Journal of Botanic Gardens Conservation International

BGjournal

Volume 13 • Number 1 • January 2016

Early warning systems for plant health

The role of botanic gardens

BGCI
Plants for the Planet

BGjournal Volume 13 • Number 1

Cover Photo: Longhorn beetle (Shutterstock.com)

Design: Seascape www.seascapedesign.co.uk

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

Further details available from:

- Botanic Gardens Conservation International, Descanso House, 199 Kew Road, Richmond, Surrey TW9 3BW UK. Tel: +44 (0)20 8332 5953, Fax: +44 (0)20 8332 5956 E-mail: info@bgci.org, www.bgci.org
- BGCI-Russia, c/o Main Botanical Gardens, Botanicheskaya st., 4, Moscow 127276, Russia. Tel: +7 (095) 219 6160 / 5377, Fax: +7 (095) 218 0525, E-mail: seed@aha.ru, www.bgci.ru
- BGCI-Netherlands, c/o Delft University of Technology Julianalaan 67, NL-2628 BC Delft, Netherlands Tel: +31 15 278 4714 Fax: +31 15 278 2355 E-mail: l.j.w.vandenwollenberg@tudelft.nl www.botanischetuin.tudelft.nl
- BGCI-Canarias, c/o Jardín Botánico Canario Viera y Clavijo, Apartado de Correos 14, Tafira Alta 35017, Las Palmas de Gran Canaria, Gran Canaria, Spain. Tel: +34 928 21 95 80/82/83, Fax: +34 928 21 95 81, E-mail: jmlopez@grancanaria.es
- BGCI-China, 723 Xingke Rd., Guangzhou 510650 China. Tel:(86)20-85231992. email: Xiangying.Wen@bgci.org www.bgci.org/china
- BGCI-Colombia, c/o Jardín Botánico de Bogotá, Jose Celestino Mutis, Av. No. 61-13 – A.A. 59887, Santa Fe de Bogotá, D.C., Colombia. Tel: +57 630 0949, Fax: +57 630 5075, E-mail: jardin@gaitana.interred.net.co, www.humboldt.org.co/jardinesdecolombia/html/la_red.htm
- BGCI(US) Inc, c/o Chicago Botanic Garden, 1000 Lake Cook Road, Glencoe, Illinois 60022, USA. E-mail: usa@bgci.org, www.bgci.org/usa

BGCI is a worldwide membership organisation established in 1987. Its mission is to mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet. BGCI is an independent organisation registered in the United Kingdom as a charity (Charity Reg No 1098834) and a company limited by guarantee, No 4673175. BGCI is a tax-exempt 501(c)(3) non-profit organisation in the USA and is a registered non-profit organisation in Russia.

United Nations Decade on Biodiversity

EDITORIAL:
TREE AND PLANT HEALTH EARLY WARNING SYSTEMS - THE ROLE OF BOTANIC GARDENS

Invasive alien plant pests and diseases can cause long term economic, environmental and social impacts both presently and as witnessed by events in the past. This includes epidemics such as potato late blight (*Phytophthora infestans*) in the 1840s leading to 750,000 hunger related deaths across Europe (Zadoks, 2008) and Dutch elm disease outbreaks in the 1920s (*Ophiostoma ulmi*) and, more dramatically, in the 1970s caused by *Ophiostoma novo-ulmi* (Brasier & Gibbs, 1973). Currently, we are faced by pests such as emerald ash borer (Agrilus planipennis); and diseases such as ash dieback (*Hymenoscyphus fraxineus*) and the bacterial pathogen *Xylella fastidiosa*, to name just a few. The threats to plant biosecurity have increased with the globalisation in trade and travel which has resulted in increased volume and diversity of plants and plant products moving worldwide (Brasier, 2008). Predicted climate change effects may also increase the risk of pest and disease establishment, spread and impact, and may influence the conditions under which previously benign pests and diseases are able to develop and cause damaging impacts (Defra, 2014). Safeguarding plant health is a key priority for National Plant Protection Organisations (NPPOs) balancing the safeguarding of plant biosecurity whilst enabling sustainable economic growth. NPPOs use risk-based decision-making to identify and target those organisms of the highest risk and ensure intervention to protect plants is proportionate and targeted to make the best use of resources available. This risk assessment process is fuelled by scientific information about alien pests concerning aspects such as host range, geographical distribution, pest biology, damage and control strategies. Evidence gaps increase the level of uncertainty when determining the threat of any alien pest or disease.

