Intergovernmental Panel on Climate Change Working Group II. Cambridge University Press, Cambridge, UK.
- CCE, 2007. Consejo Coorindinador Empresarial, 2007. http://www.cce.org.mx
- Flores, V.O., 1993. Herpetofauna of Mexico: Distribution and Endemism. Pages 253-280. In: Ramamoorthy, T.P., R. Bye, A. Lot, F. Fa (eds.). *Biological Diversity of Mexico: Origins and Distribution*. Oxford University Press, New York. USA.
- Giorgi, F., Meehl, G.A., Kattenberg, A. et al., 1998. Simulated changes in vegetation distribution under global warning. Pages 427–437 In: R.T. Watson, M. C. Zinyowera, R.H. Moss and D.J. Dokken (eds.). *The regional impacts of climate change: an assessment of vulnerability.* Special report of the Intergovernmental Panel on Climate Change Working Group II. Cambridge University Press, Cambridge, UK.
- Karl, T.A., 1998. Regional trends and variation of temperature and precipitation. Pages 411–425. In: R. T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken (eds.). *The regional impacts of climate change: an assessment of vulnerability*. Special report of the Intergovernmental Panel on Climate Change Working Group II. Cambridge University Press, Cambridge, UK.
- Lund, H.G., Torres, V., Turner, A. & Wood, L., 2002. *México. Análisis crítico de los estimados disponibles de deforestación*. USAID-SEMARNAT.
- Mittermeier, R.A. & Mittermeier, C.G., 1992. La Importancia de la Diversidad Biológica de México. In: J. Sarukan, and R. Dirzo (eds.). *México ante los retos de la Biodiversidad*. CONABIO, México.
- Neilson, R.P. 1998. Simulation of regional climate change with global coupled climate models and regional modelling techniques. Pages 439–456 In: R.T. Watson M.C. Zinyowera, R. H. Moss, and D. J. Dokken (eds.). *The regional impacts of climate change: an assessment of vulnerability*. Special report of the Intergovernmental Panel on Climate Change Working Group II. Cambridge University Press, Cambridge, UK.
- Rzedowski, J. 1993. Diversity and origins of the phanerogamic Flora of Mexico. Pages 129-146. In: Ramamoorthy, T.P., R. Bye, A. Lot, F. Fa (eds.). *Biological Diversity of Mexico: Origins and Distribution*. Oxford University Press, New York. USA.
- Sousa, S.M. & Delgado, S.A., 1993. Mexican Leguminosae: Phytogeography, endemism and origins. Pages 459-512. In: Ramamoorthy, T.P., R. Bye, A. Lot, F. Fa (eds.). *Biological Diversity of Mexico: Origins and Distribution*. Oxford University Press, New York. USA.
- Téllez-Valdés, O. & Dávila-Aranda, P., 2003. Protected Areas and Climate change: A case study of the cacti of the Tehuacán-Cuicatlán Biosphere Reserve, México. *Cons. Biol*. **17:** 846-853.
- Téllez-Valdés, O., Dávila-Aranda, P. & Lira-Saade, R., 2006. The effects of climate change on the long-term conservation of *Fagus grandifolia* var. *mexicana*, an important species of the Cloud Forest in Eastern Mexico. *Biod. and Cons.* **15:** 1095-1107.
- Turner, B.L. & Nesom, G.L., 1997. Biogeografía, diversidad y situación de peligro o amenaza de Asteraceae de México. Págs. 545-561. In: Ramamoorthy, T.P, R. Bye, A. Lot & J. Fa. (eds.). *Diversidad Biológica de México. Orígenes y Distribución*. Instituto de Biología Universidad Nacional Autónoma de México, México D. F. Mexico.
- Velásquez, A., Mas, J.F., Díaz-Gallegos, J.R. *et al*., 2002. *Patrones y tasas de cambio de uso del suelo en México*. Gaceta 62: 21-37. Instituto Nacional de Ecología. SEMARNAT, México.
- Villaseñor J.L.,2003. Diversidad y distribución de las Magnoliophyta de México. *Interciencia* **28:** 160-167.
- Villaseñor, J.L., Ibarra, G. & Ocaña, D., 1998. Strategies for the Conservation of Asteraceae in Mexico. *Cons. Biol.* **12:** 1066-1075.
- Villaseñor, J.L. & Téllez-Valdés, O., 2004. Distribución potencial de las especies del género Jefea (Asteraceae) en México. *Anales Inst. Biol. Univ. Nac. México, Ser. Bot.* **75:** 205-220.

O. Téllez, P. Dávila, M. Ayala, K. Gutiérrez & I. Melchor
Laboratorio de Recursos Naturales UBIPRO
Facultad de Estudios Superiores, Iztacala (FES, Iztacala)
Universidad Nacional Autónoma México (UNAM), Av. de los Barrios 1, Los Reyes, Tlalnepantla
Estado de México, 54090. Ap. postal 314, Mexico
E-mail: tellez@servidor.unam.mx
Internet: http://www.iztacala.unam.mx/index.php

Authors: Christopher Ellis and Mary Gibby

Research on biodiversity and climate change at the Royal Botanic Garden Edinburgh

The Royal Botanic Garden Edinburgh (RBGE) in Scotland holds living collections of 15,600 species across four gardens, over 2.5 million preserved herbarium specimens, and provides expertise in the science of botanical diversity, e.g. taxonomy, systematics, evolutionary biology, population genetics and conservation biology of plants and fungi. This represents a valuable scientific resource directly relevant to major challenges posed by climate change. Human-induced global warming will significantly threaten levels of biodiversity (Hannah *et al*., 2002; Parmesan & Yohe, 2003; Travis, 2003; Thuiller *et al*., 2005) with concerns over the subsequent loss of ecosystem services - biological resources, environmental services and ecosystem function (Hooper *et al*., 2005; Diaz *et al*., 2006; see Figure 1).

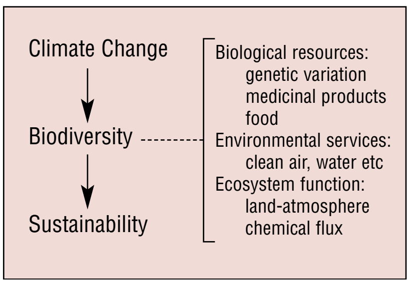


Figure 1 Biodiversity science is an essential link between the process of climate change and future environmental, social and economic sustainability – it is the natural framework supporting ecosystem processes and services.

This importance of biodiversity as the natural framework underpinning social and economic sustainability is internationally recognized and was legally ratified by the Convention on Biological Diversity (CBD Secretariat, 2007) and its lower-level frameworks (Europa, 2007; UK Biodiversity Action Plan, 2007); accordingly, biodiversity science provides a fundamental link between the physical process of climate change and subsequent impacts on social and economic well-being (Figure 1).

Climate change science at RBGE can be grouped into three interrelated themes: prediction, monitoring and evolutionary response (Fig. 2). RBGE research uses statistical models to predict the impacts of climate change on biodiversity (e.g. the response of species to IPCC scenarios) indicating which species or vegetation types may be threatened by climate change and should be closely monitored or protected (e.g. by translocation or the mitigation of other stresses). Monitoring seeks to observe the response of sensitive elements of Scottish biodiversity to climate change, providing a robust measure of change in the flora, and identifying opportunities for mitigation. However, monitoring is itself an important mechanism with which to verify model projections and thereby calibrate and improve the predictive ability of modelling studies. Prediction and monitoring thus describe the impacts of climate change on species, providing a base-line for conservation strategies (e.g. adaptation and mitigation); however, at a fundamental level the impact of climate change on biodiversity will be determined by population genetic processes (e.g. metapopulation dynamics and the ability of species to migrate through fragmented landscapes and the potential for genetic adaptation to different and possibly novel climates). This work is supported by research into the effect of past climate change on vegetation structure and function (Brncic *et al*., 2006. Ellis & Rochefort, 2004, 2006).

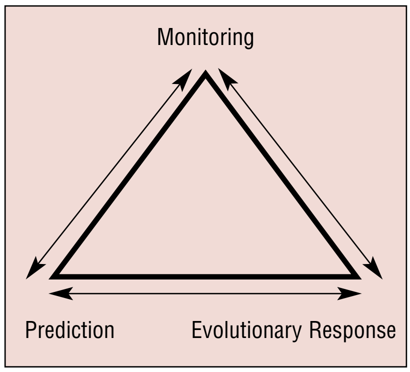


Figure 2 Research themes at RBGE which provide a base-line for strategies to mitigate the impact of climate or for species to adapt to climate change impact, adaptation and mitigation.

A number of individual research projects dealing with climate change are now well-developed and others are in the 'development stage' (project planning, grant applications pending etc.).

Left: Rhododendrons at Gang Ho Ba, Hengduan Mts, Yunnan (Photo: RBGE)

Phenology Programme

Phenology is the study of recurring seasonal events, such as flowering and leaf-fall in plants and hibernation and migration in animals. Parameters such as the date and duration of flowering can be compared with climatic parameters such as temperature, rainfall and humidity to see if there is any correlation. Phenological research at RBGE dates back to 1850, when the Curator, James McNab first recorded the flowering dates of more than 40 species. The current phenology programme at RBGE has been running for the past five years and involves recording the frequency and duration of flowering and stages with each flowering season and changes in foliage for over a hundred species. These data will increase the understanding of the mechanism in plants which responds to climate changes and will enable scientists to predict how plants will respond to climate change. Over the past five years early spring has been getting warmer and some spring-flowering plants flower more than two weeks earlier (see Figure). It is a unique experimental opportunity comprising plants from regions across the world, growing at a single site, and subject to the same approximate climatic variation.

The phenology programme based at RBGE is in collaboration between staff and research associates in the Science and Horticulture Divisions and volunteers. The programme includes a daily monitoring project, a weekly monitoring project and the special examination of Rhododendron species. These studies include the development of semi-quantitative rapid-survey methods for monitoring phenological characters (Harper *et al*., 2004; Harper & Morris, 2006).

