ISSUE 22_SPRING 2012

ISSN 1475-8245

samara

The International Newsletter of the Partners of the Millennium Seed Bank Partnership

www.kew.org/msbp/samara

Climate change and biodiversity

By Robert Watson, Chief Scientific Advisor to UK Department for Environment, Food and Rural Affairs

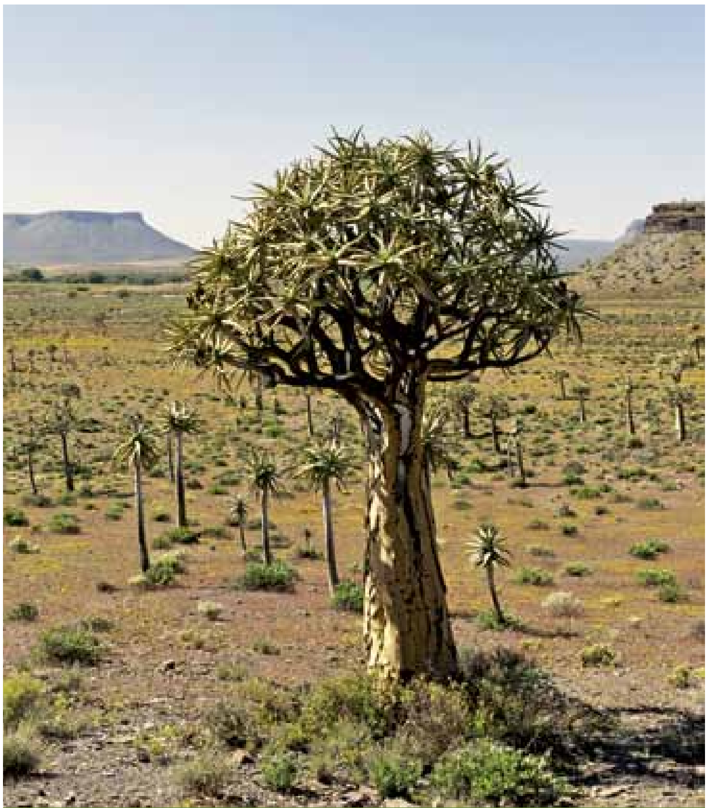
Biodiversity provides a variety of ecosystem services that humankind relies on, including: provisioning (food, freshwater, wood and fibre, fuel, and so on); regulating (of climate, floods, air quality, pollination, and diseases, for example); culture enhancing (aesthetic, spiritual, educational, and recreational); and supporting (such as nutrient cycling, soil formation, and primary production). These ecosystem services are central to our wellbeing, including our security, health, social relations, and freedom of choice and action.

Biodiversity loss is increasing at the global scale for five reasons: habitat change, for example conversion of a forest or grassland into agricultural land; invasive species, introduced either purposefully or accidentally; over-exploitation, such as over-fishing; pollution, by phosphorus and nitrogen, for example; and climate change. While climate change has not been a major cause of biodiversity loss or ecosystem degradation (except in the polar regions) over the last 100 years, it is likely to be a major threat in all biomes over the next century.

There is a clear need to address the underlying reasons for loss of biodiversity, including limiting the rate and magnitude of climate change. There is also a need to identify policies and actions that can simultaneously benefit biodiversity and the climate system, through ecosystem-based mitigation and adaptation.

Addressing the issue of biodiversity and ecosystem services requires changing the economic background to decision-making. There is a need to: (i) make sure that the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions; (ii) remove subsidies to agriculture, fisheries, and energy that cause harm to people and the environment; (iii) introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society; and (iv) establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way.

There is also a need to improve policy, planning, and management by integrating decision-making between different departments and sectors, as well as international institutions, to ensure policies are focused on protection and sustainable use of ecosystems. It will require: (i) empowering marginalised groups to influence decisions affecting ecosystem services, and recognise in law local communities' ownership of natural resources; (ii) restoring degraded ecosystems and establishing additional protected areas, particularly in marine systems, and providing greater financial and management support to those that already exist; and (iii) using all relevant forms of knowledge and information about ecosystems in decision-making, including the knowledge of local and indigenous groups.



The *Aloe dichotoma*, 'quiver tree' is indigenous to southern Africa but climate change is eroding the geographic range of this species. PHOTO W. STUPPY

There is also a need to develop and use environmentally-friendly technologies. For example, we should invest in agricultural science and technology aimed at increasing food production while decreasing the environmental footprint, and promote technologies that increase energy efficiency and reduce greenhouse gas emissions - we need to make a transition to a low-carbon economy.

Mitigating climate change will require a combination of pricing and technological mechanisms, as well as cost-effective policies and understanding behavioural change. Putting a price on carbon is critical and can lead to significant emission reductions. Pricing mechanisms include

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Kew ROYAL BOTANIC GARDENS

MILLENNIUM SEED BANK PARTNERSHIP Kew

emissions trading, taxation, and regulation across national, regional, and global scales and across all sectors. Better use of available low-carbon technologies coupled with improved development, commercialisation, and market penetration of emerging technologies is required. Therefore, there is a need for improved, efficient production and use of energy; fuel shift - coal to gas; low-carbon renewable energy and fuels; carbon capture and storage; and nuclear power. In addition to moving to a low carbon energy system, it is critical to reduce emissions from forests by reducing forest degradation and deforestation; and sequestering carbon through reforestation, afforestation, and agroforestry. Emission reduction can also be achieved in agricultural systems through conservation tillage and reducing emissions from the use of fertilisers, and livestock and rice production.

Reducing deforestation, and well-designed reforestation and afforestation activities not only assist in mitigating climate change but can be beneficial for biodiversity and assisting ecosystems to be more resilient to climate change. It is important that reforestation programmes use ensembles of native species and not monoculture plantations of exotic species.

But addressing policies and technologies alone will not be enough. We must influence individual behaviour. We can do this by providing public education on why and how to reduce consumption of threatened ecosystem services, establishing reliable certification systems to give people the choice to buy sustainably harvested products, and by providing access to information about ecosystems and decisions affecting their services.

In summary, we are changing the Earth's climate, losing biodiversity and spending the Earth's natural capital, putting such strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted. Business as usual will lead to an unsustainable world with significant changes in the Earth's climate and a loss of critical ecosystem services. Cost-effective technologies, supported by an appropriate policy framework, can lead to more sustainable practices. Effective action needs stable and credible environmental policies that support the long-term shift to a low-carbon economy and the sustainable use of natural resources. We need not just a small improvement in resource efficiency, but a radical shift. Public and private sector decision-makers need to take a longer-term perspective. We must make advances in science and technology, with the emphasis on interdisciplinary research. We must get the economics right; this includes eliminating perverse subsidies by valuing ecosystem services and internalising externalities.

