Major Tasks of Botanical Gardens: Regional Ecological Restoration and Biodiversity Conservation

Organized by Xishuangbanna
Tropical Botanical Garden (XTBG),
Chinese Academy of Sciences (CAS)
In cooperation with
Kunming Botanical Garden (KBG),
Kunming Institute of Botany (KIB),
Chinese Academy of Sciences (CAS)

Contents

Introduction

The biological diversity of tropical forests in Southeast Asia is among the very richest and most spectacular on the planet. Southeast Asia has also the highest deforestation rate of any major tropical region in the world, and is being massively altered by rampant industrial logging, plantation expansion, overhunting, the illegal trade in wildlife and wildlife products, pollution and degradation of freshwater and coastal marine ecosystems, rapid human population growth, and other threats. Many species in tropical Asia have naturally restricted geographic ranges and small population sizes, rendering them inherently vulnerable to habitat destruction and degradation; and many important ecosystems in the region are seriously underrepresented within national parks and protected areas, leaving them highly vulnerable to future loss and degradation. Biodiversity conservation has been recognized as urgency and imperative in this region.

Botanical gardens in Southeast Asia located fairly at the frontier in conservation in this region. As classic agencies for ex-situ conservation, botanical gardens in this region often harbor extremely rich living collections. Numerous botanical gardens have involved into some programs in this region relevant to ecosystem management, habitat restoration and institutional development for environmental protection. Some recently established botanical gardens have also developed impressive conservation program, allow botanical gardens in the region be more geographically represented.

In order to exchange experiences and refine potential cooperation, the 4th Southeast Asia Botanical Gardens (SEABG) Directors' Meeting is scheduled to be hold in the Xishuangbanna Tropical Botanical Garden (XTBG) of the Chinese Academy of Sciences. The meeting will provide a platform to share knowledge and information between botanic gardens, to discuss and refine to provide updates by members on their activities, and bring up topics of common interest and benefit for discussion.

The venue is situated in Xishuangbanna. Xishuangbanna is a Dai Autonomous Prefecture, which is located at the southernmost tip of Yunnan Province, bordered by Myanmar to the southwest and Laos to the south and southeast, with Jinghong as its capital. Xishuangbanna is well-known for its rich biodiversity and is the only place in China that still maintains large tracts of tropical rainforest. Thus it is reputed as Tropical Fauna and Flora Kingdom. The Lancang (Mekong) River flows through the whole area. Xishuangbanna is also rich in cultural diversity. There are 13 dominant minority nationalities such as Dai, Han, Hani, Lahu, Yi, Bulang, Jinuo, and Yao, the Dai, makes up a majority of the population in Xishuangbanna.

XTBG is a comprehensive research institution engaged in biodiversity conservation and sustainable uses of plant resources, focusing on forest ecosystem ecology, conservation biology and resource plant development. XTBG is located in Menglun Township, Mengla County, and is about 60 km from Jinghong. After 52 years of development, XTBG has become an integrated base for research on tropical botany, forest ecology, plant germplasm preservation, and public science education.

Organizing Committee:

Chairmen: Qing-Jun Li(XTBG), Shou-Hua Yin (XTBG), Wei-Bang Sun (KBG)

Members: Li-Ming Li (XTBG), Chun-Yan Fang(XTBG), Xi-Min Wang (XTBG), Wen-You Chen (XTBG), Ji-Pu Shi (XTBG), Yong-Neng Fu (XTBG), Shi Feng (KBG)

Programme

Monday, 14 November, 2011

Arrival of participants
Transportations available from the Jinghong Airport to XTBG. Dinner will be provided at the Tropical Rainforest Hall, XTBG Hotel since 6:30pm for early arriving participants.

Tuesday, 15 November, 2011

08:00-08:30 Breakfast at Tropical Rainforest Hall, XTBG Hotel.
08:30 Electronic shuttle will pick up participants from the lobby of XTBG Hotel.

Opening (Venue: Conference Hall. **Chair:Shou-Hua Yin**, Director Assistant, XTBG, China**)**
09:00-09:30 Opening Addresses

1. Dr. **Jin Chen**, Director of XTBG, CAS, China
2. Mr. **Jia-Hua Tang**, Vice Governor of Xishuangbanna Dai Autonomic Prefecture, China
3. **Joachim Gratzfeld**, Director, Regional Programmes, BGCI, UK

09:30-10:00 Group photo and coffee break.

Plenary Session (Venue: Conference Hall. **Chair: Wei-Bang Sun**, Director of KBG, China**)**

10:00-10:30
The ways in which botanic gardens can support restoration ecology: examples from Kew and Singapore. (**Nigel Taylor**, Director, Singapore Botanic Gardens, Singapore)

10:30-11:00
Collection based research in botanical gardens. **(Jin Chen**, Director, Xishuangbanna Tropical Botanical Garden, CAS, China)

11:00-11:30
Building botanic garden education programs in partnership with local governments. (**Carl Lewis**, Director, Fairchild Tropical Botanic Garden, USA)

11:30-12:00
Development of new botanic gardens for accelerating Indonesian flora conservation. (**Mustaid Siregar**, Director, Bogor Botanical Gardens, Indonesia)

12:00-13:00 Lunch at XTBG Staff Dinning Hall.