The Scottish Forestry Phenology Project aims to establish a network of sites based on RBGE's climatically contrasting Scottish gardens (at Edinburgh, Dawyck, Logan and Benmore) and including Dundee Botanic Garden. The details of the project remain to be resolved, though it is envisaged that it would be undertaken in collaboration with key stakeholders in Scottish forestry and would provide information relevant to the forest industry (i.e. phenology of material of known genetic stock under different climatic conditions).

The International Phenology Gardens Project is coordinated by Humboldt University (Berlin), with sites throughout continental Europe. The project monitors the phenology of cloned material for a range of tree species. RBGE is currently establishing a site at its garden at Dawyck which, for Scotland, has an unusual cool continental climate and will provide important new data for the project.

Cryptogam projects

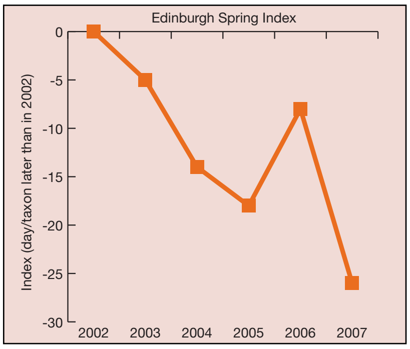
A significant body of climate related research focuses on monitoring and predicting the impact of climate change on Scottish cryptogams. Cryptogam species (i.e. mosses, liverworts, lichens, fungi and ferns) are one of Scotland's most important contributions to international biodiversity (Mackay *et al*., 2001; Gibby, 2003). RBGE studies include research to optimise patterns of habitat structure (e.g. patterns of woodland isolation and connectivity) aimed at ensuring the effective response of Scotland's internationally important cryptogam communities to future climate change (Ellis & Coppins, 2006, 2007a, 2007b).

Snow-bed ferns: In the UK, the fern *Athyrium distentifolium* is expected to be threatened by the effects of climate change. It is restricted to areas of late snow lie in the Scottish mountains and a current research monitoring programme has already shown that populations can be devastated by reduced snow cover in winter (McHaffie, 2006). The Scottish endemic *Athyrium distentifolium* var. *flexile* differs in its reproductive capacity from *A. distentifolium* (e.g. producing ripe spores earlier in the season), and it may show a different response to the changes in climate (McHaffie *et al*. 2001).

Species-response: Research using predictive models to examine the projected response of lichen species to climate change, including the interaction between climate-response and habitat structure (i.e. patch extent, fragmentation and limits to dispersal). This predictive information aims to guide the decision making process for a long-term conservation strategy. Greater understanding of the interaction between climate and habitat is essential in developing mitigation strategies for sustainable forestry projects.

Climate indicators: Lichens are popularly applied as sensitive bioindicators. Research currently in the development phase is seeking to set up a network of monitoring sites, to examine the response of lichen species to changes in climate. Selected species will potentially include sensitive arctic-alpine elements of Scotland's montane flora. This project will be established to complement studies in species-response (above), contributing to calibrating predictive models.

Snow-bed bryophytes: A new study is currently setting up long-term permanent plots, aimed at monitoring the response to climate change of Scotland's bryophyte-rich snow-bed communities. The study is in partnership with Scottish Natural



Right: The Edinburgh Spring Index takes an average of first-flowering dates for a selection of spring flowers. This graph shows the average number of days by which the first-flowering dates are earlier than 2002

Heritage.

Molecular Projects

Molecular ecology at RBGE continues to make an international contribution to biodiversity research and conservation, and this research programme has been extended to address genetic adaptation to climate change and possible mitigation of the effects of the changes in climate.

Bluebells: A project examining the ecology of native and non-native bluebells includes experimental work to examine the competitive performance of different species along climatic gradients. The study aims to broaden the debate from a single species-response to climate change to a greater understanding of species interactions. It also provides an important practical assessment for the potential effects of climate change on a threatened native and non-native species.

Gene Flow and adaptation: Existing molecular studies use data to examine the potential of species to adapt to environmental change (i.e. through sexual reproduction and selection). Populations might acquire adaptive variation from elsewhere (i.e. there might be a potential to introduce genetic variation from other populations of the species either artificially or naturally if seeds/pollen can travel over large distances). Molecular studies can examine the dispersal ability of species which will estimate their potential to migrate through patchy or fragmented habitats in response to changed climate. Recently such studies have focussed on conservation priority species. The current programme is examining diversity in species of Scotland's Caledonian pinewoods in collaboration with the Macaulay Institute and Scottish Crops Research Institute. This addresses the amount of climate related genetic variation between and among populations and the in situ adaptive capacity of species, i.e. can adaptive variation relevant to contrasting climates be dispersed across a species' range?

Flora projects

Flora projects contribute principally towards RBGE's commitment to biodiversity research and education. However, a number of projects have recently adapted this role to provide data relevant to climate change research.

Socotra: Research on the flora of Socotra has included student projects to examine the effect of climate change on areas of relict woodland (including sites on the Yemen mainland). However, the climate of Socotra is strongly controlled by small-scale topographic variation (e.g. effect of altitude), which combined with a lack of high resolution climatic data make this type of research especially challenging. The team are pursuing opportunities aimed at improving the predictive potential of climate-response models, and continue to work with local communities on issues relating to climate change and sustainable land-use.

Nepal: The flora of Nepal project has expanded its data collection from taxonomically relevant morphological characters to include additional species functional traits. These data are potentially relevant to monitoring and predicting the response of the vegetation structure and ecosystem function to climate change, and have strong potential for an integrated study with the phenology project (above). The team have established strong links in Nepal and they provide botanical expertise to organisations undertaking studies to investigate and mitigate the effect of climate change on plants (e.g. IUCN Nepal and WWF Nepal). The team are working with the British Council in Nepal to facilitate educational events that aim to promote climate change awareness, and with support from Darwin Initiative funding for 2007/2008 will supervise a Nepalese MSc student in a climate change study.

Tropics: The tropical group use phylogenetics and population genetics to understand how tropical species have responded to past environmental change. This includes palaeoecological data to examine the response of vegetation structure and function to past human socio-economy and climate change, as well as comparing reconstructed speciation rates to past periods of environmental change. Their projects examine the evolutionary potential of species to adapt and respond to climate change in the long-term (Pennington *et al*., 2005).

China: 1. Professor Yang Yong-ping, Deputy Director of Kunmimg Institute of Botany, is developing a long-term monitoring project to examine environmental change in the Hengduan Mountains of China. The foundation for this work is the capture of information on all the plant records from the region, through digitisation and databasing of herbarium records. With its rich collections of plants from Yunnan, dating back over 100 years, RBGE will be a partner in this project to provide information from our collections. 2. This work will be underpinned by current research on palaeoecology, vegetation history and climate change from the Quaternary to the present day. This research is a collaboration of RBGE with Professor Li Cheng Sen and his students at the Institute of Botany, Beijing. 3. Finally, the RBGE archive collections of photographs of Yunnan by George Forrest that illustrate past vegetation distributions and extent of glaciers will also contribute to the project.

Other resources

RBGE also provides indirect though important contributions to climate change science, for example:

Archives: RBGE photographic archives have been used by international scientists in time series studies examining landscape change (e.g. the altitudinal migration of floristic zones,

Right: Volunteers Sandra Stewart (left) and Lyn Blades monitor plants each week (Photo: RBGE)

Left: *Dracaena cinnabari*, Dragon's blood woodland in Socotra (Photo: RBGE)

or shifts in glacial features). Such studies include scientists from the Joint Nature Conservancy Council (UK) and Lakehead University (Ontario, Canada), and Kunming Institute of Botany. The archives also house a massive amount of phenological data (1906-1939) which has been extracted and examined by University of Edinburgh researchers.

Diatoms: RBGE undertakes fundamental research in the systematics and identification of diatoms. Diatoms are photosynthesising, microscopic algae; they have a siliceous skeleton and are found in almost every aquatic environment including fresh and marine waters and soils. Diatoms provide one of the most powerful palaeoenvironmental indicators and are used in palaeoclimatic studies as the basis into knowledge of the climate system. Principal palaeoresearch groups both in the UK and internationally consult with the taxonomic work carried out at RBGE, in order to resolve and interpret palaeoenvironmental records.

Education

Climate change is a rapidly developing theme in RBGE's programme of education and public outreach. With its popularity and range of visitors, RBGE is uniquely placed to engage in wider public education and discussion on climate change issues. The Gateway Project under development will include as part of its major thematic events and exhibitions: 'Climate Change – Scotland' and 'Climate Change – Global'.