Progress requires political will and moral leadership in the public and private sectors. The actions of today's generation will profoundly affect the Earth inherited by our children and future generations. Policymakers should recognise that there is no dichotomy between economic growth and environmental protection and furthermore, addressing issues such as climate change, provides economic opportunities to restructure and make a more efficient energy system, with additional benefits such as reducing air pollution, which have positive implications for human health. The benefits of limiting climate change and sustainably managing ecosystems far exceed the costs of inaction, and delaying action can significantly increase costs. Efficient resource use saves money for businesses and households, and a green economy will be a source of future employment and innovation. Similarly the conservation and sustainable use of biodiversity can have significant economic and social benefits.

Climate change threatens plant species like 'giant groundsels' *Dendrosenecio keniodendron* (Asteraceae) on the peaks of Mount Kenya. PHOTO: E. WILLIAMS

The vital role for **seed banks** in adapting to a **changing world**

by Clare Trivedi, International Projects Coordinator, MSBP

The scale of the global challenge in responding to climate change can be overwhelming to us as individuals and organisations. Many Millennium Seed Bank Partners may wonder how they can contribute to the many needs outlined in Bob Watson's article (p1). But together we can, and already are, making a significant contribution.

While global political efforts to mitigate climate change progress slowly, understanding of the impacts of climate change is improving. Current models suggest that we need to prepare for a world with a global average temperature rise of 2-4 °C (representing a rise of up to 10 °C in some areas). It is now also thought that every 1 °C rise in temperature could mean a loss of 10% of the planet's species. We know that certain habitats, such as mountains and islands, may be at greatest risk. However, it remains difficult to predict climate changes at a local level, or the impacts on individual species, as temperature and precipitation changes are compounded by so many interactions and stresses such as pollinators, pests, diseases, invasive species, and human barriers to plant migration.

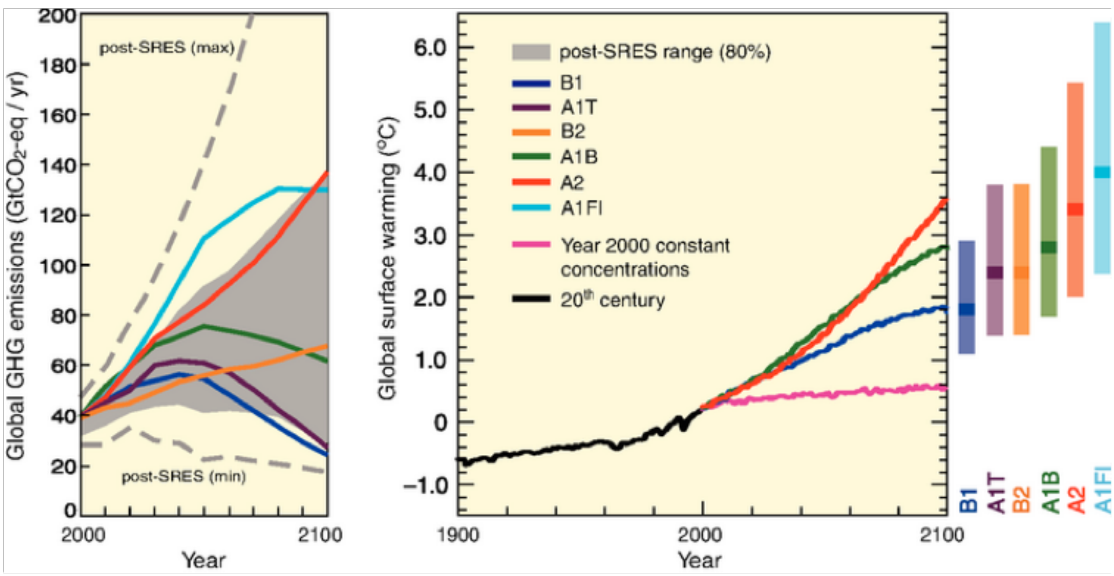
In such an unpredictable and uncertain world, seed banking provides a vital insurance against loss of biodiversity. The partners of the MSBP have already safeguarded over 30,000 species, and collecting and conserving species continues to be a key activity. The sooner we can bank species at risk the more genetic diversity can be conserved for future use. MSBP projects in East Africa (p4), Italy (p5), and South Georgia (p6) are already focusing seed collecting on mountain and polar areas, which are at risk of plant species loss due to climate change. Our research is helping us to understand better the impact of climate on plants, and their likely responses to change (p8-9). Furthermore, the data collected alongside seed collections is providing information on current species distributions and phenology, which can be built into models of future distributions and behaviour.

These seed collections, and the skills and information in germination and propagation associated with them, can provide options and solutions for adapting to climate change. Human intervention may be required to move species about, and to maintain enough diversity in ecosystems to prevent their collapse. Seed banks can also provide options and solutions for specific human challenges such as water scarcity, energy supply, human health, and food security. For example, to protect water supplies will require the restoration of catchment forests with adequate diversity to survive the new risks associated with extreme weather events and pests and diseases. The MSBP has already conserved 10,000 tree and shrub species. The Crop Wild Relative Project will support the adaptation of agriculture to climate change (p10). The MSB screens collections for their oil content which may flag options for future biofuels. Finally, the MSBP seed list facilitates the supply of seed samples (with permission from the country of origin) for research; examples have already included the development of salt tolerant pasture plants to combat salination of agricultural land.

Few trees are under greater threat from increases in sea level due to climate change than poke-me-boy, *Acacia anegadensis*, found almost exclusively on one of the British Virgin Islands (Anegada), which stands only 8 m above the Caribbean Sea. PHOTO RBG KEW

I hope the articles in this issue of Samara will remind you of the vital role that you are already playing, and inspire you to think more about specific activities which could further target your work towards the challenges associated with climate change.

For further information contact Clare Trivedi **(c.trivedi@kew.org)**



Model scenarios for future global greenhouse gas emission: six illustrative SRES scenarios (coloured lines) and 80th percentile range of recent scenarios published since SRES (grey shaded area). Dashed lines show the full range of post-SRES scenarios.

Figure taken from IPCC (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A.(eds.)]. IPCC, Geneva, Switzerland. p44 figure 3.1.
[SRES = Special Report on Emissions Scenarios]

Conserving the unique **Afromontane flora** of East Africa

by Emma Williams, Botanist, MSBP

The East African mountains are part of the Eastern Afromontane biodiversity hotspot, one of 34 global hotspots identified by Conservation International. The mountains, which are the highest on the African continent, reach up to 5800 m above sea level and are home to many unique and threatened plant species.