Session One: Reports from BGs **(Venue:** XTBG 2nd Meeting Room. **Chair: Xiang-Ying Wen**, BGCI China Program Office**)**

14:00-14:20 Hajah Jamilah Binti Haji Abdul Jalil
Ministry of Industry and Primary Resources, Brunei

14:20-14:40 Rik Gadella
Pha Tad Ke Botanical Garden, Laos

14:40-15:00 Ni War Lwin
Central Executive Committee member of Myanmar Floriculturist Association, Myanmar

15:00-15:20 Roberto Cereno
University of the Philippines, Philippines

15:20-15:40 Hsiang-Hua Wang
Taiwan Forestry Research Institute, Taiwan

15:40-16:10 Coffee break.

16:10-16:30 Nguyen Quoc Huy
HanoiUniversity of Pharmacy, Vietnam

16:30-16:50 Dayang Haktu Mabong
Ministry of Industry and Primary Resources, Brunei

16:50-17:10 Nin Chansamean
Department of Forestry Management, Cultural Landscape and Environment, APSARA Authority, Cambodia

17:10-17:30 Cho Wai Lwin
HTOO FOUNDATION, Myanmar

17:30-17:50 Chien-Wen Chen
Taiwan Forestry Research Institute, Taiwan

18:00-20:00 Banquet at XTBG staff dining hall (2nd floor).

Wednesday, 16 November, 2011

08:00-08:30 Breakfast at Tropical Rainforest Hall, XTBG Hotel.
08:30 Electronic shuttle will pick up participants from the lobby of XTBG Hotel.

08:30-12:00 Visit the living plant collections, herbarium and the museum of XTBG (Guided by Jian-Xiang Hu and Chun-Yan Fang).

12:00-13:00 Lunch at Tropical Rainforest Hall, XTBG Hotel.

14:00-18:00 Visit the XTBG Nursery and Tropical Forest Valley (Guided by Jian-Xiang Hu and Chun-Yan Fang).

18:30-19:30 Dinner at Tropical Rainforest Hall, XTBG Hotel.

20:00-22:00 Local dance performance given by XTBG tour guides (Chaired by Li-Ming Li and Kan-Wang Yi). Electronic shuttle will pick up participants from XTBG Hotel lobby at 19:55.

Thursday, 17 November, 2011

08:00-08:30 Breakfast at Tropical Rainforest Hall, XTBG Hotel.
08:30 Electronic shuttle will pick up participants from the lobby of XTBG Hotel.

Plenary Session **(Venue:** Conference Hall. **Chair: Monthon Norsaengsri**, The Botanical Garden Organization, Thailand**)**

09:00-09:30
The pivotal role of botanical gardens in advancing biodiversity, conservation and systematics research through bioinformatics and web-based tools. (**Frederik Slik**, Professor, Xishuangbanna Tropical Botanical Garden, CAS, China)

09:30-10:00
Conservation and reintroduction of the threatened trees in southwest China. (**Wei-Bang Sun**, Director, Kunming Botanical Garden, CAS, China)

10:00-10:30 Coffee break.

Session Two: Reports from BGs continued **(Venue:** XTBG 2nd Meeting Room. **Chair: Rik Gadella**, Pha Tad Ke Botanical Garden, Laos)

10:30-10:30
Contribution from the Botanical Garden Organization of Thailand to plant diversity studies. (**Monthon Norsaengsri**, The Botanical Garden Organization, Thailand)

10:30-12:00 To Be Determined

12:00-13:00 Lunch at XTBG staff dining hall.

Session Three: Discussions **(Venue:** XTBG 2nd Meeting Room, **Chair: Joachim Gratzfeld**, Regional Programmes, BGCI, UK)

14:00-15:30 **Topic 1: Opportunities and Challenges of SEABGs**

In this session, an open discussion will be organized to all participants to develop a list of opportunities and challenges that SEABGs faced. Further actions in response to those opportunities and challenges could also be discussed and proposed.

15:30-16:00 Coffee break.

16:00-17:30 Topic 2: Co-operation among SEABGs (Chaired by Jin Chen)
In this session, participants will focus on discussion of potential cooperation. Two proposals raised by XTBG that related to staff exchange and e-herbarium will be discussed. Other proposals are welcome to be presented during the discussion.

17:30-18:00 **Closing (Venue:** XTBG 2nd Meeting Room. **Chair: Shou-Hua Yin**, Director Assistant of XTBG, China)

Closing Remarks by Joachim Gratzfeld, Jin Chen and volunteer participants.

18:30-20:00 Farewell Dinner at the waterside pavilion in the Shade Plants Garden. Some XTBG professors will be invited to join the dinner.

Friday, 18 November, 2011

08:00-08:30 Breakfast at Tropical Rainforest Hall, XTBG Hotel.
08:30 XTBG buses will pick up participants from the lobby of XTBG Hotel.

08:30-12:00 Visit the 20-ha Xishuangbanna Tropical seasonal Rainforest Dynamics Plot in Xishuangbanna National Nature Reserve near Mengla County.

12:00-13:00 Lunch

13:00-16:00 Visit Dai villages on the way to Jinghong.

16:00 To Jinghong Airport.

Saturday, 19 November, 2011

08:30 KIB buses will pick up the participants from the lobby of the Hotel.