References

- Brncic, T.M., Willis, K.J., Harris, D.J. & Washington, R., 2006. Culture of climate? The relative influences of past processes on the composition of the lowland rainforest. *Philosophical Transactions of the Royal Society* **362B:** 229-242.
- CBD Secretariat, 2007. *Convention on Biological Diversity.* http://www.cbd.int/default.shtml accessed 4th July, 2007.
- Diaz, S., Fargione, J., Chapin, F.S. & Tilman, D., 2006. Biodiversity loss threatens human well-being. *Public Library of Science, Biology* **4:** 1300-1305.
- Ellis, C.J. & Coppins, B.J., 2006. Contrasting functional traits maintain lichen epiphyte diversity in response to climate and autogenic succession. *Journal of Biogeography* **33:** 1643-1656.
- Ellis, C.J. & Coppins, B.J., 2007a. Climate change and historic woodland structure interact to control future diversity of the *Lobarion* epiphyte community in Scotland. *Journal of Vegetation Science* **18:** 725-734.
- Ellis, C.J. & Coppins, B.J., 2007b. Predicted response of the lichen epiphyte Lecanora populicola to climate change scenarios in a clean-air region of northern Britain. *Biological Conservation* **135:** 396-404.
- Ellis, C.J. & Rochefort, L., 2004. Century-scale development of High Arctic polygon-patterned tundra wetland, Bylot Island (73 oN). *Ecology* **85:** 963-978.
- Ellis, C.J. & Rochefort, L., 2006. Long-term sensitivity of a High Arctic wetland to Holocene climate change. *Journal of Ecology 94:* 441-454.
- Europa, 2007. *Habitats Directive* (92/43/EEC) http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm accessed 7th July, 2007.
- Gibby, M., 2003. Overview of Scottish plant conservation: problems, research needs and policy issues. *Botanical Journal of Scotland* **55:** 1-5.
- Hannah, L., Midgeley, G.F., Lovejoy, T., *et al*., 2002. Conservation of biodiversity in a changing climate. *Conservation Biology* **16:** 264-268.
- Harper, G.H., Mann, D.G. & Thompson, R.,2004. Phenological monitoring at the Royal Botanic Garden Edinburgh. *Sibbaldia* **2:** 33-45.
- Harper, G.H. & Morris, L., 2006. Flowering and climate change – part I. *Sibbaldia* **4:** 71-86.
- Hooper, D.U., Chapin, F.S., Ewel, J.J., *et al*., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* **75:** 3-35.
- McHaffie, H.S., Legg, C.J. & Ennos, R.A., 2001. A single gene with pleiotropic effects accounts for the Scottish endemic taxon *Athyrium distentifolium* var. *flexile*. *New Phytologist* **52**: 491 – 500.
- McHaffie, H. S., 2006. Alpine Lady Ferns: are they suffering with climate change? *Pteridologist*, **4:** 162-164.
- Mackay, E.C., Shaw, P., Holbrook, J. *et al*., 2001. *Natural Heritage Trends: Scotland 2001*. Scottish Natural Heritage, Perth.
- Parmesan C. & Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* **421:** 37-42.
- Pennington , R.T., Lavin, M., Prado, D.E., Pendry C.A. & Pell, S., 2005. Climate change and speciation in neotropical seasonally dry forest plants. In: Y. Malhi & O.L. Phillips (eds.), *Tropical forests and global atmospheric change*. pp. 199-214. Oxford University Press, Oxford, UK.
- Thuiller, W., Lavorel, S., Araújo, M.B. *et al*., 2005. Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Science* **102:** 8245-8250.
- Travis, J.M.J., 2003. Climate change and habitat destruction: the deadly anthropogenic cocktail. *Proceedings of the Royal Society, London* **B 270:** 467-473.
- UK Biodiversity Action Plan, 2007. http://www.ukbap.org.uk/

Below: Part of James MacNab's register of first flowering dates (extract from Transactions of the Botanical Society of Edinburgh, vol. V, part III, p. 173)

Christopher Ellis and Mary Gibby
Royal Botanic Garden Edinburgh
20A Inverleith Row
Edinburgh EH3 5LR UK
E-mail: m.gibby@rbge.ac.uk
Internet: www.rbge.org.uk

Author: Peter S. Wyse Jackson

The potential impact of climate change on native plant diversity in Ireland

Right: View of National Botanic Gardens of Ireland (Photo: BGCI)

Climate change has become a major issue of concern for governments and international agencies over the last few years as the realization has grown that climate change is becoming a reality, rather than what might have been perceived in the past as an ill considered 'doomsday' prediction by some scientists and environmentalists. With this growing concern, public opinion and understanding of climate change issues has heightened too. This is partly as a result of apparently increasingly unpredictable weather patterns in many parts of the world, which are attributed to climate change (although it is often unclear whether this is really always the case). While climate change is now seen as a reality that must be addressed as a common concern of humanity, there is, by and large, still seriously little concern for its impact on biodiversity in general and plants in particular.

In a foreword to Ireland's *National Climate Change Strategy 2007-2012* published this year, the Irish Prime Minister (Taoiseach), Bertie Ahern T.D., recognized that 'Climate change is among the greatest challenges of our time' (Government of Ireland, 2007). Nevertheless the Strategy itself pays little attention to the impact of climate change on Ireland's biodiversity but instead concentrates on issues such as energy supplies, transport, industry, agriculture and waste – although it does acknowledge that "ecosystems are vulnerable to climate change with the risk of extinction for certain species, loss of tundra and certain forest areas". In its section on Agriculture, Land-use and Forestry, the Irish Plan recognized that extensive planting of broad-leaved trees and hedgerows can help to contribute to carbon sequestration, but does not consider whether the species planted may themselves be impacted by climate change in the future.

At the international level specific proposals and actions are however now being considered to address the threats to biodiversity from climate change. For example, the UN Convention on Biological Diversity (CBD) at its forthcoming meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA 12) in Paris in July 2007 will include climate change and biodiversity as an agenda item, supported by a discussion document prepared by the CBD's Executive Secretary, that proposed the integration of climate change activities within the programmes of work of the Convention, including options for mutually supportive actions addressing climate change within each one of the Rio Conventions(CBD Secretariat, 2007a). In addition, the Millennium Ecosystem Assessment identified numerous links between biodiversity and climate change (Millennium

Ecosystem Assessment, 2005). These initiatives recognized that to integrate biodiversity and climate change actions it will be necessary to:

a) Identify vulnerable regions, sub-regions and ecosystem types, including the components of biodiversity within these areas;
b) Assess the threats and likely impacts of climate change on biodiversity in the vulnerable areas identified;
c) Evaluate the climate change adaptation and mitigation options and measures proposed in relation to impacts on biodiversity, and
d) Implement and monitor the impact on biodiversity of adaptation and mitigation plans and measures adopted.

The CBD has also convened several meetings of an Ad Hoc Technical Expert Group on Biodiversity and Climate Change, which has developed a methodology to evaluate the risks to biodiversity from climate change, results of which are included in the CBD Technical Series No. 25. The CBD has also prepared a further important document in relation to climate change and biodiversity which include abstracts of important case studies contributed by experts worldwide, to support the SBSTTA meeting in Paris in July 2007 (CBD Secretariat, 2007b). In that publication the United Nations Secretary General, Ban Ki-Moon, noted that it is appropriate that the 2007 International Biological Diversity Day should focus on "Biodiversity and Climate Change" as integrating the mutual concerns of both will be fundamental to the achievement of the Millennium Development Goals.

Despite the above developments, the specific issue of climate change and plant conservation has been little considered to date. However, *The Gran Canary Declaration II on Climate Change and Plant Conservation* is an important new awareness-raising exercise and call to action, drawing new attention to the urgency of addressing plant loss as a result of climate change (BGCI & Cabildo de Gran Canaria, 2006). *The Gran Canaria Declaration II* also provides a useful list of taxa that may be most significantly impacted by climate change:

- Taxa with nowhere to go, such as mountain tops, low-lying islands, high latitudes and edges of continents;
- Plants with restricted ranges such as rare and endemic species;
- Taxa with poor dispersal capacity and/or long generation times;
- Species that are susceptible to extreme conditions such as flood or drought;
- Plants with extreme habitat/niche specialisation such as narrow tolerance to climate-sensitive variables;
- Taxa with co-evolved or synchronous relationships with other species;
- Species with inflexible physiological responses to climate variables;
- Keystone taxa important in primary production or ecosystem processes and function; and
- Taxa with direct value for humans or with potential for future use.

Internationally, significant efforts are continuing to improve and refine the quality of global and regional climate change models. The Irish Climate Change Strategy says that sustained efforts will be required in Ireland to maintain and develop climate modeling and down scaling capacity in order to ensure that these improvements inform decision-making at national and local levels. To date in Ireland there have not been significant high-resolution studies undertaken to measure the potential impact of climate change on plant diversity, applying the climate change models in a quantitative way to review likely changes in the Irish flora and ecosystems.

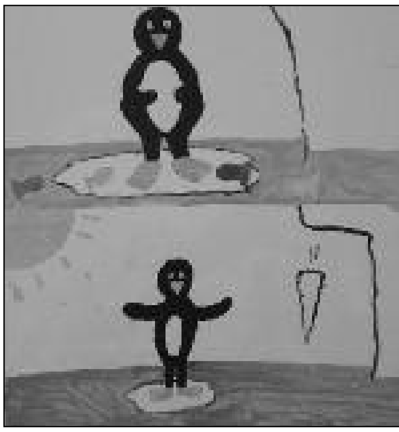
Predicted changes in Ireland's climate as a result of climate change include:

- Rises in the mean annual temperatures: between 1890 and 2004 mean annual temperatures in Ireland rose by over 0.7°C and six of the ten warmest years during this period have occurred since 1995. Predicted scenarios suggest that by 2050 there will be an increase of January temperatures of 1.5°C in Ireland and July temperatures of 2.5°C.
- Changes in rainfall and precipitation patterns: a marked reduction of between 25% and 40% in summer rainfall is also possible, according to predictions, as well as perhaps some winter rainfall increases.
- More frequent storms: The frequency of severe storms coming to Ireland from the Atlantic Ocean may increase by about 15%.
- Increase in extreme weather events: such as floods, droughts, heat waves etc.

In 2005, work began in Ireland to develop and subsequently to implement a National Plant Conservation Strategy (National Botanic Gardens, Ireland, 2007). This Strategy proposed a set of targets, actions, milestones and indicators for Ireland to fulfill its obligations under the *Global Strategy for Plant Conservation* (GSPC) as part of its commitments to the CBD (CBD Secretariat, 2003).