Typically the Afromontane flora is found above 2000 m (White, 1983). Moving up these mountains, the lowland tropical montane forests, characterised by juniper and *Podocarpus*, are replaced by tall bamboos and shrubby heathers as the altitude increases. Predominantly, above 3500 m, an Afroalpine zone is common with many unique plants adapted to the high altitudes for example *Dendrosenecio* or "giant groundsel" and the tall, sometimes woody "giant" lobelia. Many of these plant species are endemic to only one or two mountain ranges.

The primary threats to the Afromontane flora are habitat loss and climate change. Whilst most East African mountains are within protected national parks or forest reserves, many montane forests remain threatened from illegal logging, charcoal production, and fires. During the last century large areas of montane forest and upland grasslands were cleared for agriculture. Only an estimated 10% of the original vegetation of the entire Eastern Afromontane hotspot remains.

Climate change models predict an increase in temperatures between 1.8-4.3 °C in East Africa by 2080 with associated changes to rainfall patterns (IPCC, 2007). Already glaciers on the two highest mountains, Mount Kilimanjaro and Mount Kenya, are in noticeable significant retreat. We know that high altitude plant species are particularly sensitive to climate change. As temperatures increase the range of suitable mountain habitats decreases which leads to a risk of species extinction. In Europe, upwards range shifts of alpine plant species have already been documented (Lenoir et al., 2008). Studies are ongoing in East Africa but climate change models are predicting contractions of species distributions and increased risk of extinction for mountain endemics (Kreyling et al., 2010).

In Kenya, as part of the MSBP-1"Seeds for Life" project, we recognised that *ex situ* seed banking had a vital role in the conservation of the Afromontane flora. The MSBP partnership focused fieldwork on the highest mountains in Kenya: Mount Kenya, Mount Elgon, and the Aberdares. We successfully collected and banked the seed of 131 prioritised species (10% of the Kenyan Afromontane flora), including 11 Kenyan endemics.

During MSBP-2 we aim to expand our Afromontane *ex situ* collecting programme to other mountain ranges in Tanzania, Uganda, and Ethiopia.

Dendrosenecio keniensis **(Asteraceae), a Mount Kenya endemic in flower.** PHOTO E. WILLIAMS

Swertia crassicaule **(Gentianaceae).** PHOTO E. WILLIAMS

We will be supporting the conservation assessment of all Afromontane species which will allow us to prioritise threatened and endemic plant species for seed banking. However, we will not just leave the seeds in the bank vaults, but will start to use them for targeted species recovery work. In Kenya the MSBP will be working closely with our partners including the Kenya Wildlife Service, Kenya Forestry Service, and non-governmental organisations to develop models for the recovery of Afromontane species. Through this work we will ensure we have effective conservation strategies that can protect this unique and spectacular flora for posterity.

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Plants in European mountains threatened by **climate change**

By Graziano Rossi and Simone Orsenigo, Lombardy Seed Bank, University of Pavia, Italy, Andrea Mondoni, Museo delle Scienze, Trento, Italy and Jonas Müller, International Projects Coordinator, MSBP

***Papaver alpinum* L. subsp. *rhaeticum* (Leresche) Markgr. (Papaveraceae) is an Alpine species that grows on limestone debris.** PHOTO A. MONDONI

In the last decades, many studies have focused their attention on global warming, observing on-going changes in mountain areas and trying to predict future scenarios. Temperatures in the European Alps have risen by up to 2 °C in the last century and are predicted to increase further by up to 5 °C by 2085 (Nogués-Bravo et al. 2007). Plant species in mountains are adapted to live in cold climates, and it is very uncertain whether all of them will be able to cope with global warming. Biodiversity scenarios for the 21st century predict a significant reduction of Alpine habitats and the loss of many high mountain plants (Thuiller et al., 2005; Engler et al., 2011). Indeed, global warming drives a general upward shift of plants, increasing the competition between species and causing extinction of those plants which already live at the top of the mountains (Theurillat & Guisan, 2001; Parolo & Rossi, 2008). The University of Pavia is involved in the long-term research project GLORIA (Global Observation Research Initiative in Alpine Environment) studying 60 summit sites in all major European mountains. Recent results of this study provide evidence that the most cold-adapted species are declining and the most warm-adapted species are increasing. This process is described as 'thermophilization of the mountain floras' (Gottfried et al., 2012). Unfortunately, mountains host a large number of endemic plant species, which might be lost in the coming decades. It is estimated that up to 60% of species growing in the mountains around the Mediterranean Basin are threatened by extinction (Thuiller et al., 2005).

Given these circumstances, collecting and banking seeds of Alpine plant species is an effective tool to fight this potential loss of biodiversity and to provide propagation material to re-establish wild plant populations. Short timescale seed regeneration or re-collection from wild populations of Alpine species will be important to maintain high quality collections, but also to ensure conservation of large genetic diversity and novelty for replanting in future habitats (Mondoni et al. 2011).

In partnership with the MSBP, the Lombardy Seed Bank (LSB-CFA), hosted at the University of Pavia, started a new initiative, with the aim of saving threatened Alpine species growing in the southern Italian Alps and in the northern Apennines from extinction. The new initiative will undertake joint expeditions of both British and Italian researchers, to collect seeds of the most threatened species, such as endemic species, rare species and those at the boundaries of their areas of distribution. The seed collecting will take place in close cooperation with managers of protected areas, and local and national nature protection authorities. The seed collections will be stored for long term conservation in Pavia and at the MSB, and their viability will be monitored over time. The seed material can be used in future actions of assisted migration and to re-establish natural populations damaged by climate change.

***Silene elisabethae* Jan (Caryophyllaceae) is a narrow endemic species growing on calcareous meadows in the southern Alps.** PHOTO A. MONDONI

 Continued from page 5

Linaria tonzigii **Lona (Plantaginaceae) is an endemic species restricted to the Orobie mountains (Bergamo province), growing on calcareous screes.** PHOTO S. ORSENIGO

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Understanding **climate change** impacts in the **sub-Antarctic**