09:00-11:30 Visit East Garden of KBG, Kunming Institute of Botany, CAS

11:45 Group photo, in front of the East Garden of KBG

12:00 Lunch

13:30-17:30 Visit West Garden of KBG, Kunming Institute of Botany, CAS

18:00 Dinner. Then back to the Hotel after dinner.

Papers and Abstracts

The ways in which botanic gardens can support restoration ecology: examples from Kew and Singapore

Nigel Taylor
Singapore Botanic Gardens, Singapore

Abstract:

The term restoration ecology ideally implies the achievement of recovery of damaged ecosystems back to their original pristine state. However, due to the complexity of many ecosystems this aim is probably unrealistic for most botanic gardens at present and the research that is needed is still in its infancy. Nevertheless, botanic gardens can make important contributions in this area, as this talk aims to demonstrate. The presentation will address the following questions: Where to attempt restoration; What – which plants to consider; Why, in terms of benefits; How it can be done (techniques); and the Challenges to be faced. Habitats need restoring and species need rescuing for a variety of reasons, ranging from natural disasters to manmade alterations, such as habitat destruction for harvesting of timber, for agriculture, mining etc. The Royal Botanic Gardens, Kew has been involved or is planning projects in the following places in collaboration with local counterparts: United Kingdom; Caribbean – Montserrat, Turks & Caicos Islands, Bermuda; Brazil (MatoGrosso do Sul); Oceania – St Helena, Ascension Island, Easter Island (Rapa Nui); Africa – Namibia, Cameroon, Madagascar; Indian Ocean – Seychelles, Mauritius (incl. Rodrigues); whilst Singapore has concentrated efforts on its own, once very diverse flora. These projects have included re-introduction/reinforcement of rare species into their original or ecologically similar habitats (orchids, shrubs, trees, grasses, ferns and bryophytes), elimination of invasive species, seed collection from projected mining sites for future restoration re-introduction activity, horticultural nursery establishment and training for staff in botanic gardens of bio-diverse countries, and restoration in tropical forest remnants. However, before travelling away from your base, if one's own botanic garden includes natural habitats, why not start restoration practices at home? This gives many logistical advantages as well as the opportunity to showcase such work to the visiting public and gain their support. Good examples of this exist at RBG Kew (Queen's Cottage Grounds conservation area) and at Singapore Botanic Gardens'6 hectare native Rainforest remnant. In both examples, invasive species have been removed and biodiversity encouraged by management techniques. As regards the benefits that restoration ecology or its contributory activities can bring to the botanic garden, it is notable that various species now extinct or rare in nature survive in botanic gardens' living collections and could potentially be used for re-introduction. This demonstrates the value of *ex situ* collections in support of biodiversity – i.e. they are not just 'postage stamp' collections! It also gives opportunities to understand some of the challenges repatriation and re-introduction programmes are going to face and brings opportunities to build capacity in partner organizations with training courses using botanic gardens' expertise.

Furthermore, the expertise developed can be turned into profitable consultancies via contracts with mining corporations, land developers etc., thereby offsetting the botanic garden's costs of collections maintenance, research, restoration etc. The Kew Innovation Unit was established in response to this opportunity in 2008 and is now earning significant income for the organization using its accumulated intellectual property. Activities include e*x situ* horticulture in gardens' nurseries and laboratories (including *in vitro* techniques); training for foreign garden's staff and local counterparts; development of propagation protocols for conservation rated plants, recording the hard-won experience stored in gardeners' heads but often not written down or recorded in a secure way; the harvesting and storage of seed produced under controlled *ex situ* conditions for future reintroduction opportunities (storage in the seed bank); the giving of advice on control of invasive species and plant predators; and re-introduction trials in habitat. A diverse series of case studies will be presented outlining the research, learning and techniques employed by Kew and Singaporean staff. The challenges that face botanic gardens engaging in restoration ecology include: Capacity Building activity when horticultural back up in the country being served is not always available once visiting botanic garden staff return home; the need to set up techniques and mechanisms for plant establishment where there is no horticultural support, e.g. irrigation or introduction of mycorrhizas etc., where soil fertility has been degraded; the need for alternative equipment in financially challenged countries where much biodiversity resides; the experience that many local staff once trained tend to leave publicly-funded programmes to work in the commercial sector. Besides these, at home existing *ex situ* facilities need to be large enough to cope with the scale of work and to accommodate training needs of partners; this also depends on having experienced trainers. The difficulty of maintaining sufficiently large and genetically diverse collections in cultivation *ex situ*, especially if species require protection under glass should not be under-estimated (where possible, seed-banking is better). There is the serious danger of inadvertent selection of genotypes that prefer artificial *ex situ* conditions, but may not be best adapted to re-establishment in wild environments. Back-up facilities at other gardens are needed as insurance against failures with *ex situ* collections, whether for living plants or in seed banks. Staff resources are often an issue and there may be the need to face the dilemma of diverting staff away from maintaining horticultural visitor attractions towards caring for *ex situ* collections. Lastly, there is the clear need to re-focus and prioritize the acquisition and retention of living collections towards those with conservation value. A recent key reference of relevance to this talk is: Hardwick, K.A.*et al.* (2011), The Role of Botanic Gardens in the Science and Practice of Ecological Restoration. *Conservation Biology* 25: 265–275 (2011).