In order to contribute towards this National Strategy, this author undertook a preliminary qualitative assessment of the possible impact of climate change on the native Irish flora, with the aim of obtaining a clearer view of the possible (or even likely changes) in the Irish flora composition over the next c.50 years and to help inform conservation

Below: Sustainability workshop for school children at the National Botanic Gardens of Ireland and a Child's illustration of climate change from the workshop



Right: Killarney Fern (*Trichomanes speciosum*) in cultivation

priorities and measures needed for plant diversity conservation in Ireland. A total of 850 native plant species were assessed in relation to the list of criteria for Climate Change-vulnerable taxa given in the *Gran Canaria Declaration II* (above) and the predicted changes in the Irish climate. The results of this assessment are given below. It is stressed however that this is a 'qualitative' assessment only and the results should be regarded as very preliminary. It is urgent therefore that an experimental approach to the assessment of climate change-vulnerable taxa is applied in Ireland and elsewhere in order to develop predictive models for specific plants and groups of plants. Such models can then be used to support and inform better decision-making and to guide the plant conservation measures undertaken. The potential role of botanic gardens in undertaking such research studies should also be stressed, utilizing their *ex situ* collections and wide ranging facilities for scientific study, as well as for plant cultivation, propagation and long-term monitoring.

The situation in Ireland

It is suggested that the plant species that will be most heavily impacted by climate change in Ireland are the following:

- Species that are already threatened in Ireland due to a variety of factors and reasons
- Species that occur in restricted or vulnerable habitats (such as 'alpine' type habitats in the mountains, coastal sites, peatlands and other wetlands, wetland margins etc).
- Species that are particularly prone to loss due to competition from invasive alien plants.
- Species that may be adversely affected by related changes to the biodiversity in their ecosystems as a result of climate change (such as loss of pollinators, seed dispersal agents etc).

The spread of new pathogens, such as new insect pests, vectors and diseases, may also be an increasing consequence of climate change and have an impact on native plant diversity. However, the prediction of what will be the result of these on specific plant species is difficult to predict and has not been included in this assessment.

Using these criteria an assessment has been made as to whether each native species (vascular plants only) in the Irish flora is likely to be impacted by climate change in a detrimental way or not. The impacts on specific species are not listed here and only a summary of the overall results of the study are provided. A list of threatened plants in Ireland provided on the website of the National Botanic Gardens (www.botanicgardens.ie) was used for reference to review whether already rare or endangered native plants would be further threatened by climate change. No species is currently included in this list on the basis that it is threatened by climate change. Eleven species (1%) of the Irish native flora are currently either 'extinct' or 'extinct in the wild'.

The assessments revealed that, conservatively, there are at least 171 native plant species (20% of the total native flora) that appear to be particularly vulnerable to climate change during the period 2007 to 2050. Of a total of 143 threatened species currently included in the Irish threatened plants list, 74 species (52%) may have their situation made potentially worse due to climate change. In addition, 28 (3%) species that are currently not threatened in Ireland are likely to become so due to climate change.

It is also likely that plants of woodlands, long-lived species (such as trees) and species that are abundant in Ireland are generally less likely to be threatened by climate change, at least not by 2050. Species that occur in widespread and stable habitats may also be only marginally affected, such as those of hedgerows and grasslands. Species that occur in habitats that are already subject to periodic drought and / or inundation may also be relatively adaptable and resistant to climate change, such as submerged aquatics, species from dry walls and well-drained rocky places.

Nevertheless there is a wide range of species that are potentially vulnerable to the predicted Irish climate changes and unless specific conservation measures are put in place, both *in situ* and *ex situ*, it is likely that Ireland could lose a significant proportion of its native plants as a result of climate change. The question has to be asked in relation to these findings – in what ways must the focus of the plant conservation plans and programme of the National Botanic Gardens of Ireland be changed or adapted to respond to an increasingly serious plant conservation challenge? A programme to address national targets for the GSPC has already been developed (and through them, to contribute to the relevant international targets). That includes ensuring that by 2010 the Gardens are involved in or contributing to the development and implementation of a range of species conservation and recovery programmes. Our institutional target includes the inclusion of all critically endangered plants in an *ex situ* conservation programme, with the addition of 3 to 4 other species each year. The institution is also involved in several existing and proposed All Ireland Species Action Plans for endangered species, such as for the orchid *Spiranthes romanzoffiana* and the Killarney Fern, *Trichomanes speciosum*, both of which are protected in Ireland under the European Union's Habitats Directive (Europa, 2007). The institution expects to be increasingly involved in such programmes in the future and climate change impacts may result in more species becoming priorities. However, be that as it may, the existing critically endangered species will probably still remain as the most urgent priorities for action. Further initiatives that will also need to be developed include specific measures and continued vigilance in relation to existing and potentially invasive species (plants and animals), pests and diseases, so that increased pressure on already hard-pressed natural and semi-natural ecosystems and the species they contain can be managed, hopefully more effectively. The responsibility to help conserve, monitor and raise awareness of these threats to native plants and their habitats from climate change is a considerable challenge for botanic gardens in Ireland, as indeed it is for botanic gardens worldwide. Our efforts to conserve endangered plants *ex situ*, as a back up to *in situ* measures, are made even more valid and necessary as a result of climate change, when natural habitats for many threatened plants may no longer be able to support their indigenous species.

Above: View of National Botanic Gardens of Ireland (Photo: BGCI)

References

- BGCI & Cabildo de Gran Canaria, 2006. *The Gran Canary Declaration II on Climate Change and Plant Conservation*. BGCI, London, UK & Cabildo de Gran Canaria, Las Palmas de Gran Canaria, Spain.
- CBD Secretariat, 2003. *Global Strategy for Plant Conservation.* CBD Secretariat, Montreal, Canada. http://www.cbd.int/programmes/cross-cutting/plant/default.asp accessed 4th July, 2007.
- CBD Secretariat, 2006. *Guidance for promoting synergy among activities addressing biological diversity, desertification, land degradation and climate change*. Technical Series No. 25. CBD Secretariat, Montreal, Canada. http://www.cbd.int/doc/publications/cbd-ts-25.pdf
- CBD Secretariat, 2007a. *Proposals for the Integration of Climate Change Activities within the Programmes of Work of the Convention*. UNEP/CBD/SBSTTA/12/7. CBD Secretariat, Montreal, Canada http://www.cbd.int/doc/meeting.aspx?mtg=SBSTTA-12 accessed 4th July, 2007.
- CBD Secretariat, 2007b. *Emerging Issues for Biodiversity Conservation in a Changing Climate*. Technical Series No. 29. CBD Secretariat, Montreal, Canada http://www.cbd.int/doc/publications/cbd-ts-29.pdf
- Europa, 2007. *Habitats Directive (92/43/EEC)* http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm
- Government of Ireland, 2007. *Ireland National Climate Change Strategy 2007 – 2012*. Department of Environment, Heritage and Local Government, Ireland.
- Millennium Ecosystem Assessment, 2005. *Millennium Ecosystem Assessment: Ecosystems and Human Well-being - Biodiversity Synthesis*. World Resources Institute, Washington, USA.
- National Botanic Gardens, Ireland, 2007. *A National Plant Conservation Strategy for Ireland* (Final Draft). National Botanic Gardens, Glasnevin, Ireland. http://www.botanicgardens.ie/gspc/inspc.htm accessed 7th July, 2007.

Left: The curvilinear glasshouse range at the National Botanic Gardens of Ireland (Photo: Peter Wyse Jackson)

Peter S. Wyse Jackson
Director, National Botanic Gardens of Ireland
Glasnevin, Dublin 9. Ireland
Email: peter.wysejackson@opw.ie;
Internet: www.botanicgardens.ie;

Author: Jon C. Lovett

Climate change and Africa: an ecological perspective

Above: Wendy Foden measuring a specimen of Quiver Tree (*Aloe dichotoma*) (Photo: SANBI)

Climate change and ecology

By burning fossilised plants for energy huge quantities of carbon dioxide have been pumped into the Earth's atmosphere. Unlike smoke or smog it cannot be seen, but so much has been burnt that the concentration of atmospheric carbon dioxide has measurably increased. There are a number of interesting ecological changes that appear to be related to this increase. Firstly, as any botanist knows, the normal concentration of carbon dioxide is a limiting factor for photosynthesis. Plants, or at least some plants, can grow faster when there is more CO_2, a prediction confirmed by research on native African plants at the South African National Biodiversity Institute (SANBI, 2007). This increased growth has knock-on ecological effects. For example, comparison of old photographs with modern landscapes by Professor William Bond of the University of Cape Town, shows that in South Africa at least, woody plants are invading grasslands (pers.comm., 2006). These changes in vegetation then cause changes in the hydrology of water catchments. Now it is necessary to stop and think for a moment. Usually when human impact on vegetation is considered it is in relation to a particular development, perhaps ploughing a field or felling a forest. However, increased CO_2 is different because of the vast scale of the change, which is everywhere. In the South African example the concern is that the entire grassed catchment area of the Drakensberg range will be affected causing substantial changes to South Africa's water supply.

The second ecological effect of increased CO_2 is caused by its role as a 'green-house gas'. Together with some other gases, such as methane, CO_2 acts as a planetary blanket that slows down the release of the Sun's warmth from the Earth's surface. The situation is complicated by factors such as cloud cover, but the general scientific consensus now is that an observed increase in global temperatures results from the increase in greenhouse gases, notably CO_2. Again the vast scale of changes needed to be considered. Climate determines the extent of the major vegetation formations and in a warmer world whole biomes are on the move. Not all the plants can keep up; research by Wendy Foden on the Quiver Tree (*Aloe dichotoma*) in Namibia shows that populations in the northern part of the range are dying as the area experiences more drought conditions (Foden, 2002; in press). More southerly trees are doing well with young plants regenerating. However the change is happening so fast that it is hard for a long-lived and slow growing species such as the Quiver Tree to keep up. Vegetation models of the Cape Floristic kingdom by SANBI scientist Guy Midgley show that this extra-ordinary area of plant diversity will be much reduced under future climate scenarios with a huge number of extinctions predicted (Hannah *et al*., 2005, Lovett, 2005a, 2005b).