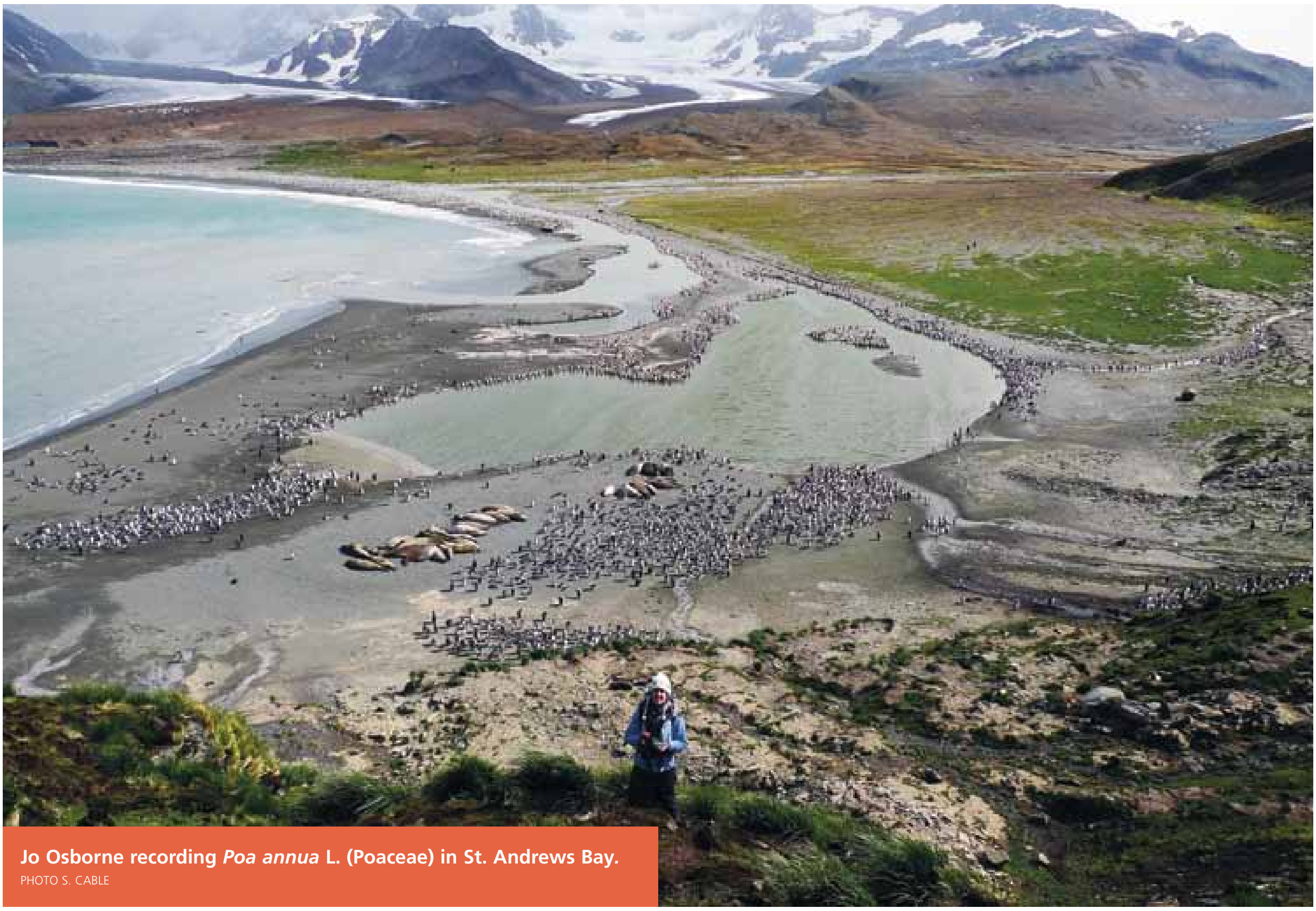
by Stuart Cable, MSBP Herbarium Team Manager

On Christmas Day in 2008, a team of four botanists from Kew (Renata Borosova, Marie Briggs, Stuart Cable, and Jo Osborne) and two entomologists from BugLife (Roger and Rosie Key) flew to the Falklands to begin a 42 day expedition to South Georgia to survey invasive plants and insects. The work was undertaken as part of the RSPB's South Atlantic Invasive Species Project, aimed at reducing the impact of invasive species in the South Atlantic UK Overseas Territories, and was funded by the European Commission through the European Development Fund EDF-9 .

The government of South Georgia and South Sandwich Islands is concerned that climate change will favour introduced species to the detriment of the native flora. The longer and warmer summers could enable introduced plant species to produce viable seeds and spread invasively, facilitated by the arrival of insect pollinators and the melting of the glaciers that restrict the movement of insects as well as reindeer and other introduced animals that act as seed dispersers. Reindeer were introduced to feed the workers of the vast industrial-scale whaling stations that operated on South Georgia until the 1960s. The whalers also introduced sheep and cattle and imported fodder from the northern hemisphere that probably contained the seeds of the invasive species that persist on the island today.

One of the most remote of the UK Overseas Territories, South Georgia lies 1600 km north of the Antarctic in the South Atlantic Ocean. With mountain ranges reaching 3000 m, most of its 3755 km² are covered in permanent snow and glaciers, but at low altitude, within the shelter of its numerous bays, there is a sparse covering of herbaceous vegetation. South Georgia is home to over 50 million seabirds, including globally important populations of wandering albatross and macaroni penguins. During the summer months, the beaches are overrun by 4.5 million fur seals and 0.5 million elephant seals.

The team spent 42 days on ***Seal*****, a yacht specially designed for high-latitude sailing in poorly charted waters.** PHOTO S. CABLE



Jo Osborne recording *Poa annua* L. (Poaceae) in St. Andrews Bay.
PHOTO S. CABLE

The government of South Georgia manages the island as a pristine wilderness with strict bio-security protocols and monitoring of visitors. South Georgia's flora consists of 25 native species of vascular plants, co-existing with as many introduced species.

The voyage to South Georgia took 5 days on the sailing yacht *Seal*, which was designed for supporting expeditions in high latitudes. Based on *Seal*, the team visited 16 sites and enumerated over 600 random quadrats and transects. They recorded 24 introduced species and the records have been combined with British Antarctic Survey (BAS) data from the 1970s to map the introduced flora and identify changes. Some of the introduced species such as mouse-eared chickweed (*Cerastium fontanum*), annual meadow grass (*Poa annua*) and dandelion (*Taraxacum officinale*) are now naturalised and were found throughout the island. Other introduced species have persisted without spreading, such as white clover (*Trifolium repens*) and curled dock (*Rumex crispus*). Further species had been reported in the past, but have subsequently disappeared, apparently unable to cope with the harsh South Georgian winters or obliterated by fur seals, which have had a significant impact eroding vegetation around the whaling stations.

The team returned with over 130 herbarium specimens for Kew and BAS, including narrow oat-grass (*Trisetum spicatum*), a new species record for South Georgia. The team also made 83 seed collections for the MSB, representing 35 species (17 native and 18 introduced). This was achieved with the help of environmentalists and writers Thies and Kicki Matzen, who live on the yacht *Wanderer III*, made famous in the classic sailing book *Around the World in Wanderer III* by Eric Hiscock (1952). The entomologists, Roger and Rosie Key, are still sorting through the 750,000 insects they collected. The haul so far represents 51 species (but several large groups remain with specialists), including 3 that are new to science and another 8 that are new to South Georgia.