In recent times, many of these incursions have damaged plants closer to home, impacting many citizens as they affect parks, gardens and the green infrastructure of urban environments. This proximity has motivated people to become more aware of the threats to the natural capital of their surroundings and a desire for its protection. Some NPPOs have recognised the opportunity to harness this shared ambition to help protect the natural environment. Engaging the public and voluntary sectors has gathered momentum in the past few years, although relatively speaking it is still in its infancy.

Botanic gardens and arboreta have a vital role to play as custodians of outstanding scientific collections of a wide range of plants, frequently growing outside their natural geographical origin. By developing pest and disease surveillance skills and capability they can help in gathering evidence needed for analysing the risk a pest poses to plant species around the world, whilst improving their own understanding of the pests and diseases that threaten their collections. This capability, appropriate pest and disease surveillance tools and reporting mechanisms to NPPOs have the potential to become an invaluable part of any country's plant health early warning system. Heightened awareness of plant biosecurity is not only beneficial to the staff and collections but also provides an excellent platform for raising awareness and encouraging good plant biosecurity practice with partners and visitors. However, opportunities to achieve this shared ambition of better plant biosecurity by both botanic gardens and arboreta and NPPOs are strengthened by initiatives such as the International Plant Sentinel Network.

- Brasier, C.M. 2008. The biosecurity threat to the UK and global environment from international trade in plants. Plant Pathology **57**: 792 808.
- Brasier, C.M. & Gibbs, J.N. 1973. Origin of the Dutch elm disease epidemic in Britain. Nature **242**: 607-609.
- Defra. 2014. Protecting plant health- a plant biosecurity strategy for Great Britain.
- Zadoks, J.C. 2008. The potato murrain on the European continent and the revolutions of 1848. Potato research. **51**: 5-45.

Dr Charles Lane,
Consultant plant pathologist, Fera
EUPHRESCO IPSN project leader

MESSAGE
FROM BGCI'S SECRETARY GENERAL

Dear *BGjournal* Reader,

Over the past few months we have been reviewing many facets of BGCI's work, including our publications, and I wanted to alert you to some changes that we will make to the next edition of *BGjournal* which will be published in July.

The feedback we have received from BGCI members is that the approach we have taken over the past few years focusing on particular topics, such as tree conservation, seed conservation and plant health (this issue) is valuable to botanic garden professionals. For this reason, we will keep this focused approach, and our next edition in July will focus on the practice of ecological restoration as practised by the botanic garden community.

However, we also recognize that by focusing on a particular topic, *BGjournal* may have limited appeal to readers who don't work in that discipline. For this reason, we will start to trial a series of regular features with broader appeal in the next issue. These will include:

- A featured garden – with a particular focus on small gardens
- A Photo Gallery of images of plants, landscapes, gardens and people
- News – with a focus on important developments affecting botanic gardens
- Resources available to BGCI members
- Training courses
- Interviews with botanic garden staff
- Plant hunting and plant conservation stories

As always, we welcome your feedback and any other suggestions for regular items that we could include in *BGjournal* or in *Roots*.

Many thanks,
and happy reading!