Although much of the recent research on plants and climate change has been carried out in South Africa, with some dramatic conclusions, the impacts will be continent-wide (McClean *et al*., 2006; McClean *et al*., 2005). When global temperatures increase there are huge changes to the world's weather systems with all sorts of knock-on effects. For example, Africa produces about half of the world's dust, much of it coming from the Sahara and Sahel. The dust modifies climate by reflecting solar energy, provides nutrients for carbon-dioxide absorbing plankton in the ocean and helps fertilize Amazon soils. If rainfall in the Sahara and Sahel were to increase thereby causing increased vegetation cover, and there are indications that this is currently the case, then there could be changes in

Right: Quiver Tree (*Aloe dichotoma*) Karoo Desert National Botanical Garden (Photo: SANBI) the amount of dust. More storms in the Sahel are also associated with a higher frequency of Atlantic hurricanes. Extreme weather conditions that can cause great economic damage in countries around the Gulf of Mexico seem to start in the highlands of Ethiopia, travel westwards across Africa and then over the Atlantic to wreak havoc on the sea-board of the USA and Caribbean countries.

However, long-term predictions are for a drier western Africa and expansion of the Sahara southwards into what are now the Congo rainforests (see Figure 1). Interestingly, it appears that this has happened before during previous global climate change as the present-day forests are growing on desert sands. Models of vegetation shifts suggest that forest plants will move southwards into Angola and up into the mountains of the central rift. The wetter parts of central Africa, which are the coastal regions of Cameroon and Gabon, are predicted to retain more plant diversity than elsewhere, as are the mountains of eastern coastal Africa. Compared with the past, these predictions match locations of proposed African rainforest refugia, even though the refugia were during times of a colder, drier climate instead of a hotter one. There are several possible reasons for this. Firstly it is rainfall that determines where the rainforests are. So in times of drought the rainforests will contract in both hotter and drier climes. Secondly, mountains tend to be wetter as they act as condensers of moisture; and thirdly, mountains offer plants the chance to move to a different climate in a short distance. Simply by going up a few hundred metres in elevation a plant can find a cooler habitat, unlike the poor Quiver Tree, which has to move hundreds of kilometres.

Climate change and society

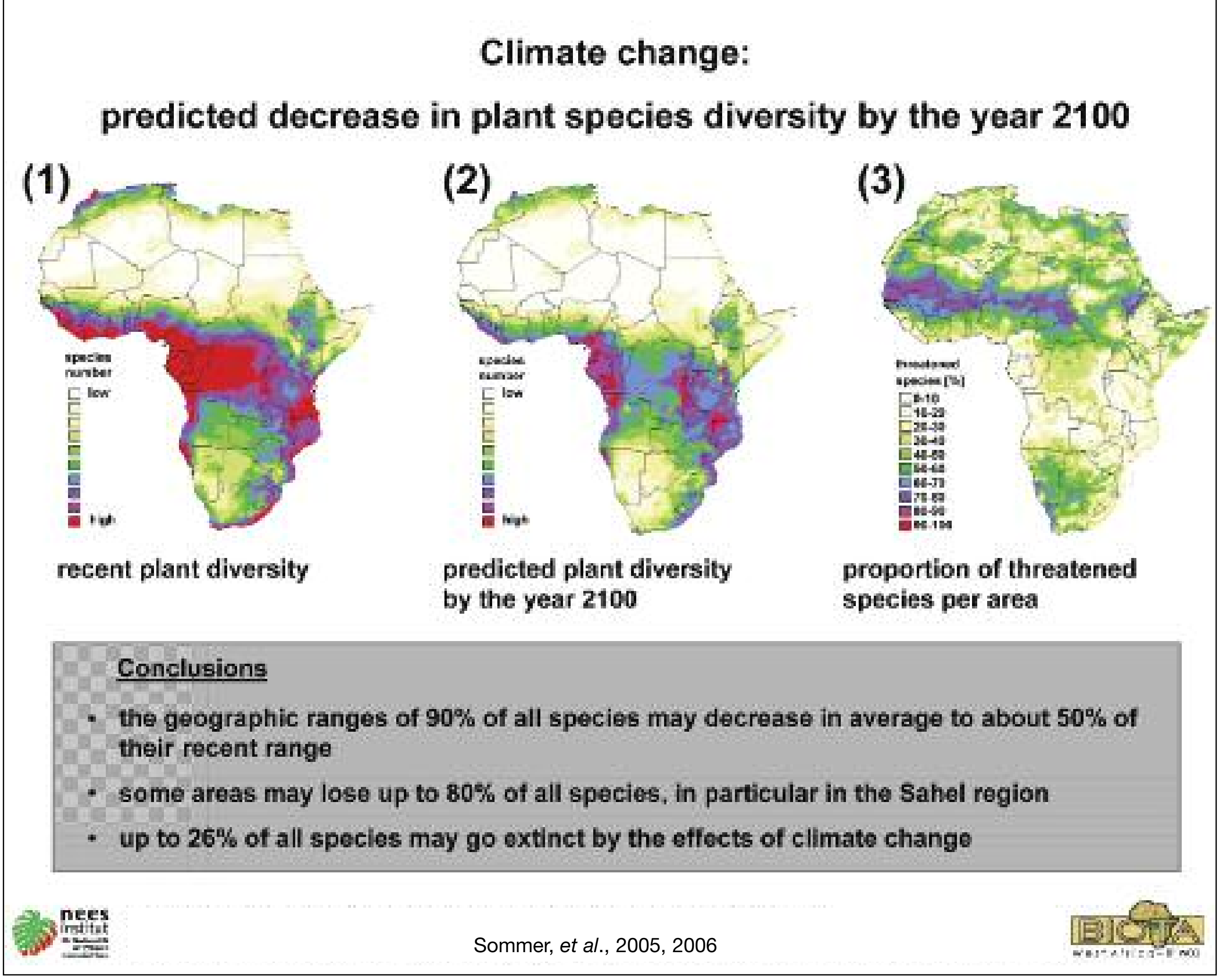
Humans live under all kinds of climatic conditions. In Africa people live on high altitude grasslands, in the deep forest and driest deserts. But the type of climate plays an important role in how societies are organised and if the climate changes then social structures will need to change too. This can be seen in African history. Drying of the Sahara from about 5300 years ago has been associated with the rise of the Pharaohs along the Nile. Collapse of the city of Mapungubwe in 1290 AD in southern Africa and subsequent rise of Great Zimbabwe can be linked to drought followed by a wetter climate. More recently, drought contributed to the ecological shocks of cattle disease and small pox experienced in eastern Africa at the end of the 19th century, known by the Maasai as the Emutai period. The rains failed completely in 1897 and 1898. The Austrian explorer Dr Oscar Baumann, who travelled in Maasailand in 1891, wrote chilling eye-witness accounts of the horror experienced by the Maasai people:

"There were women wasted to skeletons from whose eyes the madness of starvation glared ... warriors scarcely able to crawl on all fours, and apathetic, languishing elders. Swarms of vultures followed them from high, awaiting their certain victims."
(Baumann 1894, Masailand)
History looks set to repeat itself. The world was faced with similar scenes from Eritrea during the 1980s and recently the UN Secretary General Ban Ki-moon suggested that the Dafur crises was due to drought and conflict between settled farmers and nomadic herders over scarce water supplies – problems which he linked to climate change. The Intergovernmental Panel on Climate Change states that Africa is the continent most vulnerable to climate change with an increase in both the frequency and severity of droughts and floods. The 1991-1993 drought in south-eastern Africa affected about 100 million people, where-as floods in the region in 2000 reduced Mozambique's annual economic growth rate from 8% to 2%. At the same time as World leaders have agreed on Millennium Development Goals to reduce poverty and improve environmental sustainability, climate change is unzipping the fabric of societies caught up in its effects.

Left: *Aloe dichotoma* (Photo: SANBI)

Policy responses

Scientific investigations of climate change have been warning for some time that human activities that increased atmospheric concentrations of greenhouse gases could have global effects, leading to a concerted international policy response. The United Nations Framework Convention on Climate Change entered into force on 21 March 1994; most countries have signed up to it, and it has been ratified by 191 countries. At the first conference of the parties in Berlin in 1995 it was decided that there needed to be a stronger protocol containing detailed commitments for industrialized



Right: Figure 1. Climate change: predicted decrease in plant species diversity by the year 2100

countries. This lead to the Kyoto Protocol being adopted at the third conference of the parties in Kyoto on 11 December 1997, which listed the industrialized countries that needed to take action in an annex, leading them to be called the 'Annex 1 countries'. However, the individual needs of nations made it difficult for State governments to ratify the Protocol as there was considerable concern about the economic impacts of limiting greenhouse gas emissions in economies largely dependent on burning fossil fuels for power and transport. Moreover there was also concern about the principle of 'differentiated but common responsibilities' in which developing countries (called the non-Annex 1 countries) did not have any commitments under the protocol. To many this might seem fair, after all, why should developing African nations have to curtail their economic growth to counter a problem that was not of their making? But not all developing countries have the carbon footprints of those in Africa. Of particular concern in 1997 was the potential economic rise of India and China, both non-Annex 1 counties in the Kyoto Protocol and so not subject to any controls on greenhouse gas emissions. This led the United States senate to pass the Byrd-Hagel Resolution in July 1997 by 95 votes to 0:

Resolved, That it is the sense of the Senate that—
(1) the United States should not be a signatory to any protocol to, or other agreement regarding, the United Nations Framework Convention on Climate Change of 1992, at negotiations in Kyoto in December 1997, or thereafter, which would—
(A) mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period, or
(B) would result in serious harm to the economy of the United States; and
(2) any such protocol or other agreement which would require the advice and consent of the Senate to ratification should be accompanied by a detailed explanation of any legislation or regulatory actions that may be required to implement the protocol or other agreement and should also be accompanied by an analysis of the detailed financial costs and other impacts on the economy of the United States which would be incurred by the implementation of the protocol or other agreement.