Collection based research in botanical gardens

Jin Chen
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, China

Abstract

Significant research capacity in botanical gardens (BGs) may allow BGs to develop proper conservation strategy and implement accurate living collection. Meanwhile, what kind of research that BGs are ideal place to conduct and what are the research programs that BGs need to take as priority are still questioned. In this talk, author will present some examples that occurred in BGs for emphasis the needs of collection based research in BGs. Several priority areas for research will be also proposed.

Building botanic garden education programs in partnership with local governments

Carl E. Lewis
Fairchild Tropical Botanic Garden, USA

Abstract

Cooperation between botanic gardens and local governments can yield exceptional environmental education programs. These programs have the potential to train new generations of scientists to address local and regional conservation issues. At Fairchild Tropical Botanic Garden we work with our local government to teach students beginning at age 4 and extending through the university level. Our programs are aimed toward local and national priorities for science education. These priorities include (1) increasing emphasis on the environment; (2) establishing links between science, the arts, and the humanities; and (3) diversifying the scientific workforce. To meet these priorities we begin working with children at an early age and use a variety of methods to expose them to science and the environment throughout their education. Students are given multiple opportunities to experience and participate in scientific research. We encourage students to work with mentors who can guide them toward careers in science and conservation. The partnership we have established with our local government has proven to be effective in our community, and it can serve as a model for other botanic gardens to follow. Our programs are now being adapted and put into practice in other communities throughout the world.

Development of new botanic gardens for accelerating Indonesia flora conservation

Mustaid Siregar
Bogor Botanic Gardens, Indonesian Institute of Sciences, Indonesia

Abstract

Indonesia, known as a megadiversity country, has the highest number of biodiversity in the world. Indonesia's species richness comprises of approximately 38.000 species in total or contributes 10% of world flora; 55% of them are endemic across 47 ecosystem types. However, Indonesia is also a hotspot that is indicated by the highest threats on its species. To protect the Indonesian biodiversity, the Government has declared Terrestrial Conservation Area covering 22,498,378 ha; but, this policy is challenged by the increasing deforestation and threats on natural habitats. Therefore, the *ex situ* conservation is increasingly strengthened. To date, Indonesia has four national botanic gardens as *ex situ* conservation sites, although ideally all Indonesian flora should be conserved in botanic gardens. Those four botanic gardens: Bogor BG, Cibodas BG, Purwodadi BG and Bali BG are managed by Indonesian Institute of Sciences (LIPI) as the National Government. Indeed, these national botanic gardens have limited conservation areas, resources and habitat types. At the moment these gardens have been conserving 69,050 living collections belonging to 8,304 species which is 20% of Indonesian flora. Since their maximum capacity is 30-40%, it is important to expand the *ex situ* conservation area through more botanic gardens development in many Provinces or Regencies.

Since 2005, Bogor Botanic Gardens – LIPI in collaboration with Local Governments has initiated the development of 19 botanic gardens scattered in 16 Provinces/Regencies. Ten of them have built the infrastructures and collected living specimens from the rainforests, although, they performed varying progress.

The ten botanic gardens have been collecting plants for 3 years resulting in 19,862 specimens (the total number of species has not been reported yet) planted in their botanic gardens and they are maintaining 34,876 seedlings in their nurseries. The scheme of the plant collection activities is "Indonesian Flora Expedition" coordinated by Bogor Botanic Gardens that aims at collecting local flora richness and to be planted in their local botanic gardens so that they are grown in similar habitat types as in their natural habitats. The rests have already been in preparation stages under excellent master plans to achieve the same stages of infrastructure development and plantings as the others by 2015.

In terms of ex situ conservation, Indonesia should have at least 45 botanic gardens to cover its flora diversity, ecosystem types and biogeography. At the moment Bogor Botanic gardens have been preparing a grand design of botanic gardens development in Indonesia. This grand design determined how many and where the botanic gardens should be. Therefore, this design guides the Local Governments who intend to build their botanic gardens. Based on the grand design, Bogor Botanic gardens also recommends the National Government (LIPI) which botanic gardens in provinces/regencies are eligible as National botanic gardens to be managed by the National Government. Therefore there will be botanic gardens managed by the National Government or Local Government.

Plant Biodiversity Conservation between Government Institutions & Local NGOs in Myanmar

Ni War Lwin
CEC Member, Myanmar Floriculturist Association, Myanmar

Abstract

In this presentation, plant biodiversity conservation in Myanmar is introduced by current details and situation including with their concerned maps. Two types of conservation in Myanmar: *In-situ* and *Ex-situ* conservation and their present functions are explained by regionally significant data. Emphasizing the *Ex-situ* conservation of Myanmar: a Botanic Garden, Wildlife Parks, several Herbal and Floral Parks are shown by outstanding features of their environment. Moreover, globally threatened plant species of Myanmar defined in IUCN Red Data List which are currently planted in urban areas for their natural beauty, cultural value and conservation purposes are also mentioned.

Leucaena Removed and Tropical Coastal Forest Restoration in Kenting National Park, Southern Taiwan

Hsiang-Hua Wang
Fushan Botanical Garden, Taiwan Forestry Research Institute, Taiwan
Yau-Lun Kuo
Dept. Forestry, National Pingtung University of Sci. & Tech, Taiwan

Abstract

Leucaena leucocephala (Leucaena), an exotic invasive species, has spread extensively and posed serious threat to the coastal forest in Kenting National Park. Therefore, researches on *Leucaena* removal and forest restoration treatments are urgent. Three study sites, dominated by *Leucaena* before treatments, were selected for vegetation response observations in Kenting coastal forests. To understand the effects of different restoration practices, several treatments were selected at different sites.