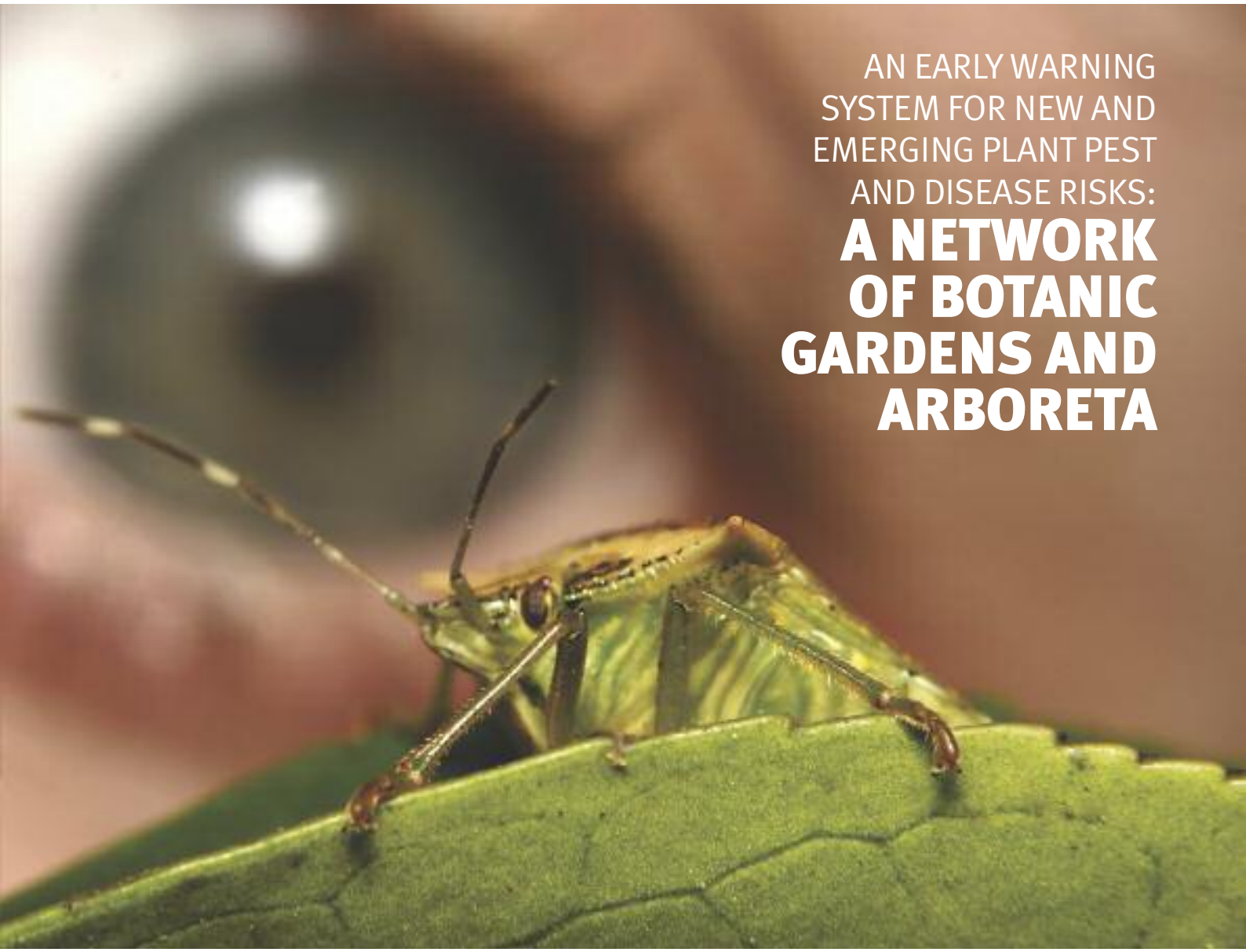
Dr Paul Smith
BGCI Secretary General

Missouri Botanical Garden (BGCI)

Red palm weevil (Chris Malumphy, Fera)

Bluebells flowering in UK woodland

Author: Ellie Barham



AN EARLY WARNING SYSTEM FOR NEW AND EMERGING PLANT PEST AND DISEASE RISKS: A NETWORK OF BOTANIC GARDENS AND ARBORETA

The plant collections of the world's botanic gardens and arboreta include more than one third of known plant species – a unique resource to support global plant health.

International Plant Sentinel Network

Introduction

In a previous edition of BGjournal Kramer and Hird (2011) discussed the potential role that botanic gardens and arboreta can play in plant health research. The authors discussed a survey of botanical institutes with plant collections which identified an existing presence of expertise and resources related to plant health and biosecurity. However, over half of the institutes surveyed identified a need for training in all areas regarding entomology, mycology and plant pathology. Further to this, it was concluded that with coordination and support, existing efforts could be leveraged to provide valuable data which could be used to help safeguard plant health on a local, regional and global scale.

The International Plant Sentinel Network (IPSN) has been developed in order to provide this support. The network provides training and coordination; including developing and providing links to resources and expertise, facilitating global surveys, identifying potential collaborations and sharing information. The IPSN is now coming to the end of its 3 years of initial funding, and is

looking to further its work by utilising the power of the network to provide key information for plant health scientists and National and Regional Plant Protection Organisations (NPPO & RPPO).

The threat

In recent years, the globalisation of trade and the ever-increasing effect of climate change have resulted in an increase in invasive plant pests and pathogens which have caused large scale damage to native flora. These organisms pose one of the greatest threats to ecosystems and biodiversity worldwide, whilst also bearing heavy economical costs (Aukema *et al*., 2011, Tomoshevich *et al*. 2013). Further to this, trees and forests have high social and cultural significance and provide important (and unique) ecosystem services, all of which are at risk of being lost (Aukema *et al*., 2011, see box 1).