More work is needed to verify the effects of climate change on the flora. Eight of the non-native species have had germination testing at the MSB and all passed with 89-100% success. Four of these (*Cerastium fontanum, Poa annua, Poa pratensis*, *and Taraxacum officionale*) are already naturalised and will be impossible to eradicate. Two species (*Cardamine glacialis and Lobelia pratiana*) are thought to be recent arrivals from high latitudes in the southern hemisphere and occur in small patches. Attempts are being made to eradicate *Cardamine glacialis*, which probably arrived with building materials from the Falkland Islands, but it is proving to be a tenacious weed. The *Lobelia pratiana* has hardly changed in extent over 30 years and might have arrived naturally. The team only noted vegetative spread even though the seeds have proved to be viable. The other two species (*Sagina procumbens and Veronica serpyllifolia*) are from the northern hemisphere and have potential to become invasive. Kew is advising the government of South Georgia on how to manage its invasive plant species.

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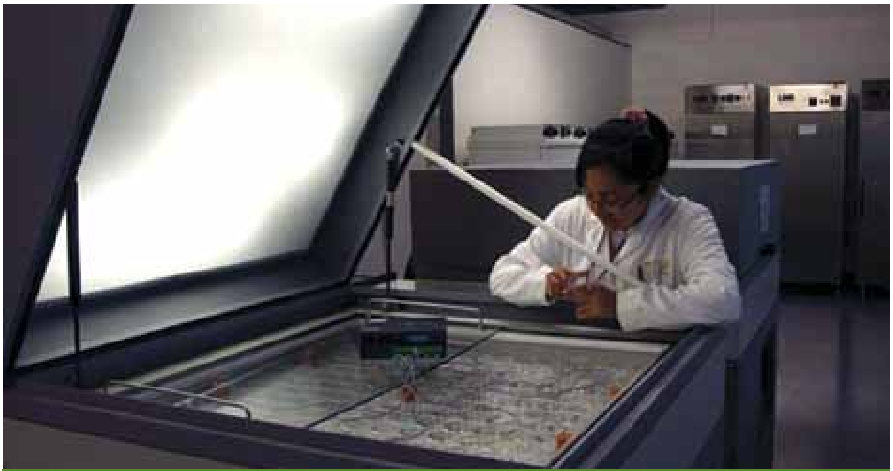
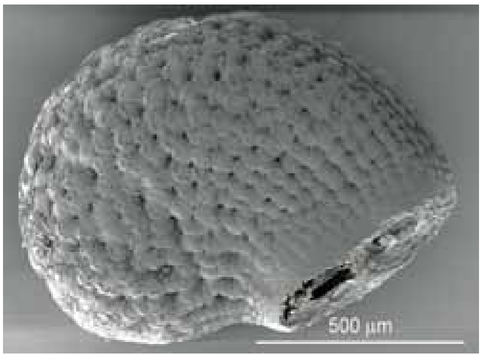
A non-native species *Cardamine glacialis* DC. (Brassicaceae), which is tenaciously spreading around King Edward Point in Grytviken. It is thought to have been introduced from the Falkland Islands with building materials. PHOTO S. CABLE

Assessing the **vulnerability** of species to **climate change** by Charlotte Seal, Research Scientist, MSBP



Germination was performed at 14 constant temperatures using a thermogradient plate. PHOTO C. SEAL

The germination of species such as *Cleistocactus acanthurus* are being studied through germination temperature threshold models. PHOTO N. RAMÍREZ



Left and far left:
Seeds of *Cleistocactus acanthurus*.
PHOTO N. RAMÍREZ

As a result of climate change, species are being increasingly exposed to abiotic stress factors such as high or low temperature, drought and salinity. The vulnerability of a species to abiotic stress factors is not only a function of length and duration of exposure (Kranner et al., 2010) but also a function of genetic adaptation to the stress, and of the phenotype which may be expressed differently under different environmental conditions. This plastic response of the phenotype, which indicates sensitivity to stress, is an important trait of plants in responding to environmental change.

As the majority of the world's flora rely on germination for the regeneration of natural plant populations, understanding the sensitivity of germination to environmental change is essential. A recently published study on *Ribes multiflorum* ssp. *sandalioticum*, a rare mountain species endemic to Sardinia, discovered the release of morpho-physiological dormancy and subsequent germination to be highly synchronised with the Mediterranean seasonality (Mattana et al., 2012). For species such as *R. multiflorum*, which have a narrow thermal germination response, climate change is a serious threat to natural emergence in the field.

Phenotypic plasticity is also pertinent to longer-lived perennials, which are slow to incorporate new adaptive traits into the genome in response to environmental change. This includes the Cactaceae, a family of over 1400 species which occupy a range of habitats from arid deserts to tropical rainforests and have worldwide nutritional and economic value. The distribution of cactus plants is predicted to be severely reduced with climate change (Téllez-Valdés and Dávila-Aranda, 2003) but the effect of climate change on germination is unknown. To address this gap in our knowledge, a collaborative study is ongoing with research partners from across Latin America, to assess the impact of global warming on the germination of 54 taxa of Cactaceae. Seeds were collected from sites across Argentina, Chile, Dominican Republic, Mexico, Peru and USA, covering a range of 70° latitude and 3700 m altitude. Many of the taxa are of conservation concern, with one taxon listed as 'critically endangered', four taxa listed as 'endangered' and ten taxa listed as 'vulnerable'. Germination experiments have been carried out for each taxon at 14 temperatures between 10 °C and 40 °C on the MSBP's thermogradient plates and took over five years to complete. The data is being used to determine the temperature limits to germination and to develop germination temperature threshold models to assess the sensitivity of the germination response to temperature and to compare the germination behaviour with projected climate change scenarios. This approach will highlight which of the 54 taxa are most vulnerable to future changes in environmental temperature and promote the need for conservation action to ensure their persistence in the natural environment.