Vegetation surveys were conducted before and after restoration treatments, including removal of *L. leucocephala* which was done prior to the rainy season in May and restoration planting in June or July when soil was fully moisturized by rain. Our results showed that after two years' treatment: (1) Canopy cover and basal area of reserved native tree significantly increase. However, the Species number doesn't significantly increase yet; (2) Planted seedlings had 60% of survival rate and grew to 100-150 cm in height. The maximum high growth of planted seedling could reach 5 m, and framework species had been choused for ongoing restoration project; (3) *Leucaena* seedling and sprouts spread soon under unclosed canopy after restoration treatment, which needed several cutting per year for at least two years' operations. Nevertheless, density of seedling and sprouts tend to decline while the coverage of herbal and tree canopy getting higher; (4) With the protection of preservation zones, densities of saplings and seedlings were higher then those at no-preservation zones.

Our research suggest: (1) Reserving the advanced native trees is a key to restoration success, (2) The reserved zone could be a economic windbreak and shading part of the sun, which could dry the soil soon, in tropical coastal area. To fully understand the effects of *Leucaena* removal and subsequent vegetation regeneration, long-term observations are suggested.

Conservation and development of new traditional Vietnamese medicines from Stephania species (important medicinal plants) in Vietnam

Nguyen Quoc Huy
Hanoi University of Pharmacy, Vietnam

Abstract

Stephania (S.) is a big genus in Vietnam's flora (There are 6 species of the genus in Vietnam red book, 1996). These species are important role in many herbalist's remedy from remote area comunities. Many species (tuber species) has been using in tradition and modern pharmaceutical for long time, but it is not clear in classification, chemical composition, bioactivity and conservation. Up to now we find the best way to conserve stably them base on 6 stages of research and development those species as follow: (i) Collect and identify scientific name (based on morphology and DNA); (ii) Establish original garden of those species; (iii) Study propagating (asexual and sexual); (iv) Conservation (insitu in the National Park; exsitu in the herbalist medicinal garden, HUP's botanic garden, on farm and seed banking); (v) Develop studying (chemical compositions: 22 alcaloids and 3 flavonoids were isolated from 5 species: *S. brachyandra, S. dielsiana, S. sinica, S. kwangsiensis, S. glabra*; Bioactivities: tranquilizer, relieve, unti- inflammation; Oxostephanine was isolated from the tubers of *Stephania*sp 1.has antitumor activity in liver; lung and pericardium cancer cells; cepharanthinwas isolated from the tubers of other species, it has antitumor activity…; (vi) Study developing new pharmaceutical products from these species and pure substances extract from them; benefit of pharmaceutical product are sponsored conservation activities.

Digitization and Archiving of the Herbarium of the Taiwan Forestry Research Institute

Chien-Wen Chen

Division of Botanical Garden, Taiwan Forestry Research Institute, Taiwan

Abstract

The herbarium of the Taiwan Forestry Research Institute (TAIF) is the oldest herbarium in Taiwan (since 1904), and it holds over 350,000 specimens. The work of digitally cataloging the collections at TAIF began in the early 1990s. At first, a stand-alone database software was used, then a network database for a specimen catalog was developed to increase the rate of specimen cataloging. Over 282,000 sheets of specimens (ca. 80% of the collection of the TAIF) have been cataloged. The specimen database of TAIF is based on the concept of an accession-duplicate relationship, which makes the information of each accession traceable, and shared information is identical. In addition, to increase the data quality of cataloging information, values of the scientific name, person, and locality fields have to be input from a "pick-up" list. TAIF began the digitization of specimen images in 2004. Image digitization produces an original electrical image file size of 300 dpi, then smaller 800-pixel-wide image files and thumbnail image files are produced for network browsing. Over 230,000 specimen images have been digitized and are now available online. TAIF has become the biodiversity occurrence data provider of the Global Biodiversity Information Facility (GBIF). More than 161,000 records of specimens have been harvested and published on the data portal of the GBIF.

The pivotal role of botanical gardens in advancing biodiversity, conservation and systematics research through bioinformatics and webbased tools

Frederik Slik
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, China

Introduction

Many parts of the world are currently experiencing a biodiversity crisis (refs). The combination of fast human population growth and economic development has led to habitat fragmentation and land use changes that are unprecedented in their spatial and temporal scale and are now directly and indirectly affecting the global biosphere (refs). This ongoing habitat degradation has already reduced the ranges of many plant and animal taxa to fractions of their original distribution, and many species are now on the brink of extinction (refs). Meanwhile our ecological understanding of how species co-exist and organize themselves and especially our taxonomic knowledge of many plant groups, especially in the tropics, is not keeping up with the rate of habitat and species loss (refs). There is a serious risk that many natural habitats, and with them many plant species, will have disappeared completely before we fully know how these systems worked and how many species depended on them for their existence, information that is essential if we ever decide to effectively protect or restore these natural ecosystems.