Eventually the Kyoto Protocol entered into force on 16 February 2005, primarily because of ratification by the European Community and Russia. But by this time the fears expressed in the Byrd-Hagel resolution had come to pass as some non-Annex 1 countries have become major economic players and carbon emissions from China look set to exceed those of the United States in a few years time.

Mitigation and adaptation

Even in the face of the scale and magnitude of climate change there are things that can be done. The Kyoto Protocol contains a series of measures aimed at reducing greenhouse gas emissions, known as mitigation, most notably the Clean Development Mechanism (CDM). The CDM allows Annex 1 countries to offset their emissions by investing in emission reduction projects in developing countries. This flexible approach is regarded as a 'win-win' strategy by policy-makers as developing countries benefit whilst developed countries are able to meet their Kyoto commitments. South Africa was the first African country to launch a CDM project with approval of the Kuyasa low-cost urban housing energy upgrade project in Cape Town. This focuses on renewable energy and energy efficiency by fitting solar water heaters, insulated ceilings and low energy light bulbs in existing low cost houses. Another form of mitigation that has attracted a lot of interest from conservationists is the potential for obtaining CDM payments to cover the cost of forest conservation on the grounds that carbon lost through deforestation will contribute to greenhouse gas emissions. From a conservation perspective this is a 'win-win' in that forest biodiversity will be protected whilst preventing CO2 emissions, however this avoided deforestation policy is a long way from gaining acceptance. In addition to energy reduction projects, as in the Kuyasa example, carbon could be sequestered in plantations, or biofuels could be planted to replaced oil-based transport fuels in developed countries. However, Africa as a continent has not yet taken full advantage of the funds available under the CDM and there is more that could be done. A controversial suggestion for mitigating South Africa's own emissions, and an approach that is much discussed in developed countries, is an expansion of nuclear power to replace energy derived from coal-fired power stations. South Africa has operated a nuclear power plant at Koeberg near Cape Town since 1984 and has substantial stocks of uranium. But the nuclear option comes with its own ecological problems notably the possibilities of an accident and disposal of waste.

It is also getting a little late for completely effective mitigation as global warming is already upon us. Political impasse on international agreements for greenhouse gas reductions means that CO_2 levels will continue to rise. The world is left with adaptation. For Africa, adaptation means coping with extreme droughts, floods and a rising sea level. It is necessary to bear in mind the social impacts of global warming when discussing ecological adaptation and what botanists have to do to cope with the present changes. From a policy perspective an important step is to integrate the ecology of global climate change into the Convention on Biological Diversity. For example the *Global Strategy for Plant Conservation*, which contains important agreements such as protection of 50% of the world's important plant areas (IPAs) by 2010, needs to include provisions for the movement and extinction of plants in a warmer world. It will be self-defeating if a lot of effort is put into protecting areas that are home to plants that will either no longer grow in the IPA or are dead. So for *in situ* conservation it is necessary to focus on the places that will be buffered from climate change, protect places where plants will move to and create corridors to help plants move into safety. Those plants at risk of extinction because their habitat will change and unable to move fast enough to find a new home, need to be helped to move and bring them into cultivation or seed-banks ready for a return to the wild when possible. All of this will require a major co-ordinated effort for which botanic gardens are well placed. Not only for direct conservation action, but also education about the effect of global warming and the potential mitigation measures that everyone can participate in – from energy reduction to tree planting.

References

- Foden, W.B., 2002. Mortality of *Aloe dichotoma* (the Quiver tree) in the Succulent Karoo, South Africa - are the effects of climate change already apparent? MSc Thesis, University of Cape Town.
- Foden, W., Midgley, G.F., Hughes, G., Bond, W.J., Thuiller, W., Hoffmann, M.T., Kaleme, P., Underhill, L.G., Rebelo, A. and Hannah, L. (in press). A changing climate is eroding the geographical range of the Namib Desert tree *Aloe* through population declines and dispersal lags. *Diversity and Distributions*.
- Hannah, L., Midgley, G., Hughes, G. Bomhard, B., 2005. The view from the Cape: extinction risk, protected areas, and climate change, *BioScience* **55(3)**: 231-242. http://scholar.google.com/ accessed 25th June, 2007.
- Lovett, J.C., 2006. Climate and society, *African Journal of Ecology* **44:** 421-422. http://www.blackwell-synergy.com /toc/aje/44/4 accessed 25th June, 2007
- Lovett, J.C., Midgley, G.F., & Barnard, P. 2005a. Climate change and ecology in Africa, *African Journal of Ecology* **43:** 167-169. http://www.blackwell-synergy.com /toc/aje/43/3 accessed 25th June, 2007
- Lovett, J.C., Barnard, P., & Midgley, G.F., 2005b. National Climate Change Conference in South Africa, *African Journal of Ecology* **43:** 279-281. http://www.blackwell-synergy.com /toc/aje/43/4 accessed 25th June, 2007
- McClean, C.J., Doswald, N., Küper, *et al*., 2006. Potential impacts of climate change on Sub-Saharan African plant priority area selection, *Diversity and Distributions* **12:** 645-655.
- McClean, C.J., Lovett, J.C., Küper, W., *et al*., 2005. African Plant Diversity and Climate Change, *Annals of the Missouri Botanical Garden* **92:** 139-152.
- SANBI, 2007. South African National Biodiversity Institute http://www.sanbi.org/research/climatechange.htm
- Sommer, H., Küper, W., Lovett, J. & Barthlott, W., 2005. The future of Africa's plant diversity - potential effects of climate change on species distributions. Poster at the South African National Climate Change Conference, 17-21 October 2005 in Midrand, South Africa.
- Sommer, H., Küper, W. &. Barthlott, W., 2006. Implications of climate change on Africa's plant diversity. Talk at the ESSP Open Science Conference: Global Environmental Change - Regional Challenges, 9-12 November in Beijing, China.

Jon C. Lovett
Centre for Ecology, Law and Policy
Environment Department
University of York
York YO10 5DD UK
E-mail: JL15@york.ac.uk
Internet: http://www.york.ac.uk
and Technology and Sustainable Development Group
University of Twente, Enschede, The Netherlands

Author: Etelka Leadlay

Report on 3rd Global Botanic Gardens Congress Wuhan, China

Right: Opening Ceremony of the 3GBGC (Photo: BGCI)

The 3rd Global Botanic Garden Congress (3GBGC) held in Wuhan, China from April 16-20, 2007 was extremely successful. The Congress provided a forum for 954 delegates from botanic gardens in 67 countries to consider matters of mutual importance and concern for global plant conservation. The scientific programme included 4 plenary sessions, 42 symposia with a total of 202 oral and 145 poster presentations. The Congress also included many spectacular social events such as the Welcome Reception and the BGCI and WBG Anniversary Celebration in the Wuhan Botanical Garden, the Congress banquet and acrobatic display by the Wuhan Acrobatic Troupe and a one-day tour of Wuhan.

BGCI and all those who attended the Congress are extremely grateful to the hosts of the Congress: the Wuhan Botanical Garden and the co-organizers: the Chinese Academy of Sciences, the Hubei Provincial Government, the Wuhan Municipal Government and the State Forestry Administration for making the Congress such a success. The Congress organization was faultless and everyone was made to feel very welcome. Wuhan was an excellent venue and the overseas delegates were very pleased to have the opportunity to visit China, which for many was their fist visit.

The main aim of the Congress was to review the contributions of botanic gardens to the *Global Strategy for Plant Conservation* (GSPC) (CBD, 2003) through the implementation of the 2010 Botanic Garden Targets (Wyse Jackson, 2004). There were 12 plenary addresses which addressed the themes of the GSPC and the parallel sessions were developed to highlight the contribution of botanic gardens to the most relevant targets of the GSPC. The moderator of each session documented the key points: 1) the present status; 2) the gaps and/or barriers; and 3) suggestions for future work. The conclusions were then given at the closing plenary session and can be found on the BGCI website. This review will help provide a framework and guidance for the work of botanic gardens for the period 2007-2010 and beyond. It has also been included in the in-depth review of the implementation of the GSPC (UNEP/CBD/SBSTTA/12/3) and presented to the twelfth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA 12) to the Convention on Biological Diversity (CBD) in Paris at the beginning of July. BGCI is very grateful to the volunteers who presented the conclusions for each theme: Tim Entwisle (Botanic Gardens Trust, Australia) Understanding and documenting plant diversity; Kayri Havens (Chicago Botanic Garden, USA) Conserving plant diversity; Suzanne Sharrock (BGCI) Using plant diversity sustainably; Li Mei, (Nanjing Botanic Garden Mem. Sun Yat-Sen, China) Promoting education and awareness about plant diversity and Stella Simiyu (BGCI/CBD Secretariat, Kenya) GSPC overview.

One of the most valuable aspects of an international congress is the opportunity for delegates to meet and share experiences and develop future collaboration. This was done informally and also formally through regional network meetings: East Asia Botanic Gardens Network (EABGN) chaired by Yong Shik Kim (Korean Association of Botanic Gardens and Arboreta

Far left: Sara Oldfield, Secretary General, BGCI (Photo: BGCI)

(KABGA); Asia Pacific Botanic Garden Network Meeting chaired by Philip Moors (Royal Botanic Gardens, Melbourne, Australia); African Botanic Gardens Network (ABGN) chaired by Christopher Dalzell (Coordinator, ABGN); North American Partnership for Plant Conservation (NAPPC) chaired by David Galbraith (Chair, NAPPC); Latin American & Caribbean Association of Botanic Gardens and Arboreta (ALCJB) chaired by Alberto Gómez Mejía (President, ALCJB) and the inaugural meeting of the South Asia Association for Regional Cooperation (SAARC) convened by Chandrakant Salunkhe (Krishna Mahavidyalaya, India).

