SHORT COMMUNICATION

THE CENTRE FOR MIDDLE EASTERN PLANTS: PROJECTS IN SOCOTRA, ARABIA AND SW ASIA

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ABSTRACT

The Centre for Middle Eastern Plants (CMEP) was established in 2009 as a distinct unit within the Science Directorate of the Royal Botanic Garden Edinburgh (RBGE). In this article, the history of research on Socotra, in Arabia and South West Asia undertaken at the Royal Botanic Garden Edinburgh is briefly outlined. The strategic goals of CMEP, including biodiversity conservation, capacity development and research, are also discussed and illustrated through a range of projects funded from diverse sources. A focus on Socotra and the projects and achievements that CMEP have contributed to demonstrates how these strategic goals can be achieved for the benefit of biodiversity conservation, the sustainable use of natural resources, and improved livelihoods for local communities.

Key words: Centre for Middle Eastern Plants, CMEP, Socotra, biodiversity conservation, capacity development, sustainable use of natural resources.

INTRODUCTION

The Royal Botanic Garden Edinburgh was established in 1670 as Scotland's first Physic Garden. It has subsequently relocated several times, moving to current location in Edinburgh's Inverleith district in 1820, where in the last 200 years it has established an outstanding living and preserved collection of plants of global importance (http://www.rbge.org.uk/about-us/history/a-brief-chronology). It also includes three satellite gardens in Scotland, each located in a distinct climate zone and focusing collections on plants from different regions that are suitable to the local conditions.

As well as a globally renowned plant research and conservation program, RBGE is also home to a contemporary art gallery and exhibition spaces, and features a range of education and interpretation programs and facilities. As a visitor attraction, it receives more than 800,000 visitors per year. It draws upon the expertise of over 200 staff in a range of strategic programs to achieve its mission: 'exploring and explaining the world of plants for a better future'.

RBGE has a long association with the flora of the Middle East and SW Asia. It holds historical collections dating back almost 200 years, and has been a focal centre for work on Flora Iranica, the Flora of Turkey, the Flora of the Arabian Peninsula and Socotra, and the Ethnoflora of the Soqotra Archipelago. The herbarium (E) holds close to 3 million specimens; perhaps as many as 250,000 of these are from Arabia and SW Asia, with an active digitisation program to make them globally accessible. This association has been maintained in part through the Plant Life of SW Asia symposia, first held in Edinburgh in 1970 and subsequently in Germany, Turkey and Uzbekistan. These gatherings bring

together botanists, conservationists and other interested parties from the region and globally for the presentation and discussion of topics of regional relevance. The 8th symposium was also held in Edinburgh in 2013, and will continue at more regular intervals in the future.

THE CENTRE FOR MIDDLE EASTERN PLANTS

The Centre for Middle Eastern Plants (CMEP) was established in 2009 to develop the Royal Botanic Garden Edinburgh's (RBGE) portfolio of projects in the Middle East and SW Asia, building upon institutional expertise regionally and globally. CMEP projects use not only the historical and contemporary research and plant knowledge base in the floras of SW Asia, but also draw upon additional expertise within the departments of horticulture, education and interpretation. CMEP collaborates with a wide range of external partners, including governments, NGOs, research and development organisations, the United Nations, and with a broad field of regional specialists.

CMEP research covers a wide range of disciplines, from taxonomy and systematics through molecular evolution and population genetics to conservation and protected areas. Our staff have published widely in diverse peer-reviewed journals, and have contributed to conservation programs and priorities regionally.

Our capacity development programs are targeted at a wide range of stakeholders, from school children through undergraduate and graduate students to conservation professionals. Much of our work supports requests for training to help organisations and institutes achieve the obligations of international treaties and strategies.

CMEP also undertakes a wide range of consultancy projects, underpinned by regional plant expertise, to ensure ongoing sustainable financing for our conservation and capacity development work. This diverse portfolio is highlighted in Table 1.

Table 1: Examples of projects undertaken by the Centre for Middle Eastern Plants at the Royal Botanic Garden Edinburgh, highlighting the diversity of skills and outputs.

Project	Summary
Oman Mountain Project	Multi-disciplinary survey to record the flora and fauna of Oman's high mountains. CMEP responsible for floristic surveys and reports, with numerous field visits undertaken. Online Atlas to be published.
Saudi Arabia PA	Collaboration with the Saudi Arabia Wildlife Commission and other Arabian countries to refine the Important Plant Area selection criteria in an Arabian context, via extensive networking and workshops. Site selections and site surveys are ongoing. Publication outlining regional IPA guidelines (Al-Abbasi et al. 2010).
Building capacity for *in situ* conservation in Iraq	Raising awareness and developing capacity for biodiversity conservation in schools, universities and professionals through building tools, online and in country courses and workshops, and collection of botanical and ornithological data to support the designation of Piramagroon Mountain as Kurdistan's first National Park.
Kurdistan Botanic Garden	Development of a Master Plan for the Kurdistan Botanic Garden, Sulaimani, through extensive workshops and discussions between partners.