Current rates of species discovery and description depend almost entirely on the number of taxonomists in the world (Webb et al. 2010). Since there are not nearly enough taxonomists around to deal with the overwhelming amount of plant material being collected worldwide each year, the shortage of taxonomists forms the main bottleneck in most biodiversity and conservation studies, especially in the tropics (Stork et al. 2009). Because this situation is unlikely to change in the foreseeable future there is an urgent need to develop methods that can speed up plant discovery, description and classification to support biodiversity and conservation driven research (Webb et al. 2010). A possible way to achieve this is by setting up an automated system that can deal with large quantities of collected plant material, works in parallel with and makes use of traditional taxonomy, but will speed up rates of species identification, description and classification by making use of current state of the art bioinformatics, taxonomic and molecular techniques.

Fortunately, in these times of global biodiversity crisis, we are currently experiencing important breakthroughs in the biological sciences that, within a bioinformatics framework, can be used to make available and link the most critical data and methods relevant for taxonomic, biodiversity and conservation studies. These advances include: (1) the reconstruction of the phylogenetic relationships between all major angiosperm plant families (APG 1998, APG 2003, APG 2009), (2) the recently initiated plant DNA-barcoding initiatives (CBOL 2009), (3) automated species classification methods (PhyLoTa, ref), and (4) availability of digital curation software that is able to link all these new developments via universally exchangeable data formats. Here we propose to integrate these new developments into a system that can speed up the rate of plant discovery, identification, description and classification while simultaneously providing the basic data for biodiversity, systematic and conservation studies.

The pivotal role of Botanical Gardens

This project depends strongly on the availability of reliably curated living plant material for making digital photographs, scoring functional traits and taking DNA samples. Botanical gardens are a prime source of such data since they maintain large living collections of plants that usually contain exemplars of local vegetation types, rare and endangered species, and a selection of plant specimens from around the world. These collections are well administrated, i.e. the plant taxonomy, collector, collecting date and collecting locality are usually known, while additional data is sometimes available on phenology and growing preferences. This makes that botanical gardens have the unique opportunity to quickly collect, and make available, data from a broad range of plant species from all over the world. If botanical gardens could agree on a common approach to make all this data available to the general public in a way that is scientifically sound, this resource could be of incredible importance for biodiversity and systematic research and conservation efforts.

E-taxonomy as a tool for biodiversity, systematics and conservation studies

Of fundamental importance for advancing systematic, biodiversity and conservation studies is designing new plant identification and classification methods than can circumvent the taxonomic bottleneck caused by the scarcity of taxonomists. This will require the automation of plant identification, description and classification combined with data storage that can be accessed and used by any computer system worldwide. For this part of the proposal we will make use of existing bioinformatics tools developed by Campbell Webb (Arnold Arboretum, Harvard University). The key components of this approach will be:

1. Training people to perform much of the basic data collection and taxonomic work (plant DNA collecting, digital photography, character scoring, specimen sorting, image recognition, digital curation).

2. Use of computational approaches to organize and classify taxa based on morphological matrices and DNA barcode sequence data.

3. Produce a classification based on inter-specimen distances.

4. Make all data and bioinformatics tools available via the internet with open source programs and data formats that follow protocols for universal data exchange.

This E-taxonomy effort will aim to digitally curate (placing on the internet) specimens from all plant species present in botanical gardens. For each specimen all available data will be accessible, including collection locality (with possible exception of rare and endangered species which could be overexploited), habitat, morphological characters (which will include a number of pre-defined functional traits of ecological importance), pictures of live specimens (taken in a standardized manner), and DNA-barcodes. Most botanical gardens in the world have already started doing this kind of work, but a remaining problem is that this data is usually not freely or only partly available and often uses digital formats that are difficult to share or compare between data bases. One of the main aims of this effort will therefore be that data should be freely available and exchangeable among databases. This will enable users like

taxonomists, conservationists and ecologists, to take maximum advantage of the available species data. It also means that data storage can be decentralized so that, in principle, anyone can set up a specimen data base anywhere in the world but still contribute to a shared aim, namely making species data available for taxonomic, ecological and conservation research.
This E-taxonomy data base will be dynamic, meaning, for example, that it will be possible for users to provide identifications for specimens. These name changes will be added to the collection data record so that the identification history of each specimen can be directly assessed. The most important dynamic component of the E-taxonomy effort, which differentiates it from existing databases but makes it extremely useful for taxonomic, biodiversity and conservation studies, will be the automated generation of taxonomic and ecological hypotheses based on the available molecular and morphological data. This can include taxon delimitation, taxon description, integration of existing data, development of diagnostic guides, species distribution or niche models, and phenetic and phylogenetic classification of taxa.

Methods

Plant collection sites

Botanical gardens.

DNA collecting and digital photography

Initially, the plant selection procedure should be aimed at maximizing the number of species represented in the database. This will be done by including one or two specimens per species per botanical garden only. For each specimen DNA material will be taken and stored directly after collecting in air-tight containers with silica gel to assure quick drying. DNA material can thus be stored for later DNA extraction and sequencing. Digital macro photographs of all fresh plant parts of the specimens will be taken, including bark and twig cross-section, twig overview to show leaf insertion, details of twig tip, petiole-twig connection, petiole leaf connection and leaf lower- and upper-surfaces, whole inflorescence, details of inflorescence, a flower or fruit dissection, and detailed lower, upper and side views of flowers and fruits. It might be necessary to return to the specimens at regular intervals to capture the flowering and fruiting cycles of the plants. These photographs will be added to the specimen info that will be placed on the internet for our E-taxonomy effort, while it is also essential for plant identification purposes. All collected specimens should have an associated voucher in a herbarium (if this is not yet the case, it should be made during the project).