A congress also provides an opportunity to attend training workshops and these were very popular. Six training workshops were held on the Sunday before the Congress attended by a total of 173 people on the following topics: Efficient seed preservation, Translocation of threatened plants, Education for sustainable development a step-by-step process for botanic garden educators, Plant records for the management of *ex situ* living collections, New internet communication tools and Red listing: why is it important? BGCI is very grateful to the facilitators for these useful workshops.

BGCI would like to thank the staff of our partner organizations particularly Professor Hongwen Huang, Director of Wuhan Botanic Garden whose vision was translated into such an outstanding Congress. BGCI would also like to thank the Deputy Directors of Wuhan Botanic Garden Tianquan Xu and Junjie Gong and their staff who worked so tirelessly with the co-organizers and National Organizing Committee to make Congress run so smoothly. BGCI is also extremely grateful to Xuejun Zhang who headed the Congress Secretariat and her staff Yinzhu Tan and Lina Chen

Left: Professor Hongwen Huang, Director, Wuhan Botanic Garden (Photo: BGCI)

for their work in coordinating the venues, hotels, congress materials, social event, caterers, transport, tours and all the many tasks associated with a congress and for registering the delegates with such efficiency and patience. On behalf of the delegates, BGCI would also like to thank the smiling and helpful volunteers who made the Congress such a memorable event.

BGCI staff are very grateful to the Chair of the BGCI Board, Baroness Walmsley for attending the Congress and speaking on the behalf of BGCI and to other Board members Peter Raven, Steve Hopper, David Bramwell, Stephen Blackmore, Peter Wyse Jackson and Julian Stanning for their support. BGCI would like to take this opportunity to thank Anle Tieu (former BGCI China Programme Coordinator) who contributed a great deal to the organisation of the Congress.

A BGCI International Advisory Council was held attended by Chin See Chung, Maite Delmas, Timothy Entwisle, David Galbraith, Alberto Gómez–Mejía, Esteban Hernández Bermejo, Hongwen Huang, Angela Leiva, Jan Rammeloo, Philippe Richard, Annie Lane and Heiki Tamm.

The Congress was well covered by the local and national press and media. Internationally, it was covered by China Dialogue (http://www.chinadialogue.net) and news of the Congress was posted on the websites of BGCI and the Chinese Academy of Sciences (http://english.cas.ac.cn/eng2003/news/detailnewsb.asp?infono=26509). A personal flavour was given by bloggers, Pam Allenstein (http://publicgardens.wordpress.com/) and Elizabeth Haegele (http://lizstriptochina.blogspot.com/2007/04/3rd-global-botanic-gardens-congress.html).

Delegates from 12 countries and BGCI staff were supported to attend the Congress by the HSBC *Investing in Nature* Programme, Rufford Maurice Laing Foundation, Mitsubishi Corporation, Mitsubishi Corporation Fund for Europe and Africa for which BGCI is very grateful. The Congress Secretariat supported 31 scholars from 16 countries which was a very important contribution. The East Asia Botanic Gardens Network (EABGN) meeting was generously supported by the Mitsubishi Corporation and through this support two scholars from Mongolia and two from North Korea were able to attend the EABGN meeting and the Congress.

BGCI intends to distribute a CD of the Proceedings and post them on the BGCI website.

Finally, BGCI are very grateful to all the delegates who participated in the meeting to ensure that the Congress achieved its aims and provided a lasting legacy for the botanic garden community through the network links fostered around the world.

References

- CBD, 2003. *Global Strategy for Plant Conservation* (GSPC). Secretariat of the Convention on Biological Diversity. http://www.cbd.int/gspc/default.shtml accessed 4th July, 2007
- Wyse Jackson, P., 2004. Developing international targets for botanic gardens in conservation: a consultation document. *BGjournal* **1(1):** 4-6. http://www.bgci.org accessed 4th July, 2007.

Etelka Leadlay
Botanic Gardens Conservation International
Descanso House, 199 Kew Road
Richmond, Surrey TW9 3BW U.K.
E-mail: Etelka.Leadlay@bgci.org
Internet: http://www.bgci.org

Below: The 3GBGC Welcome Reception in the Wuhan Botanic Garden (Photo: BGCI)

Biodiversity and climate change: a resource list

This list of references will provide further resources on the topic of climate change and biodiversity. Apart from two books, it only includes references which can be downloadable in full and have been accessed 9-13 July, 2007.

Background

Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch/
Important website for up-to-date and useful information with publications and graphics.

Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Pub_SPM-v2.pdf
The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change. Useful summary for general aspects of climate change.

Climate Change 2007: Mitigation of Climate Change. Working Group III contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report
http://www.mnp.nl/ipcc/docs/FAR/ApprovedSPM0405rev4b.pdf
The Working Group III contribution to the IPCC Fourth Assessment Report (AR4) focuses on new literature on the scientific, technological, environmental, economic and social aspects of mitigation of climate change. Mentions forest-related mitigation options and reducing both loss of natural habitat and deforestation can have significant biodiversity, soil and water conservation benefits.

Climate Change and Biodiversity. IPCC Technical Paper V Intergovernmental Panel on Climate Change (IPCC), 2007
ISBN 92 9169 194 7
http://www.ipcc.ch/pub/techrep.htm (In English, French Spanish)

Climate Change and Biodiversity. Thomas E Lovejoy and Lee Hannah (eds.), 2005.
Yale University Press. ISBN-10: 0300104251(hardcover) ISBN-10: 0300119801 (paperback)
This important book focuses on the likely impacts of climate change on biological diversity. Beginning with lessons learned from the fossil record about the consequences of past changes in climate, the book surveys the climate-related changes in the distribution and abundance of plants and animals that are already documented, and looks ahead to the acceleration in extinction rates expected under various assumptions about future inputs of greenhouse gases. It concludes with chapters on conservation and policy responses.

A guide to facts and fictions about climate change. The Royal Society, 2007.
http://www.royalsoc.ac.uk/downloaddoc.asp?id=1630
This document examines twelve misleading arguments put forward by the opponents of urgent action on climate change and highlights the scientific evidence that exposes their flaws. It has been prepared by The Royal Society, the national academy of science of the UK and the Commonwealth.

Climate Change Science—Questions Answered. Department of the Environment and Heritage, Australian Greenhouse Office, Australian Government, 2005. Commonwealth of Australia ISBN 1 920840 79 6
http://www.greenhouse.gov.au/science/qa/pubs/science-qa.pdf
A practical and informative guide to climate change.

The Atlas of Climate Change: Mapping the World's Greatest Challenge. Kirstin Dow and Thomas E Downing, 2006. Earthscan, London, UK. ISBN-10: 1844073769 New edition due in October, 2007 ISBN-13: 9781844075225
This atlas examines the possible impact of climate change on our ability to feed the world's people, avoid water shortages, conserve biodiversity, improve health, and preserve cities and cultural treasures. It also reviews historical contributions to greenhouse gas levels, progress in meeting Kyoto commitments, and local efforts to meet the challenge of climate change.

GRID-Arendal, 2007
http://www.grida.no/
The mission of GRID-Arendal is to provide environmental information, communications and capacity building services for information management and assessment. Established to strengthen the United Nations through its Environment Programme (UNEP), the focus is to make credible, science-based knowledge understandable to the public and to decision-making for sustainable development. GRID-Arendal is an official United Nations Environment Programme (UNEP) centre located in Southern Norway, with out posted offices in Geneva, Ottawa and Stockholm. There is a useful collection of maps and graphics that have been prepared for publications and web-sites from the last 15 years in a wide range of themes related to environment and sustainable development with a section on Maps and Graphics on Climate Change.

The Stern Review on the Economics of Climate Change. Nicolas Stern, 2006. Cabinet Office, HM Treasury, UK Government.
http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm accessed 25th June, 2007.
Nicholas Stern, 2007. The Economics of Climate Change The Stern Review.
Cambridge University Press ISBN-13: 9780521700801 (Paperback)
This Review on the Economics of Climate Change was commissioned by the British Government during its G8 Presidency. The Review marks a watershed in that it brings economics squarely into the debate and thus provides a firm and compelling basis for policy. The former World Bank Chief Economist estimates that the impact of global warming could cost as much as 20 per cent of the world's GDP. He urges immediate action since postponement will only increase the eventual costs. All countries will be affected by climate change, but the poorest countries will suffer earliest and most. Deeper international co-operation will be required in many areas, most notably in creating price signals and markets for carbon, spurring technology research, development and deployment, and promoting adaptation, particularly for developing countries.

Impact of climate change on biodiversity

Plant Growth and Climate Change.
James I.L Morrison and Michael D. Morecroft (eds.), 2007.
Biological Sciences Series, Blackwell Publishing, Oxford, UK
ISBN-10: 1405131926

Climatic conditions are key determinants of plant growth, whether at the scale of temperature regulation of the cell cycle, or at the scale of the geographic limits for a particular species. The climate is changing, due to human activities - particularly the emission of greenhouse gases - and therefore the conditions for the establishment, growth, reproduction, survival and distribution of plant species are changing. This volume explores plant growth and anthropogenic climate change, and focuses on the features of climate that are important to plants, emphasizing aspects of temporal pattern, seasonality and extremes.

Cross-roads of Planet Earth's Life: Exploring means to meet the 2010-biodiversity target. Netherlands Environmental Assessment Agency (MNP), 2006. MNP report 555050001/2006.
http://www.cbd.int/doc/gbo2/cbd-gbo2-global-scenarios.pdf
This is a scenario study from 2000 to 2050 to explore the effects of future economic, demographic and technical developments on environmental pressures and global biodiversity. Policy options that affect global biodiversity were analyzed on their contribution to the 2010 biodiversity targets agreed upon under the Convention on Biological Diversity (CBD). The investigation was performed by Netherlands Environmental Assessment Agency (MNP) at the request of the Executive Secretary of the Convention on Biological Diversity (CBD). It includes maps of spatial distribution of biodiversity for 2000 and 2050 by continent.