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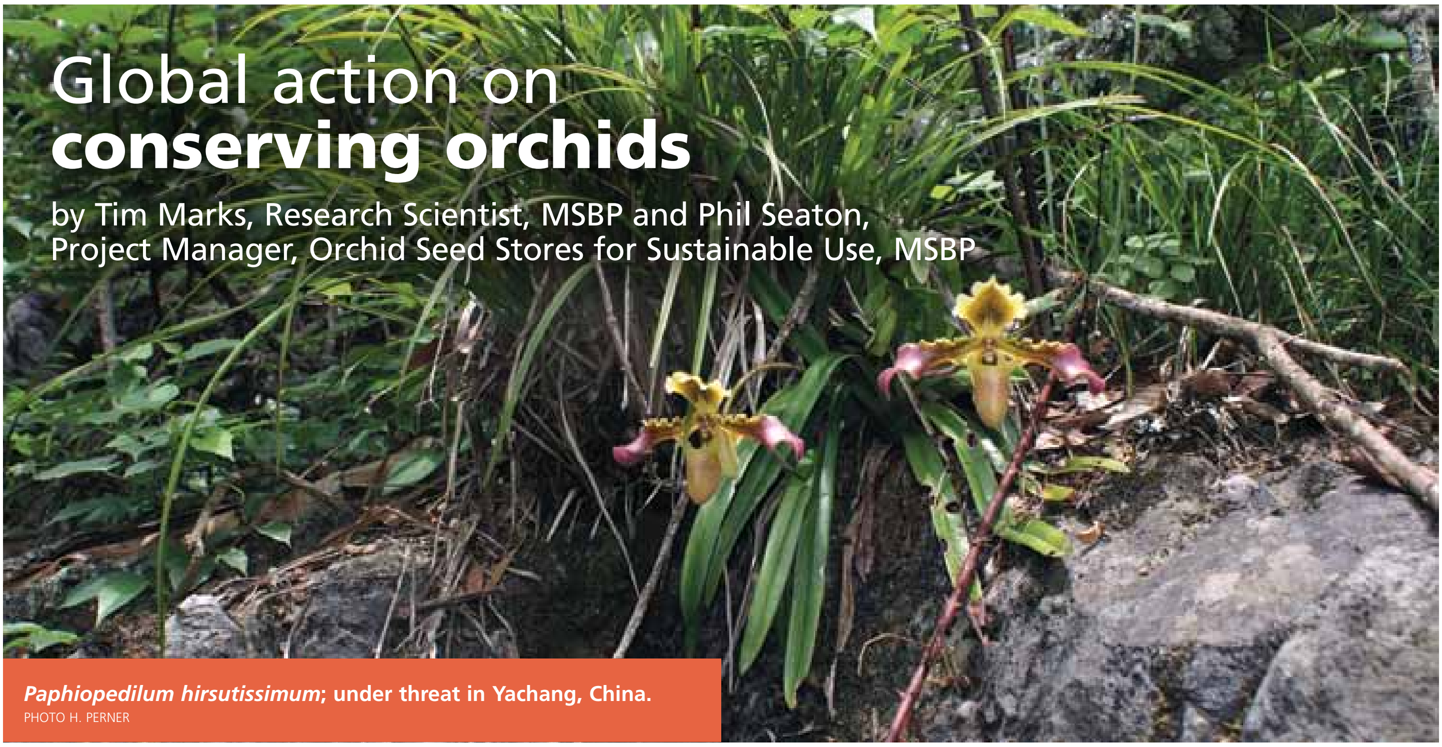
Global action on **conserving orchids**

by Tim Marks, Research Scientist, MSBP and Phil Seaton,
Project Manager, Orchid Seed Stores for Sustainable Use, MSBP



***Paphiopedilum hirsutissimum*; under threat in Yachang, China.**
PHOTO H. PERNER

There is currently increasing concern about the effects of future global climate change and associated habitat alteration on the long-term survival of many plant species in their natural environments. Orchids, with their reliance on mycorrhizal fungi at critical stages in their life-cycles, have a unique potential to act as indicator species for healthy environments; to act as the 'canaries in the coal mine'. The relationships of orchid flowers with their insect pollinators is often intricate and sometimes bizarre; sexual mimicry is common. As temperature and precipitation change, we do not know whether there will be synchrony of phenologies between orchids and their pollinators or what the potential consequences may be for their mutual survival. The majority of tropical orchids are epiphytes, growing high up in tree canopies. Recent findings on the adverse effects of climate change on populations of large and old trees indicate that loss of such trees could have a disastrous effect on certain epiphytic species (Laurance, 2012).

These concerns are being addressed through the Orchid Seed Stores for Sustainable Use (OSSSU; www.osssu.org) project which was established in 2007 (Darwin Initiative; Defra) to create a network of orchid seed banks in biodiversity hotspots around the globe and promote the conservation of native species. Initially focusing on Latin America and South East Asia, the network is rapidly expanding to further encompass both other tropical regions and countries with more temperate climates. OSSSU partners have so far stored seeds representing more than 300 species, and developed the *in vitro* germination of *c.* 240 species on a common medium (Knudson, 1946). This is the first time that a large scale comparison has been made using common procedures across a broad range of orchid species. A key objective is to develop an understanding of the factors affecting seed longevity, and through insights into their biology, enhance our capability for long-term seed storage. Sharing expertise has enabled members to conserve large quantities of germplasm; for example, the enormous capsules of *Grammatophyllum speciosum* can contain as many as two million seeds, but even the much smaller capsules of *Aerides odorata* can contain over 200,000. These have a huge potential to enhance re-introduction programmes, such as the successful re-introductions of *G. speciosum* and *Cymbidium finlaysonianum* in Singapore (Yam Tim Wing, personal communication). In addition to conserving seed, data on the phenology of seed set and capsule maturation times can inform more effective seed harvesting protocols, and compare responses to climatic differences between countries.

A current focus for developing OSSSU is in the biodiversity hotspots of South China where in addition to their susceptibility to climate change, many species of *Cypripedium* and *Paphiopedilum* (horticultural value) and *Dendrobium* and *Cymbidium* (horticultural and medicinal value) are under threat from over-collection and habitat degradation due to changes in land usage. Changes to vegetational zoning up mountain sides can also have dramatic effects upon the distribution of some species, and under rapidly changing pressures to adapt, certain species will inevitably die and may become extinct in the wild. By conserving the Chinese species as seed, or as living collections, and improving our understanding of the seed biology of this iconic family of plants world-wide, we have a greater opportunity to conserve many of these charismatic plants for future generations (Seaton et al., 2010).