Molecular techniques

For DNA extractions a modified CTAB DNA isolation protocol will be applied (Porebski et al. 1997) as this is the most cost effective method, but we will fall back on Qiagen's Plant DNeasy extraction kits where needed. All other lab methods will follow standard procedures. We will generate classifications (phylogenies) using the *rbcL, trnH-psbA* and *matK*, plastid coding regions that have demonstrated near universality in amplification (Kress & Erickson 2007; Lahaye et al. 2008; Gonzalez et al. 2009), and that have been identified as barcode regions of choice by the Consortium for the Barcode of Life (Chase et al. 2007; CBOL Plant Working Group 2009). With this strategy we expect to be able to place specimens into a well resolved phylogenetic classification (at least up to genus level, but for many groups up to species level). In a DNA barcoding pilot study where we already sampled several hundred species of trees from the 20-ha Bubeng Forest Dynamic Plot we managed to get very high DNA barcode amplification and sequencing success rates (Table 1).

Table 1. Our pilot study's DNA barcode amplification and sequencing success rate for 325 tree species collected in the 20-ha Bubeng Tropical Forest Dynamics Plot, Xishuangbanna, Yunnan, China.

DNA-region	Amplification success rate	Sequencing success rate
*rbc*L	95.4%	93.9%
*mat*K	80.1%	74.5%
*trn*H-*psb*A	89.2%	87.3%

Biodiversity informatics

We will make use of open source bioinformatics and curation tools developed by Campbell Webb (Arnold Arboretum, Harvard University). His approach uses an open-access core database with plant collection information, a dynamic website for human users, and several well-documented web service interfaces, that present the field data comprehensively and rapidly. Xmalesia (http://phylodiversity.net/xmal) forms the core of this resource which is based on a carefully constructed XML schema (http://phylodiversity.net/xmal/schema/xmalesia.rnc) and a XML database serving data in various formats in response to XQUERY queries. These tools are free and open source, and can be easily redeployed as a package (via SVN) to serve our needs. The system can be run on field notebooks as well as webservers.

The XML schema is organized around records of individual plants, with nested metadata (e.g., image URLs, multiple collections, phenology, growth data, determination history, location). Innovative aspects of this schema include: a full history of matching of specimens in herbaria, requiring levels of confidence to be supplied for every identification, and details of legal documents and intellectual property rights covering collections. XSLT stylesheets are used to generate human-readable web pages for each individual plant, and will easily permit translation into other formats, e.g., a Simple Darwin Core record set (TDWG: http://www.tdwg.org/biodiv-projects/projects-database/) or SDD descriptions (TDWG). Data will also be accessible to GBIF (http://www.gbif.org) as a web service. The XSLT-generated webpage interface for each individual contains linked Google Image and Google Map lookups and individuals with DNA sequences can be BLASTed against GENBANK with a single click. Each taxonomic determination links to name queries at the Biodiversity Heritage Library and GBIF portal, thus connecting to material useful for further determination.

Automating taxonomy and classification

We will hook up with efforts presently being developed by Cambell Webb in cooperation with M Sanderson (University of Arizona), that take DNA barcodes as a starting point for automated taxonomy (PhyLoTa, ref). As collections accumulate in the database, DNA sequence differences between closely related taxa will decrease. When two individuals differ by less than some specified number of base pairs (Blaxter et al. 2005), they will be flagged for morphological examination. Additionally, Operational Taxonomic Units (OTUs) will be delimited, and then physical specimens will be examined to record the characters (if any) that differentiate among similar OTUs. Thus, a dataset useful for diagnosis will be built up far more efficiently than is possible by scoring all taxa for all characters.

The product will be a dynamic 'digital monograph' that organizes the individual collection webpages into OTUs and higher classes. Images for different individuals in the same OTU will be instantly comparable. Diagnostic keys will be generated automatically, as will 'florulas' for the various sites. Recognized taxa, based on matching of their members to herbarium collections and written descriptions, will link out to taxonomic information via a localized synonymy database (Slik & Webb, 2009; The Plantlist). The OTU classification can be saved in a 'versioned snapshot' for reference, but the foundation will always be the inter-individual molecular and morphological similarity matrices.

We will aim to automate the generation of phylogenetic hypotheses for our individuals as much as possible, an approach already implemented on Xmalesia using CLUSTALW alignments (Larkin et al. 2007) and PHYLIP's DNMAL maximum likelihood (Felsenstein 2005). From GenBank we will also be able to include samples not collected by ourselves (Sanderson et al. 2008). Our goal is to create a tool-chain and work flow that permits local parataxonomists and programmers to organize and describe biodiversity of understudied groups in megadiverse countries. Software in this tool chain will be easily redeployable by other projects.

Expected outcome

A universal plant collection and web-based digital curation and data sharing protocol that automatically contributes to our taxonomic knowledge of collected plants via the following steps:

- Voucher collection for storage in a herbarium.
- DNA collection for DNA-barcoding.
- Digital photographs of a standard list of plant characters of each field collection.
- Digital curation by placing the collection and all its data directly on the internet.
- Automated classification and identification of collections based on DNA-barcodes and morphological characters.