Lebanon Red Listing	IUCN Red Listing workshops focusing on plants, to enable the creation of plant micro reserves for Lebanese endemic species.
Botanical Training, Oman	Professional training for rangers, government officials, university and NGO staff and students in field work and plant identification in Oman's Important Plant Areas.

SOCOTRA AND EDINBURGH: A LONG TERM RELATIONSHIP

Although several naturalists had made small collections of plants from Socotra in the early 18th century, it was the pioneering collections and publications of Isaac Bayley Balfour that put Socotra 'on the map' in botanical terms. His collections resulted in more than 200 plant species being described as new to science. Although not based in Edinburgh when he visited the archipelago in 1880, he was accompanied by Alexander Scott, then a horticulturalist at RBGE. By the time the monumental 'Botany of Socotra' was published (Balfour 1888), he was Regius Keeper (Director) at the Royal Botanic Garden Edinburgh, a position held until 1922 after establishing RBGE as a major centre of taxonomic research. As such, Edinburgh became the *locus operandi* for studies on Socotran plants: subsequent collectors often sent specimens to Edinburgh as duplicates or for identification, and the collections (both historical and contemporary) are unmatched globally to this day. There are also a range of living collections growing in the Edinburgh Gardens, including such well known Socotra endemics as the Dragon's Blood Tree *Dracaena cinnabari*, Socotra Rock Rose *Adenium obesum* subsp. *socotranum*, *Begonia socotrana* and *Pelargonium insularis*.

Since Professor Quentin Cronk visited Socotra for a few days in 1985, establishing that the condition of the environment was largely unchanged since Balfour's visit more than 100 years previously (Cronk, 1986), RBGE has been involved in over 30 expeditions to Socotra. Although many were primarily collecting and surveying trips designed to establish the distribution of native plant taxa across the Archipelago, there have also been trips focused on capacity development, horticultural training, and a range of targeted surveys and impact assessments including searches for rare endemic plants and surveys of under-recorded regions. Tony Miller was present on the majority of these trips, and has collected several thousand plant specimens from Socotra resulting in the description of more than 30 species new to science (see Tab. 2), and completion of IUCN Red List Assessments for all Socotran endemic plant species.

CMEP and RBGE have always maintained a collaborative approach to work in Socotra and Yemen, working with both local and international partners on a variety of projects. This is exemplified by work carried out by Lisa Banfield from December 2007 until May 2008, the majority of which time was spent on Socotra. This work was undertaken for RBGE in association with the Socotra Conservation & Development Programme. Her work covered a range of activities, including survey work and recommendations on plant species of conservation priority, surveys of areas previously under-surveyed, assessments of road and their conservation and development impacts, re-visiting panoramic monitoring points across the island, and a range of support activities alongside staff from the Socotra Environmental Protection Agency and the Socotra Botanic Garden.

Table 2: Species new to science described from Socotra by Tony Miller

Family	Taxon
Asparagaceae	*Chlorophytum graptophyllum* (Baker) A.G.Mill.
	Dipcadi kuriensis A.G.Mill.
	Drimia porphyrostachys (Baker) A.G.Mill.
	Ledebouria grandifolia (Baker) A.G.Mill.
	Ledebouria insularis A.G.Mill.
Polygalaceae	*Polygala kuriense* A.G.Mill.
Moraceae	*Dorstenia socotrana* A.G.Mill.
Begoniaceae	*Begonia semhaensis* M.Hughes & A.G.Mill.
Euphorbiaceae	*Euphorbia hamaderoensis* A.G.Mill.
Geraniaceae	*Pelargonium insularis* Gibby & A.G.Mill.
Malvaceae	*Hibiscus dioscorides* A.G.Mill.
	Hibiscus diriffan A.G.Mill.
	Hibiscus noli-tangere A.G.Mill.
	Hibiscus quattenensis Thulin & A.G.Mill.
Resedaceae	*Ochradenus arabicus* Chaudhary, Hillc. & A.G.Mill.
	Ochradenus socotranus A.G.Mill.
Capparaceae	*Cadaba insularis* A.G.Mill.
Brassicaceae	*Farsetia inconspicua* A.G.Mill.
	Nesocrambe socotrana A.G.Mill.
Portulacaceae	*Portulaca kuriensis* A.G.Mill.
	Portulaca samhaensis A.G.Mill.
	Portulaca sedifolia A.G.Mill.
Apocynaceae	*Socotrella dolichocnema* Bruyns & A.G.Mill.
Boraginaceae	*Echiochilon pulvinata* A.G.Mill. & Urban
Plantaginaceae	*Nanorrhinum kuriensis* (Radcl.-Sm.) A.G.Mill.
Lamiaceae	*Leucas hagghierensis* A.G.Mill.
	Leucas samhaensis Cortes-Burns & A.G.Mill.
Verbenaceae	*Coelocarpum haggierensis* A.G.Mill.
Asteraceae	*Distephanus qazmi* N.Kilian & A.G.Mill.
	Helichrysum dioscorides Atkinson & A.G.Mill.
	Helichrysum nogedensis Atkinson & A.G.Mill.
	Helichrysum samhaensis Atkinson & A.G.Mill.
	Helichrysum socotranum Atkinson & A.G.Mill.