***Cattleya maxima*; its habitat in Ecuador is disappearing.**
PHOTO P. SEATON

***Cattleya quadricolor*; endemic and Red listed as vulnerable in Colombia.** PHOTO P. SEATON

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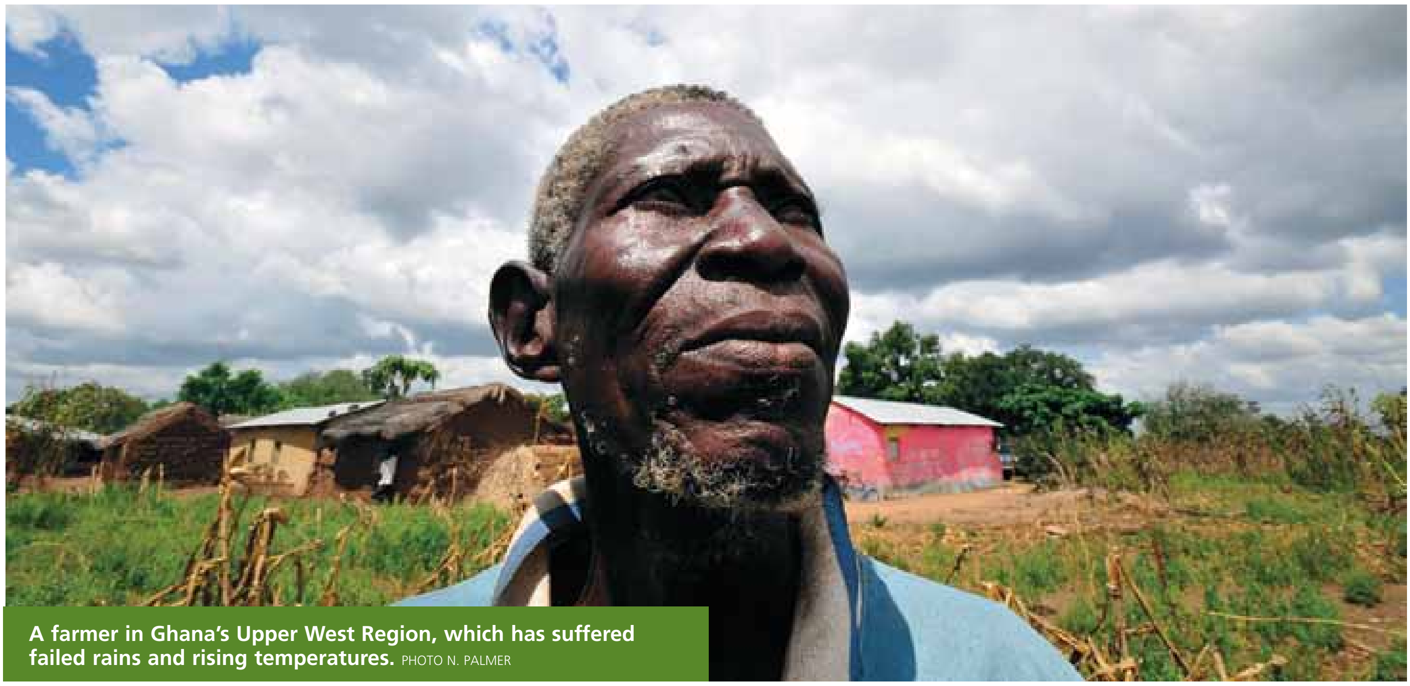
Battling a perfect storm with **plant biodiversity**

By Hannes Dempewolf and Luigi Guarino, Global Crop Diversity Trust



A farmer in Ghana's Upper West Region, which has suffered failed rains and rising temperatures. PHOTO N. PALMER

Most predictions agree that by 2050 the world's population will have risen to 9 billion people. At the same time, climate change modellers tell us that the world's global agricultural production is under serious threat from climate change. Growing season temperatures by the middle of the 21st century will bear little resemblance to that which most regions experienced in 1900-2000. A perfect storm is brewing that will lead to food shortages around the world. Increasing food production by taking more land under cultivation is not an option without serious impacts on biodiversity, and although significant headway can be made by improving agricultural practices and cutting down on waste, this can only provide a partial solution. It will be crucial to increase crop yields through genetic improvement.

Crop domestication has led to a severe reduction in genetic diversity within crops, as only a narrow range of diversity was selected by early farmers - an effect commonly described as the domestication bottleneck. But breeders need all the genetic diversity they can get their hands on to improve the world's crops. Many are therefore keen to reach back through time and get hold of some of the diversity in so-called 'crop wild relatives' (CWR). These taxa are increasingly recognised as being of key importance to breeding efforts that aim to help adapt agriculture to climate change. In order to unlock this treasure-chest, Kew Garden's Millennium Seed Bank and the Global Crop Diversity Trust have embarked on a global, long-term effort to collect and conserve the wild relatives of crops, with funding from the Norwegian government. This collaborative collecting effort is described in *Samara* issue 18/19 (2010).

The list of possible traits that could be used to enhance crop adaptation to the world's new climates is long, including everything from enhanced root growth to faster grain filling. What reasons are there to think that such traits can be found in the generally unimpressive-looking wild and weedy plants that are the closest relatives of crops? We know that many CWRs grow in conditions of climate and soil that are marginal for the crop. We also know that many show marked differences from the crop, such as perenniality, fleshy roots and distinct phenology. Some of these are likely to be of important for adaptation. For example, a CWR has recently been used to change the time of flowering of rice to avoid the hottest part of the day. Adaptation to biotic stresses, drought, cold and salinity have all been improved in crops through the use of CWRs, as well as the nutritional quality.

Using wild species in crop improvement programmes can be a lengthy process. As one breeder has put it, "it's a bit like crossing a house cat with a wildcat. You don't automatically get a big docile pussycat. What you get is a lot of wildness that you probably don't want lying on your sofa." One of the goals of the project is therefore to initiate and support the use of wild diversity through a process called pre-breeding. The project team has initiated a series of expert consultation meetings, where breeders, taxonomists, climate change modellers and genebank curators come together to discuss the most promising pre-breeding strategies for each crop. Once this consultation process and the collecting period has concluded, the focus of the project will shift to support the use of this newly collected wild plant diversity by experienced breeders around the world.

Wild plant biodiversity may turn out to be the crucial tool in our armoury to battle the approaching perfect storm of an ever-increasing world population and a rapidly changing climate.

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A rice farmer in Guarayos, Santa Cruz, Bolivia, prior to a huge storm. PHOTO N. PALMER

NEWS

The new panels in place on the roof of the Millennium Seed Bank.
PHOTO: W. STUPPY

Seed Bank goes solar

By 2020, the Millennium Seed Bank is aiming to reduce its energy consumption and fulfil 100% of its energy requirement through the generation of renewable energy. The first step in this journey was carried out late in 2011 when a 50 kW solar photovoltaic system was installed on the roof. This system is expected to generate 48,500 kWh of renewable energy per year, reducing CO_2 emissions by 26 tonnes and saving around £3,900.

Another example of energy-reducing improvements carried out recently is the conversion of six incubators to reduce their power demand from 0.6 kW per hour to 0.1 kW per hour. Annual savings of 26,280 kWh, £2,117 and 14 tonnes of CO_2 are expected.

RBG Kew implements an ISO 14001 certified environmental management system covering energy usage, water management, waste management, pollution control and procurement. ISO drives improvements through its requirement that a strict utility monitoring programme is implemented. This allows the Wakehurst Place Sustainability Team to identify anomalies and prioritise areas for action. Over the last three years, by engaging with staff, this group has led the reduced energy consumption of the MSB.

