The importance of seed banks in a changing climate

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Introduction

There are various models predicting the impact of climate change on habitats in the scientific literature: up to 40% of the Cape's fynbos will be gone in the next 100 years (Malcolm et al., 2002); 60% of Europe's mountain flora at risk of extinction in the next 75 years (Thuiller et al., 2005), and so on. There *is* now irrefutable physical evidence that climate change is taking place (IPCC report 2007), but we don't yet know how it will affect habitats and plant diversity. Against this background, wild seed banks can help us to understand and meet the challenge of climate change in three main ways: through measuring the impacts of climate change on plant diversity; by insuring against the loss of plant species in the wild; and by helping humanity to adapt to climate change by restoring habitats and using plant species sustainably to ensure they deliver services to people.

Measuring the effects of climate change on plant diversity

Plant assemblages or habitats are often used by ecologists as surrogates for whole ecosystems, because plants are the basis of life, upon which so much else depends. It therefore makes sense to look at plants first if we are to understand the impacts of climate change on ecosystem functioning, and biodiversity as a whole.

Plants have two main ways of dealing with climate change – they can move or they can adapt. Perhaps the most useful way that botanists can assess the impact of climate change on plant diversity is to measure these responses *in situ*. For example, whenever Millennium Seed Bank Project (MSBP) seed collectors are in the field they collect information about the wild plants that are the source of the seed. In this way the MSBP has collected data from around 20,000 wild plant populations, across the globe in the past five years. For each of these populations we now have a baseline, against which future population fluctuations and movement can be monitored. In addition, the seed collections themselves represent a genotypic sample frozen in time, against which future genetic or biochemical adaptation can be measured. This is the first step towards a global early warning system. If we go back and monitor these populations again in 10 or 20 years time we will be able to measure how climate change is affecting different species, and we may see patterns arising that will enable us to predict which kinds of plants are most vulnerable.

We know that certain types of plant are better at moving long distances than others. Plants like dandelions (*Taraxacum* spp.) that produce light, wind dispersed seeds are able to move further, more rapidly, than plants like poppies (*Papaver* spp.) that just drop their seeds. The problem is that for many plant species, irrespective of their dispersal method, humans have disrupted that movement. For example, Kenilworth racecourse sits in the middle of municipal Capetown, and the 40 hectare field that the horses run round is one of the few remaining fragments of sand fynbos. These 40 hectares contain around 270 plant species, 30 of which are nationally threatened and three of which occur nowhere else but Kenilworth. The three Kenilworth endemics are a heather (*Erica margaritacea*), a reed (*Restio micans*) and a sedge (*Trianoptiles solitaria*). All have relatively short distance dispersal capability, and none of them have anywhere to go. One small advantage that these plants do have, however, is a short generation time. This might enable them to adapt and keep pace with climate change that way.

The MSBP is currently supporting a PhD student at the Environmental Change Institute at Oxford University to investigate life history strategies that predispose plant species to survival or extinction. The only advantageous characteristic to emerge in this study so far is that it is beneficial to be both useful and dispersed by humans. Another study carried out recently at the Millennium Seed Bank suggests that some plants adapt to different climatic conditions by changing their behaviour (Daws *et al*., 2004). For example, the horse chestnut, *Aesculus hippocastanum*, which was introduced to Britain from the Balkans in the 16th century, produces seeds that are five times larger in Greece than in Scotland. In addition, Greek horse chestnuts show some tolerance to dessication, which enables them to survive periods of drought. The same species living in Scotland produces smaller seeds with less drought resistance. Similar trends have in been observed with the sycamore (*Acer pseudoplatanus*). Conversely, recent studies indicate that invasive species may gain advantage from producing larger seeds than in their natural ranges (Daws *et al*., 2007a). By understanding how species behave in relation to climate and in the context of a human-dominated ecology, we will begin to be able to predict which species are most vulnerable to extinction, and which species are most likely to be successful.

Human adaptation: insuring against the loss of plant diversity

When policy makers talk about climate change they use the terms ‘mitigation’ and ‘adaptation’. Mitigation includes strategies such as reducing our carbon emissions, but by ‘adaptation’ they mean *human* adaptation to climate change. How are we going to cope? One of the most obvious human adaptation strategies is seed banking as an insurance policy. Throughout history, people have been putting seeds away for the next season or for a rainy day. This is the mission of the Millennium Seed Bank Project, which aims to collect and conserve the seeds of 10% of the World’s wild plant species by 2010. The MSB currently holds around 18,000 species of wild plants. By 2010, this will be 30,000.