Since the early 1990s research on the flora of Socotra in Edinburgh has been active and ongoing. This has included a range of MSc and PhD students studying a range of subjects including ethnobotany, vegetation classification, and 'wet' refugial endemic conservation on Socotra, as well as taxonomic and systematic studies in genera as diverse as *Begonia* (Begoniaceae), *Polycarpaea* (Caryophyllaceae), *Boswellia* (Burseraceae), and *Indigofera* (Fabaceae). These studies are continuing, with students in 2014 studying *Coelocarpum* (Verbenaceae), *Dyerophytum* (Plumbaginaceae) and the endemic Brassicaceae of Socotra.

A major push forwards in documenting and understanding the flora of Socotra began in the mid-1990s with two projects: the Conservation and Sustainable Use of the Biodiversity of the Socotra Archipelago (1996-2000) funded through the Global Environment Facility (GEF) and United Nations Development Program (UNDP) (Project Code YEM/96/G32), and the Biodiversity Inventory of the Socotra Archipelago (1997-2001) funded by the Darwin Initiative for the Survival of Species (Project Code 162/6/113). These programs brought together a range of collaborators including the Yemen Environmental Protection Council, Birdlife International, the Socotra Conservation and Development Programme, Yemen Ministry of Agriculture, and Dr Miranda Morris (a globally renowned expert in southern Arabian ethnography). The main driver behind the former programme was to establish a Master Plan for the Development of the Socotra Archipelago, including awareness raising, capacity development and sustainable use management priorities. These priorities were designed to remove pressures on natural resources in order to conserve unique biodiversity and improve local livelihoods. A focus was placed upon the positive interdependence of biodiversity conservation, environmental management and development.

The collection of botanical and ethnobotanical data from both programs resulted in the publication of the 'Ethnoflora of the Soqotra Archipelago' (Miller & Morris, 2004) and the detailed 'Manual of Traditional Land Management' (Morris & Miller, 2002). These publications are still the essential reference works for any professional or amateur botanist visiting Socotra or examining material collected there. Even so, since publication in 2006 several new species have been recorded (Kilian & Hein, 2006) including an assessment of a number of alien plant species (Senan et al., 2010).

Since establishment in 2009 the Centre for Middle Eastern Plants has maintained the relationship between Edinburgh and Socotra, and this is exemplified by the current research program 'Conserving the Flora of Socotra: integrating evolution into conservation' funded by the Leverhulme Trust. This project is addressing three main objectives:

Objective One: Are protected areas on Socotra best defined by patterns of plant phylogenetic diversity?

Currently, protected areas are designated based largely upon taxon richness. As an alternative or complementary measure of diversity, Phylogenetic Diversity (PD) encapsulates the amount of evolutionary history contained within taxa in a given area, through assessment of branch lengths and evolutionary time (Cadotte & Davies, 2010; Forest et al,. 2007). While patterns of taxon richness and phylogenetic diversity often covary closely, they are likely to become decoupled under certain scenarios, for example when the underlying phylogeny is unbalanced and there is significant phylogeographic structure (Rodrigues et al., 2005). These scenarios are features common to endemic radiations, and are often documented in isolated island systems. Forest et al. (2007) identified such a decoupling between taxon richness and PD in the Cape Flora Hotspot, and noted that site selection via complementarity differed among the two metrics: selecting

areas based upon taxon richness ignored areas that would give high gains in PD. Evidence subsequent to the selection of Sites of Special Botanical Interest in the Socotra Conservation Zoning Plan show that adaptive radiations may be a feature of these areas: of the ca. 200 endemic species restricted to wet refugia >20% belong to only two families: Asteraceae and Fabaceae (Banfield 2006).