Mozambique joins the Millennium Seed Bank Partnership

Mozambique joined the Millennium Seed Bank Partnership on December 12th 2011 when Dr Calisto Bias, Director General of the Instituto de Investigação Agrária de Moçambique (IIAM), signed a five-year Access and Benefit Sharing Agreement between RBG Kew and IIAM. Kew and IIAM have worked together on previous projects but this new agreement establishes a framework for an integrated programme of technical co-operation involving IIAM's herbarium, seed bank and tree seed centre. Initial collaboration activities will focus on the conservation and sustainable use of wild plant resources for the benefit of local communities in Matutuine and Sussundenga Districts.

More information: **http://www.kew.org/science-research-data/directory/projects/Enhancing-Mozambique.htm**

New MSB agreements

Country	Start date	Duration (years)	Counterpart name
International	27 February 2012	5	Tree Aid, UK based charity supporting tree planting and re/afforestation in Africa – MoU
International	8 March 2012	5	World Agroforestry Centre (ICRAF) based in Nairobi, Kenya - MoU
Malawi	8 March 2012	5	Government of Malawi represented by the National Commission for Science and Technology (NCST) - ABSA
Mozambique	12 December 2011	5	Instituto de Investigação Agrária de Moçambique (IIAM) - ABSA

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3. Chen, H., **Pritchard, H. W., Seal, C. E., Nadarajan, J.**, Weiqi, L., Yang, S., & Kranner, I. (2012). Post desiccation germination of mature seeds of tea (*Camillia sinensis* L.) can be enhanced by pro-oxidant treatment, but partial desiccation tolerance does not ensure survival at -20˚C. *Plant Science* 184 (March) 36-44.
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The Partnership on film

The MSBP has been the subject of a short documentary in the Al Jazeera English series 'Earthrise'. The series showcases innovative projects to protect the environment. The documentary focuses on the partnership in Georgia and includes footage both in Georgia and at the MSB in the UK. You can view it on Youtube at http://www.youtube.com/watch?v=6Qb9VntUzSE

Sky 3D and Atlantic Productions have recently finished filming a new David Attenborough mini-series *Kingdom of Plants* 3D which features Kew and the MSB. The series reveals a fascinating new look at plant life through the use of 3D time-lapse filming techniques. It will be broadcast in the UK in May.

Finally, Kew has produced a new short film on the MSB which is available on You Tube at: **http://www.youtube.com/watch?v=KvL3B9594Vk&feature=BFa&list=UUNa8wJk6VYIRK78JuDSRnTQ&lf=plcp**

Millennium Seed Bank Partnership notice board

We are currently working with our IT and Digital Media Team to develop an MSB Partnership notice board through which you will be able to identify and contact other partners in the network, upload your blogs and videos, post news messages and ask and answer questions posed by others in the network. We hope that this notice board will be owned by the whole network, and that all will be able to contribute articles and ideas. Watch this space.

A **message** from Paul Smith

Millennium Seed Bank Partnership Leader

Plant-based solutions are essential to both adaptation and mitigation of climate change. We will need to adapt our agricultural, horticultural and forestry practices to cope with changes in temperature and precipitation, and we will need to mitigate climate change by locking up carbon in the natural and fallow areas that we manage. Seed banks, and specifically the Millennium Seed Bank Partnership, can make a major contribution to this effort by providing researchers and natural resource managers with new species and varieties of plant that will be resilient to the effects of climate change. The MSB Partnership is already doing this in agriculture with our 'Adapting agriculture to climate change' project with the Global Crop Diversity Trust (see page 10) through which we will systematically collect, conserve and characterise crop wild relatives with useful traits from 26 of the world's major crop species. Likewise, through our Forest Landscape Africa consortium (see below) we will supply agroforestry, plantation forestry and catchment restoration schemes with a wide range of well adapted, low input (preferably indigenous) tree species. The key to both adaptation and mitigation is learning to manage a greater range of plant diversity in the landscape because diversity equals resilience. Fortunately, diversity is what we do!

MSBP workshop on **public sector forestry** in West, East and Southern Africa

By Moctar Sacandé, International Projects Coordinator, MSBP

The '*MSB International Forestry Workshop: afforestation in Africa - constraints and opportunities*' was held at the World Agroforestry Centre in Nairobi on the 5-10th December 2011. It was attended by forestry institutes from 11 African countries (Botswana, Burkina Faso, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Tanzania and Uganda). In addition, representatives from the Royal Botanic Gardens Kew, ICRAF, FAO, Forest & Landscape Denmark, UNEP, DFID and others attended.

Net deforestation is still occurring in all of the African countries represented at the meeting. Mozambique has the highest forest cover remaining (50%), Kenya has the lowest (6%). Forest cover, in terms of actual area, is being removed fastest in Nigeria (410,000 ha per annum), Tanzania (403,000 ha) and Mozambique (217,000 ha). As a proportion of what remains, forest is being removed most rapidly in Nigeria (-3.7%) and Uganda (-2.6%) while Ghana (-2.1%). Kenya (-0.3%) and Madagascar (-0.4%) have the lowest deforestation rates.

On average government tree seed centres and forestry institutes supply 40 tonnes of seeds of 558 species and 398 million seedlings per annum. The majority of seeds and seedlings supplied by public sector forestry organisations are of exotic species. However, all of the forestry institutions present at the workshop also supply indigenous tree seeds and seedlings, although in smaller amounts than exotics.

All of the participants cited increasing public and political awareness of the importance of sustainable natural resource management as creating an opportunity for re/afforestation activities. Ecosystem services, climate change, carbon capture, biodiversity offsets and sustainable livelihoods all present opportunities. Decentralised tree seed centres, extension services and the participation of the private sector were all seen as an opportunity to scale up and reach more communities and individuals. All of the participants felt that the technical consortium proposed by this workshop, built on decades of bilateral relationships, created a major opportunity in a number of technical areas. The Consortium was also seen as an opportunity to better engage with policy makers and donors, and to greatly scale up afforestation activities.

The plenary sessions of the workshop concentrated on the opportunities afforded by the establishment of a mutually supportive technical consortium, tentatively named '**Forest Landscape Africa**' that would include a range of facilitating/support organisations with complementary expertise, and an array of delivery organisations who could put trees back into the landscape. Next steps were outlined and agreed on, including collating project ideas, concepts and proposals that will be developed by delivery partners at local, national and regional level, and the collective vision that will all be presented to policy makers, sponsors, donors and supporters.

MSBP International Forestry Workshop group. PHOTO ICRAF

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Millennium Seed Bank Collection Figures April 2012

Total collections	59,878
Number of species	31,353
Number of genera	5,271
Number of families	330

WE WANT TO HEAR FROM YOU!
***Samara* is your newsletter, so send us news and articles about yourself and your work.**

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Samara aims to provide information and inspiration for MSBP partners and a flavour of the successes of the Partnership for other interested recipients and is available as a PDF from the MSBP website at: **www.kew.org/samara**

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