Much regulation surrounding plant health relies on inspecting for known organisms at export and import points. Pest Risk Analysis (PRA) is required in European countries to determine if an organism should be listed as a pest, if it should be regulated and the strength of any phytosanitary measures imposed (Baker *et al*., 2009). PRA is a relatively new science which relies on the gathering and analyses of scientific and economic evidence, which can be a lengthy and work-heavy process. Often, particularly for new and emerging pests, the information required just does not exist, partially exists (e.g. gaps in knowledge), has not been verified or exists in a form not freely available to PRA scientists (e.g. in a different language). All of this can severely hamper any PRA efforts.

Photographing scale insects in China

Prevention rather than cure

Prevention is arguably the best management option available to plant health regulators and scientists, both environmentally and economically (MacLeod *et al*., 2002). However, the majority of temperate forest pests that have caused outbreaks in recent years were either unknown to science or not known to be pests before damage was recorded (Kenis *et al*., 2011). This is largely due to a lack of evolved resistance by new hosts and/or as a result of an absence of natural enemies, which would typically control numbers to a manageable level (Tomoshevitch *et al*., 2013). This makes predicting which organisms could become invasive in the future a difficult task; a significant issue in plant health regulation. The IPSN aims to utilise plant sentinels in order to address this issue and provide early warning of such organisms.

Participants at the IPSN and Huntington Botanical Gardens Workshop (Abby Hird)

Sentinel Plants

Sentinel research involves monitoring and surveying plants maintained outside of their natural ranges that are exposed to native pests and diseases. Monitoring and surveying these exotic plants for damage can help to provide anecdotal evidence of potential future threats (Britton *et al*., 2010). This initial identification can help to focus the efforts of scientists to study these organisms further and aid plant protection efforts at a regulatory level (for example within PRAs).

Box 1: European ash and ash dieback

European ash, *Fraxinus excelsior*, is a key and abundant native species in many countries throughout the region; it is the third most common tree species in the UK (Woodland Trust, 2016). As a result European ash is an environmentally, economically and socio-culturally important species. It has a high commercial value and is used for tools, hardwood floors and sports equipment, it has significance in Norse mythology, and it plays a keystone role for many important ecosystems across Europe. It is a key species in riparian areas, particularly in floodplains and often acts as a pioneer species in the restoration of forest habitats from grassland. Further to this, it is a common species in hedgerows, field margins, private and public gardens and urban spaces; supporting high levels of biodiversity from lichen and fungi, to invertebrates and birds, some of which are specific to ash and could face extinction upon its destruction. Therefore the loss of ash in Europe would have a cascading effect on the biodiversity and habitats it supports (Pautasso *et al*., 2013).

Hymenoscyphus pseudoalbidus (or *Chalara fraxinea*, its asexual form), commonly known as ash dieback, is currently spreading across Europe devastating European ash populations (Halmschlager & Kirisits, 2008). Unlike many pathogens, ash dieback kills trees of all ages, from saplings to ancient trees, regardless of surrounding conditions and health before infection (Kowalski *et al.*, 2006). Although it kills younger trees quite quickly, it is likely that the full extent of damage by ash dieback will not be revealed for another 40 years or so, when its effects on ancient trees (which take much longer to die) become obvious. Due to this, and ash's ecological importance, ash dieback poses a significant conservation challenge in Europe. As a result, it requires collaboration between experts from a diverse range of fields and countries to tackle the approaching challenges (Pautasso *et al.*, 2013).

IPSN workshop at the Royal Botanic Gardens, Kew

Sentinel research also offers the chance to address knowledge gaps for organisms suspected to be potential threats to plant health, which is particularly important in the creation of PRAs. Research can increase our understanding regarding an organism's biology, life history and identify its natural predators which could suggest potential biological controls. Further to this, it can reveal further pest-host associations, identifying which plant species are susceptible and to what degree they are affected. All of this information is important in creating appropriate PRAs, and reliably assessing the risk they pose. In addition, information can aid and drive the creation of robust and viable management practices, including eradication, containment or, preferably, prevention.

Botanic gardens and arboreta

With over 2,500 botanic gardens and arboreta around the world playing host to an estimated one third of all known plant species, these institutes provide the perfect setting for sentinel research. These collections hold exotic species of all ages (from the newly planted to the ancient), are well documented (histories, previous management and origin) and well managed (monitored daily and kept healthy, eliminating the potential for damage to have an abiotic cause). Further to this, their staff are well-trained, knowledgeable, passionate people who work with the plant collections on a daily basis and are able to recognise, monitor and record changes in plant health, as discussed by Kramer & Hird (2011).