Beyond 2010, the MSBP will aim to collect and conserve 25% of the world’s plant species by 2020. In this phase, collection programmes will prioritise species from montane, dryland, coastal and island ecosystems, which models suggest are most vulnerable to climate change (Malcolm *et al*. 2002; Thuiller *et al*. 2005). In addition, collection programmes will prioritise species of greatest utility to man, including: drought resistant crop and forage species that sustain the world’s poorest communities; salt tolerant and desert pioneer species that combat desertification; photosynthetically efficient and energy rich plants with potential as biofuels; and medicinal species effective against microbial pathogens and cancer. All of the methodologies needed to find and collect these species have been developed and successfully employed in the current phase of the MSBP.

Some of the research challenges associated with banking seed in the long term include understanding seed behaviour in order to employ appropriate ex situ conservation techniques. According to the current literature (Tweddle *et al*., 2003) approximately 90% of spermatophytes produce orthodox seeds that can be dried and stored at temperatures below freezing. However, it is likely that this is an over-estimate, as seed behaviour characteristics are only known for about 10,000 species, and most research has been carried out on temperate and dryland species, which are naturally predisposed to be dessication tolerant. The remaining 10% or more species produce dessication sensitive seeds, which require taxon-specific cryostorage protocols to be developed (see Sarah Ashmore’s paper in this volume). Seed longevity amongst dessication tolerant species is also variable. We know that certain species can live for hundreds of years (Daws *et al*., 2007b) in a conventional seed bank without significant loss of viability, but other species are more short lived (Walters *et al*., 2005). Relative seed longevities need to be elucidated so that short lived seeds can be multiplied and re-banked at appropriate intervals.

Human adaptation: restoring and using plant diversity

Of course if we persuade people to pay the $100 million ‘insurance premium’ that it costs to collect and bank 30,000 species, we need to be sure that we can pay out if the worst happens. This means that we have to be certain that we can turn these seeds into the living plants that deliver the goods and services that we need. For example, more than 3000 collections have been sent out by the MSB since 2000 to support applied research in areas such as water, energy, health and agriculture. Examples of how seed from the MSB is currently being used include: counteracting salination of agricultural lands in Australia; selection of drought resistant forage species in Pakistan and Egypt; screening for photosynthetically efficient (C4) forage species in the USA; culturing threatened medicinal plant species in Pakistan; improving and controlling the quality of essential oils in Brazil; understanding the poisoning of livestock by 'locoweeds' (*Astragalus*) in Canada; and developing new forage legumes in Mexico. The provision of seed for applied and fundamental research will continue to be a vital function of the MSB, and as our collections increase, our ability to provide this service will increase too.

Seed from the MSB is also currently being used in re-introduction and restoration programmes worldwide. Examples include: restoration of tall grass prairie in the USA; restoration and fire management of sand plain fynbos in South Africa; reintroduction of starfruit in the UK; and restoration of mined lands in Australia and Madagascar. Habitat restoration and species reintroductions will become increasingly important technologies as the effects of climate change become more marked. However, we still have some way to go. The science of restoration ecology, for example, is still in its infancy, and our understanding of complex habitats is incomplete.

What we can do routinely is to turn the seeds into plants. Every single collection that comes into the MSB is germination tested. This means that we are carrying out around 10,000 germination tests every year, and most of the species that we test have never been germinated by man before. The germination protocols that result from our studies are probably the most valuable scientific output of the Project because they are the starting point for sustainable use and restoration.

Conclusions

From the above, it is clear that wild species seed banks have an important role to play in understanding the impacts of climate change on plant diversity, and in human adaptation to climate change. However, there are many challenges ahead - not just for seed banks, but for botanic gardens in general. A group of representatives from botanic gardens across the world met last year in Gran Canaria to discuss some of these challenges, and suggest ways forward. The results of this meeting are captured in the Gran Canaria Declaration II (2006), which makes recommendations for policy makers, researchers and conservation practitioners that relate to climate change.

Perhaps the biggest challenge to botanic gardens is cultural. The role of botanic gardens as visitor attractions and in public education is well understood by everyone. Similarly, the role of BGs in ex situ conservation is well established. The real challenge for botanic gardens and for the broader conservation community is in developing the roles that botanists need to play in enabling sustainable use of wild plant species, and in habitat creation and restoration.

Conceptually this should not be difficult. The history of botanic gardens is founded on botanical exploration and exploitation. Botanic gardens have traditionally provided technical underpinning of the sustainable plant industries - horticulture, agriculture and forestry. In this role we have catalysed massive land use changes, not always for the better as it turns out. Now it is time for us to truly enter the environmental age, and rise to the challenge that we have helped to create.

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