This E-taxonomy approach will greatly contribute to our knowledge of plant taxonomy and enhance the speed and accuracy of biodiversity and conservation studies by providing plant identifications and classifications automatically thus bypassing the time consuming step of having all plants identified by a limited, and shrinking number of taxonomists. At the same time it can guide classic taxonomic efforts more efficiently by grouping specimens a priory. These groups of specimens can then be studied in detail for taxonomic revisions and species circumscriptions.

Contribution from the Botanical Garden Organization of Thailand to Plant Diversity Studies

Monthon Norsaengsri
The Botanical Garden Organization, Thailand

Abstract

At present, the loss of biodiversity in the world is in the alarming rate due to the high exploitation of the natural resources throughout. The importance of research on biodiversity in the tropical region is still increasing since the later half of 20th century. Southeast Asia is considered as one of the regions having high biodiversity. Unfortunately, the information and knowledge concerning forests and biological diversity are not completely known. The Thai government has realized the problems and put strong efforts to restore the biodiversity in the country. To make the best use of the resource and to obtain a sustainable benefit from them, promotion of research work and propagation of these valuable plants should go hand in hand with environmental conservation.

As a result, the Botanical Garden Organization of Thailand (BGO) was established in 1992 to be responsible for collecting various kinds of plants for planting, studies and propagation, especially rare, endangered and economically important species. Up to present, six botanical gardens have been established all over the country, *viz.* Queen Sirikit Botanic Garden, Chiang Mai; Muang Phon Botanic Garden, Khon Kaen; Rayong Botanic Garden, Rayong; Ban Rom Klao Botanic Garden, Phitsanulok; Phra Maeya Botanic Garden, Sukhothai and Koh Ra Botanic Garden, Phangnga. More than 3,000 species of native Thai plants have been conserved including 30% of Thai Orchids, approximately 400 species, are collected as a living. In addition there are almost 50,000 herbarium specimens, approximately 60% of native Thai species, have been collected for references collection. At least 12 international scientific publications published per year and more than 20 botanical books have been continuously printed.

A general overview of practical contribution from BGO to plant diversity studies will be presented and the need for collaboration is emphasized.

Botanical exploration of Halmahera, North Maluku, Indonesia

Carl E. Lewis
Fairchild Tropical Botanic Garden, USA

Abstract

Fairchild Tropical Botanic Garden has formed a research partnership with the Indonesian Botanic Gardens (Kebun Raya Indonesia), Herbarium Bogoriense, Birdlife Indonesia (Burung Indonesia Halmahera), and Aketajawe-Lolobata National Park to study and collect the plants of Halmahera Island, Eastern Indonesia. Halmahera has an area of 17,780 km^2 and is part of the Wallacea hotspot of biological diversity. In contrast to surrounding islands, the flora of Halmahera is poorly known and poorly represented in herbaria.

Forests on the island are threatened by large-scale mining operations and logging. Objectives of the research partnership are to (1) add to the knowledge of North Maluku biodiversity by collecting new plant specimens and data, (2) contribute to regional plant checklists, and (3) support conservation initiatives. Field study began during July 2011 and yielded more than 500 herbarium specimens for Herbarium Bogoriense, including many that had not been collected previously from the island. We also added more than 100 new species to the living collection of Kebun Raya Indonesia. Additional field and herbarium research, followed by data analysis and conservation planning, are expected to continue through 2014.

Information management of plants in the Taipei Botanical Garden, Taiwan

Huan-Yu Lin
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Abstract

Taipei Botanical Garden was established more than 100 years ago during the Japanese colonial period. Owing to its long history, this garden is rich in plant species, including native species of Taiwan and exotic species collected from the Americas, Europe, Australia, Africa, and Southeast Asia. According to a 1993 survey, 4368 plants, belonging to 440 families and 674 genera, were recorded. Because of the rich collection of living plants, specimens and seeds, a large amount of complicated information has accumulated.

Appropriately managing these collections and displaying data are important for a botanical garden. In order to reach this goal, we have designed a web-based information system, called the "Botanical Garden Network Platform". This system follows the concept of BG-BASE, including functions such as ACCESSION ENTRY, PROPAGATIONS, GERMPLASM, NAMES, etc. To enhance the educational function, it also serves as volunteer management, a photograph warehouse, plant showcases, etc. In addition, this system is executed via Internet Explorer, instead of having to install any programs on a PC.

To assist people in finding a target plant in the garden, we completed an exact spatial survey of all plants in Taipei Botanical Garden in 2006. Each plant was tagged with an ID, Chinese name, and scientific name. The diameter at breast height and TM2 coordinates were also measured. Those data were integrated into the Botanical Garden Network Platform. We thus constructed a website called an "E-Map" to indicate the position of every plant in the garden. When a plant is cultivated, dies, or is removed from the garden, this information will accordingly be recorded in the system. To 2011, 4654 individuals, belonging to 171 families, 585 genera, and 1035 species, in the exhibition area have been tagged and recorded. This system provides useful plant information to managers and researchers.

A web-based and multi-user database system, executed with a built-in web browser, is simple and effective for users. However, correct information depends on effective management workflow and an immediate data-updating mechanism. Therefore, systematizing the management of Taipei Botanical Garden will continually be implemented to promote the function of the Botanical Garden Network Platform.

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