The range and spread of these gardens also allows research to be carried out on an international scale. With the increased globalisation of trade being a major pathway for the introduction and spread of invasive pests and pathogens (Britton *et al*., 2010), tackling these issues on a global scale is crucial to success. Since its launch in 2013, the IPSN has worked hard to ensure international participation from a wide range of organisations.

An international network

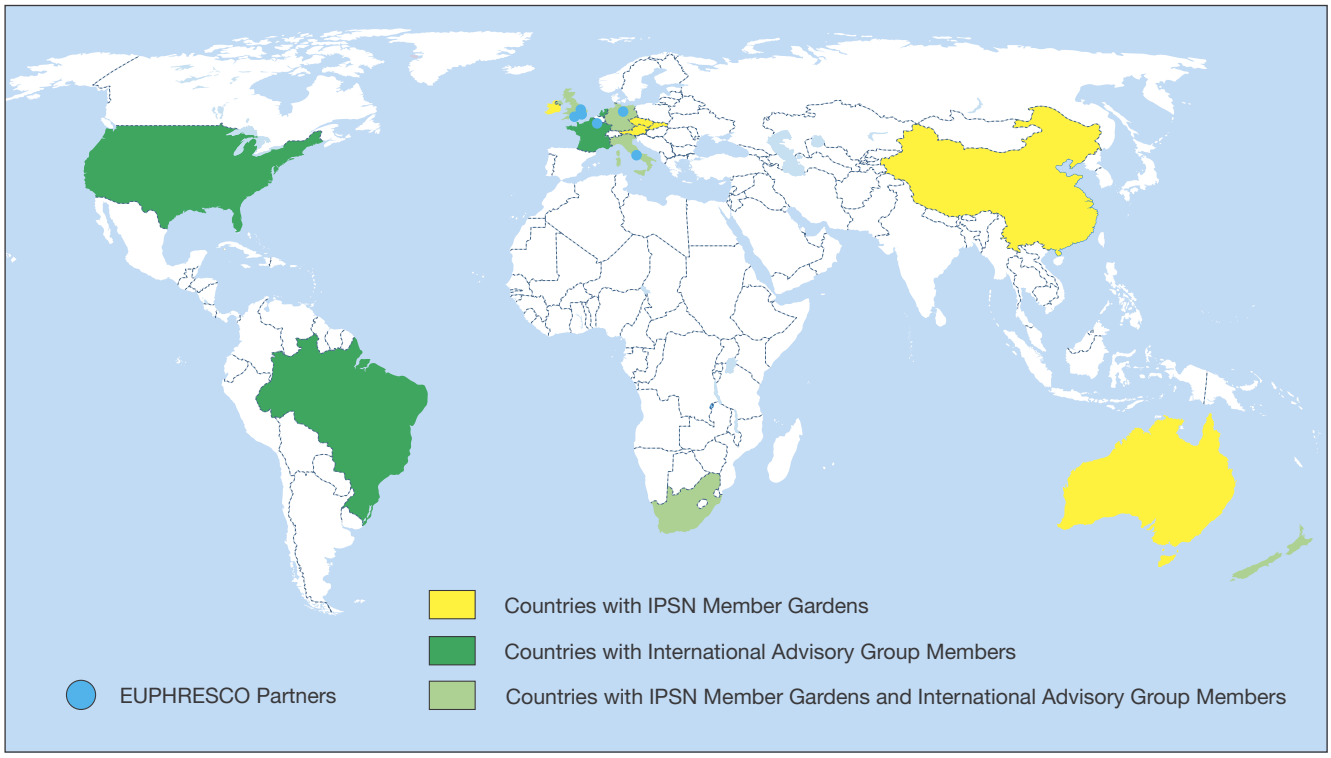
The IPSN is part of a EUPHRESCO[1] project which in the UK is funded by the Department for the Environment, Food and Rural Affairs (Defra) and is led by Fera, with CABI-UK and Forest Research (UK). Other EUPHRESCO partners are the Julius Kühn-Institut (Germany), the Plant Protection Services (Netherlands) and the Department for Innovation in Biological, Agro-food and Forest systems, University of Tuscia (Italy). The IPSN, which includes additional botanic garden and arboretum partners (see map) is, and will continue to be, coordinated by BGCI. BGCI manages two unique databases that contribute to IPSN activities. GardenSearch, a global database of all known gardens listing key information such as significant collections, location (country, region, GPS coordinates) and contact details, all of which can be used to identify gardens in areas of interest. PlantSearch, a global database cataloguing living plant, seed and tissue collections of gardens, allows the location of particular species in countries around the world to be identified. Both of these tools can be used to help identify, facilitate and drive research. For example, studying the susceptibility of *Fraxinus* spp. to ash dieback, GardenSearch can help identify gardens in areas where the pathogen is present and PlantSearch can be used to identify gardens with a diversity of *Fraxinus* spp. in their collections.