Using phylogenetic diversity to establish priority areas for conservation is based upon the premise that it offers a better chance of adaptation against change, as more botanical features are conserved in a spatially explicit context. It has also been argued that, rather than a surrogate measure for evolutionary potential or functional diversity, evolutionary diversity should conserved in own right (Winter et al., 2013). By sequencing the entire flora, it will be possible to generate phylogenetic diversity measures that can be compared in a spatially explicit analysis to other measures of diversity.

Objective Two: What is the origin of the Socotran flora, and what processes have driven the evolution of the island's endemic species?

Little is known about the origin and evolution of the flora of Socotra, and whether this has occurred through vicariance or dispersal followed by responses to local environmental variables, genetic drift in isolation, or colonizing lineages being pre-adapted or evolutionarily labile. For example, many of Socotra's endemic plants are concentrated in wet refugia at high altitudes: whether these are palaeo-endemics that represent refugial remnants of previously more widespread groups, or evolved from recent single or multiple immigrations ('relictual series' vs. 'colonization window': Carine, 2005) is currently a matter of speculation.

Several studies have inferred areas of origin for monophyletic Socotran clades, with northeast Africa the most commonly identified area, for example *Chapmannia* (Lavin et al., 2000), *Echidnopsis* (Thiv & Meve, 2007), *Leucas* (Scheen & Albert, 2009), and *Zygocarpum* (Thulin & Lavin, 2001). Socotran *Aerva* species are weakly supported as sister to Arabian taxa (Thiv et al., 2006), and Socotran *Exacum* species are strongly supported as being derived from Arabian and SW Asian ancestors (Yuan et al., 2005). Those studies that have dated the origin of Socotran clades estimate ages of 5-7mya indicating dispersal rather than vicariance. At least one lineage is older than Socotra itself: the cucumber tree *Dendrosicyos socotranus* (Cucurbitaceae: Schaefer et al., 2008). However, no studies have sampled multiple accessions of all Socotran endemics within a genus, and the relationships among Socotran endemics at this fine scale remain unknown. Studies from other islands demonstrate how such evolutionary trajectories can be resolved: Howarth & Baum (2005) used four nuclear loci to show that, in a monophyletic clade of seven species of *Scaevola* from Hawai'i, an initial diversification separated five taxa by habitat (mesic vs. wet forest). Within each habitat, monophyletic taxa could be separated by environmental factors which likely contributed to the cessation of gene flow among colonizing groups. Initial studies on Socotran endemic taxa (eg. *Boswellia*, *Polycarpaea*) suggest that using a range of variable loci will give resolution among endemic species allowing *in situ* evolutionary trajectories to be inferred.

Objective Three: How can evolution be integrated into practical conservation strategies?

Despite recognition that measures of evolutionary diversity and distinctiveness should be a core feature of conservation planning (Hoffman & Sgro, 2011), they are rarely implemented due to practical constraints (Mace & Purvis, 2008). These constraints include

the short timescales at which conservation planning is undertaken, and the tendency to conserve the *status quo* rather than adopting a more fluid approach potentially better matched with changing environmental conditions and evolutionary pressures. Another common constraint is a lack of information about evolutionary processes in a given area or set of taxa: the Cape Flora of South Africa is currently the only biodiversity hotspot with a detailed conservation plan that incorporates ecological and evolutionary processes, albeit at a broad scale (Cowling et al., 2003). Socotra represents a unique opportunity to develop such a comprehensive conservation plan.

As well as comparing taxon richness and phylogenetic diversity metrics, taxa will be defined by functional types and traditional ethnobotanical uses, as these features may represent the best options for adapting to future changes and also hold value for communities who depend upon plants in their day-to-day lives for a variety of purposes. Methodologies will be proposed for incorporation of these metrics into protected area selection and management systems. In order to take into account environmental change in protected area design, environmental envelopes will be constructed for exemplar taxa and their distribution predicted under environmental change scenarios.

A fundamental data resource for these analyses is the database of Soqotran plants held at CMEP. This database contains more than 20,000 plant distribution records, and is increasing. Importantly, almost half of these are represented by physical herbarium collections, with about half of those present in the herbarium at Edinburgh. Physical specimens form the backbone of any taxonomically accurate data resource: this is important, as field notes (while valuable) cannot be re-examined in the face of taxonomic, systematic or nomenclatural changes. These herbarium records, particularly the more recent collections, are also a valuable resource for DNA research: as arid land plants are easily dried and desiccated, the DNA is often well preserved in specimens dating back even to the 1960's and 1970's, allowing the extraction of nucleic acids for molecular studies.