Ensemble forecasting of species distributions. Miguel B. Araújo and Mark New, 2007.
Trends in Ecology and Evolution **22**(1): 42-47.
http://www.sciencedirect.com/science/journal/01695347

Ecological and Evolutionary Responses to Recent Climate Change. Camille Parmesan, 2006. *Annual Review of Ecology, Evolution, and Systematics* **37**:637–69.
http://cns.utexas.edu/communications/File/AnnRev_CCimpacts2006.pdf

The future of vascular plant diversity under four global scenarios. Detlef P. van Vuuren, Osvaldo E. Sala & Henrique M. Pereira, 2006. *Ecology and Society* **11**(2): 25
http://www.ecologyandsociety.org/vol11/iss2/art25/

Biodiversity hotspots through time: an introduction. Katherine J Willis, Lindsey Gillson and Sandra Knapp, 2007.
Phil. Trans. R. Soc. B 362: 169–174.
http://www.journals.royalsoc.ac.uk/content/aq81225v77524071/fulltext.pdf

Climate Change and Biodiversity in Europe Hannah Reid, 2006.
Conservation and Society **4** (1): 84–101
http://conservationandsociety.org/cs_4_1_84-101.pdf

Conservation strategies

Conserving biodiversity in a changing climate: guidance on building capacity to adapt. Hopkins, J.J., Allison, H.M., Walmsley, C.A. et al., 2007. Department for Environment, Food and Rural Affairs, London, UK.
http://www.ukbap.org.uk/Library/BRIG/CBCCGuidance.pdf
Explains six key strategies that can be used now by land managers, to help wildlife adapt to climate change, to conserve biodiversity. The guidance recommends that to allow species to find new homes as climate changes, it will be necessary to manage entire landscapes, not just the protected sites where species now occur.

Gardening in the Global Greenhouse: The Impacts of Climate Change on Gardens in the UK. Bisgrove, R. and Hadley, P., 2002 Technical Report, UKCIP, Oxford. Copies of the report are available form The UK Climate Impacts Programme, Union House, 12-16 St Michael's Street, Oxford, OX1 2DU, U.K.
Tel: +44 01865 432076, Fax: 01865 432077,
E-mail: enquiries @ukcip.org.uk, Internet: www.ukcip.org.uk The report or the Executive summary can be downloaded from the main partner websites: www.rhs.org.uk, http://www.nationaltrust.org.uk/main/.
BGCNews 3(9):43-44.
http://www.bgci.org/worldwide/article/108/
http://www.rhs.org.uk/research/climate_change/climatechange.asp

National biodiversity and climate change action plan 2004 – 2007. Natural Resource Management Ministerial Council, Department of the Environment and Heritage, 2004
Commonwealth of Australia. ISBN 0 6425 5051 4
National biodiversity and climate change action plan 2004 - 2007 (PDF - 2,042 KB)
http://www.environment.gov.au/biodiversity/publications/nbccap/pubs/nbccap.pdf
Changes to Australia's climate are already occurring over and above natural variability (e.g. long-term spatial and temporal changes in rainfall and temperature patterns) and these changes are expected to have an impact on Australia's biological diversity. This action plan is a detailed adaptation strategy developed at a national level for biodiversity.

How to join Botanic Gardens Conservation International

The mission of BGCI is to mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet. It was founded in 1987 and now includes over 525 member institutions in 115 countries.

Institutions can join BGCI for the following benefits:
- Membership of the worldwide plant conservation network
- Botanic Garden Management Resource Pack (upon joining)*
- Regular publications:
  - the regular newsletter, *Cuttings*
  - *BGjournal* – an international journal for botanic gardens (2 per year)
  - *Roots* - environmental education review (2 per year)
  - A wide range of new publications
- Invitations to BGCI congresses and discounts on registration fees
- BGCI technical support and advisory services

	Institution Membership	£ Stlg	US $	€ Euros
A	BGCI Patron Institution	5000	8000	7500
B	Institution member (budget more than US$2,250,000)	600	1000	940
C	Institution member (budget US$ 1,500,000 - 2,250,000)	440	720	660
D	Institution member (budget US$ 750,000 - 1,500,000)	300	500	440
E	Institution member (budget US$ 100,000 - 750,000)	160	250	220
F	Institution member (budget below US$100,000)*	75	120	110
	**Generally applies to institutions in less developed countries*			

Other Membership Categories:

Membership benefits depend on category - see below. These can include:

- Regular publications:
  - the regular newsletter, *Cuttings*
  - *BGjournal* - an international journal for botanic gardens (2 per year)
  - *Roots* - Environmental Education Review (2 per year)
- Invitations to BGCI congress and discounts on registration fees

	Corporate Membership	£ Stlg	US $	€ Euros
G	Corporate Gold Member (*BGjournal*, *Roots* and *Cuttings* plus more)	5000	8000	7500
H	Corporate Silver Member (*BGjournal*, *Roots* and *Cuttings* plus more)	1000	1600	1500

	Individual Membership	£ Stlg	US $	€ Euros
J	Conservation donor (*BGjournal*, *Roots* and *Cuttings* plus more)	250	450	420
K	Associate member (*Cuttings* and *BGjournal*)	35	60	50
L	Associate member (*Cuttings* and *Roots*)	35	60	50
M	Friend (*Cuttings*) available through online subscription only (www.bgci.org)	10	15	15

*Contents of the Botanic Garden Management Resource Pack: *The Darwin Technical Manual for Botanic Gardens, A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild, BGjournal - an international journal for botanic gardens (2 past issues), Roots - environmental education review (2 past issues), The International Agenda for Botanic Gardens in Conservation, Global Strategy for Plant Conservation, Environmental Education in Botanic Gardens, BG-Recorder (a computer software package for plant records).*

Payment may be made by cheque payable to Botanic Gardens Conservation International,or online at www.bgci.org or by VISA/Mastercard sent to BGCI, Descanso House, 199 Kew Road, Richmond, Surrey, TW9 3BW, U.K or Fax: +44 (0) 20 8332 5956.

❑ I wish to apply for membership of Botanic Gardens Conservation International.

Name ....
Telephone ....
Address ....
....
Fax ....
E-mail ....
Internet site ....

Membership category .... Annual rate ....
VISA/Mastercard number .... Credit card expiry date ....
Signature .... Print name ....

❑ I would like to make a donation to BGCI. Amount ....

Please clearly state your name (or the name of your institution) on all documentation. Please contact info@bgci.org for further information.

This publication is supported through *Investing in Nature*
A partnership between BGCI, Earthwatch, HSBC and WWF
and the Rufford Maurice Laing Foundation

Botanic Gardens Conservation International

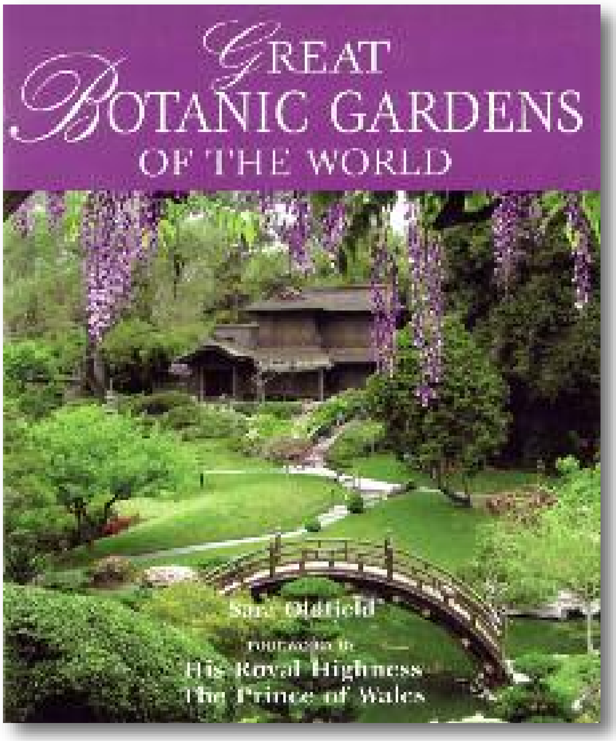
Descanso House, 199 Kew Road, Richmond, Surrey, TW9 3BW, U.K.

Tel: +44 (0)20 8332 5953
Fax: +44 (0)20 8332 5956
E-mail: info@bgci.org
Internet: www.bgci.org

BGCI
Plants for the Planet

Printed on 100% recycled paper

ISSN 1811-8712



New Book published by BGCI and New Holland

The vital role of Botanic Gardens in conservation and their spectacular beauty, explored in one authoritative volume

Great Botanic Gardens of the World is a new work by BGCI Secretary General, Sara Oldfield. This exquisitely illustrated book explores the rich and varied history of botanic gardens and the vital role they play in fields of education, scientific research and conservation.

The book focuses on botanic gardens in every continent of the world, highlighting the fact that these great institutions are as diverse as the collections found within them. The development of gardens in over 30 countries is examined as are the inspirational people behind them and their important work.

The current, global context for the work of botanic gardens is also highlighted. The role of important international initiatives such as CITES and the *Global Strategy for Plant Conservation* in guiding their efforts is explored along side the pioneering work of individual gardens.

With a foreword by **HRH The Prince of Wales**, in which he describes Botanic Gardens as 'living laboratories … vital in conserving plant species', *Great Botanic Gardens of the World* represents a stunning tribute to the beauty of botanic gardens and their role in building the relationship between people and their environment.

Special Introductory Offer

Great Botanic Gardens of the World
by Sara Oldfield

New Holland Publishers, UK (2007)
ISBN: 978-184537-593-5

Offer price £20 (rrp. £24.99)
plus free postage and packing within the UK*

Offer runs from August 2007 until 31st January 2008
Offer code: NHGBCI/01

Telephone: +44 (0)1476 541080
Fax: +44 (0) 1476 541075

Simply quote the book title, ISBN and offer code.

** European and International postal charges upon request.*