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CZECH DEVELOPMENT ASSISTANCE PROJECT ON SOQOTRA: "SUPPORT OF SMALL-SCALE FARMERS AND AGRICULTURAL EDUCATION ON SOQOTRA ISLAND"

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From August 2012, a new project supporting Soqotri people is being implemented by Mendel University experts. The project is funded by the Czech Republic Development Cooperation via Czech Development Agency, with a budget of 12.42 mil. CZK. The objective of the project is to support the island's population in an effort to improve their food safety and nutritional quality of the food, and to increase food self-sufficiency of local communities through educational activities in the field.

Project activities continue mostly in extension of results of previous Czech projects implemented on Soqotra Island. More than 100 interested families were encouraged to establish or expand their home gardens; one of the supported crops was traditional "bambe" (*Eleusine coracana*), which nearly disappeared from the Soqotri diet but now it is again of great interest to indigenous locals. Nurseries producing seedlings of agricultural crops, and cultivation of endemic species was supported by provision of a variety of equipment, and by paying a salary to nursery managers.

After two years of project implementation, positive results were achieved not only in the form of newly founded or improved gardens, but also in the number and species diversity of crops produced in supported areas. An inherent benefit of the project is the increased awareness, by the target groups, of the necessity of a nutritionally balanced diet for overall human health and condition, as well as the cultivation and subsequent processing of staple crops. This was achieved by the provision of training focused on human nutrition, cooking using the crops grown (including distribution of a simple cookbook created within the project) and basic agronomic methods and management practices in home gardens. In a number of municipalities and schools a water source was created, thereby enabling access to quality and safe water.

Seven larger agroforestry objects were established during the project and serve as practical examples and training centres; in some of these fenced areas, local endemic trees are supported to grow beyond the reach of livestock – *Dracaena cinnabari* in Shibehon, *Boswellia elongata* in Homhil – Leeyeh, *Commiphora ornifolia* in Quareh and *Boswellia socotrana* in Galelhan.

Another activity, which is new on the island, was added. In collaboration with the Education Centre, schools suitable for school garden construction or expansion were selected. Each school was supported by fencing an area sufficient for establishment of a garden. The fence was stabilised with iron sticks and concrete blocks. Fertile soil, seedlings of local tree species and vegetable seeds were provided by the project. As a water source, plastic or concrete reservoirs were bought or constructed; in some of the schools water was brought from a nearby aqueduct. Schools were also provided with tools - wheelbarrows, shovels, rakes, hoes, hoses etc. and by materials such as educational brochures, paper, pens, colour pencils etc. Planted trees should serve in the courtyards of the schools for shading; they will provide shade for pupils in the future, which is needed especially in the hot streets of Hadibo city. Pupils and students led by trained teachers will

take care of gardens during lessons or in extracurricular activities, which are of great interest especially to students in Hadibo. Students are encouraged to cultivate the land from a young age, achieve a consciousness about producing food plants and disperse their knowledge within their families.

Criteria for the selection of schools were suitability of land, number of students and also the motivation of the director or teachers, which should ensure continuity of the project. During 2012 and 2013, the following schools were supported:

Primary school Galelhan
Primary school and Secondary School Qualensiyah
Primary school Rehen
Secondary school Al-Zahra`a (Hadibo)
Secondary school Khaled Bin Alwaleed (Hadibo)
Primary school Hafeg
Primary school 30 November
Primary school Alwahda (Manofo)
Primary school Oam Alcora
Primary school Homhil
Primary school Mahfirhin
Primary school Gisfo
Primary school and Secondary school Madahubo
Primary school Selmeen (Mori)
Primary school Osama bin Zaeed
Primary school Saeed (Haif)
Primary school and Secondary school Abu Bakar Asadik (Steroh)
Primary school Zahag
Primary school and Secondary school Mohamed Mahmood Zubeiry (Noged Station)
Primary school Darho
Primary school 7th July (Haaleh)
Primary school Matiaf (Noged)
Primary school Ashukani (Quariah)
Primary school Salahadin (Hadiboh)

Czech activities on Soqotra Island, thanks to its long history, are very welcomed by the community and the cooperation with local people is pleasant and fruitful. It could be proven also by obtaining two diplomas from local schools, expressing their gratitude to Mendel university team in support of their school gardens.

Fig.1: One of the school gardens supported by the project (photo Irena Hubalková)