> *"IPSN member gardens are located in countries around the world."*

So far, the IPSN has participation from 26 gardens from countries around the world (see map). In addition to its EUPHRESCO partners, the network is guided by an International Advisory Group; leading experts in their field from across the world including Europe, the U.S.A (the APGA Sentinel Plant Network), South Africa and New Zealand. A full list is available at www.plantsentinel.org/international-advisory-group. Many of these individuals and organisations were or are involved in existing sentinel research projects and thus provide unrivalled guidance and support to the development of the IPSN.

Participants at the IPSN and Shenzen Fairylakes Botanical Gardens workshop (Hui Dong, FLBG)

[1]www.euphresco.org



IPSN resources and training

The IPSN aims to build capacity and capability in botanic gardens and arboreta in order to support surveying and good biosecurity practise. Since its launch the IPSN has run a number of workshops, hosted by engaged botanic gardens; including workshops at Shenzhen Fairy Lakes Botanical Gardens (China) (see p. 16-19), Huntington Botanical Gardens (U.S.), Royal Botanic Gardens, Kew (UK) and the Yorkshire Arboretum (UK). All of these gardens already have experience in surveying and pest identification, and were able to share examples of best practises with attendees. Establishing links between organisations, including botanical institutes, is another key component in the work of the IPSN.

The IPSN website (www.plantsentinel.org) supports a host of training materials. This includes examples of best practise, comprehensive guides to damage, posters, forums, and links to external databases, resources and information from around the world (see p. 31-32).

Resources include tools to aid surveying work, most notably an IPSN developed surveying tool called the Plant Health Checker (see p. 33-36). This form enables users to check for, record and then make a logical decision regarding 'next steps' for infected and damaged plant specimens in their collection. Through using this standardised approach, e.g. listing all the signs and symptoms that are indicative of a biotic cause, alongside the training documents that accompany the form, it is hoped staff will become familiar with such warning signs and become constantly on the lookout. The form's creation involved collaboration from leading diagnostic scientists alongside botanic garden staff such as the Yorkshire Arboretum (UK), whose involvement is discussed further on page 9-11, and the Core Facility Botanical Garden at the University of Vienna (Austria).

The future of the IPSN

The IPSN is coming to the end of its initial 3 years of funding, in which time it has established a global network of participants and developed a potential infrastructure for monitoring and surveying. The next phase of the IPSN will be to utilise these resources and provide meaningful data to plant health regulators that can ultimately help conserve plant species from new and emerging plant health risks. A key part of this work will be to continue to provide support, guidance and training to botanic gardens and arboreta. This will aid staff, volunteers and students in collecting data; providing evidence to address research gaps and identify potential future threats.

Illustrating damage by the goldspotted oak borer (Abby Hird, BGCI)

The IPSN is currently in the pilot phase of developing an online reporting system and a supporting public-facing database. This work is being led by CABI; a not-for-profit research and publishing organisation that focuses on international development. CABI has much experience in this area having previously developed the CABI compendia, inventories of datasheets for known pests, and the Plantwise Knowledge Bank, a diagnostic tool to aid farmers in hard to reach regions. The IPSN previously facilitated a link between CABI's open-access Invasive Species Compendium and BGCI's PlantSearch database, to guide users to the major threats for a given plant species. This new reporting system aims to build on this, potentially further linking existing databases, and providing an easy and user-friendly tool for staff to

Discoloured needles as a result of Dothistroma needle blight

aid in the collection of surveying data. The system will simplify and aid data collection whilst providing data storage for results; allowing gardens to access and manage previously uploaded records to track the progress of any damage. The front-facing database will also help plant health scientists to identify and track any reports, signs, symptoms or organisms of concern, and provide a way to identify patterns of symptoms, spread and host species.

Ultimately, the IPSN aims to create a viable and robust network that will be championed by BGCI; it is included in its 5-year strategic plan, but led by its key stakeholders. This includes botanic gardens and arboreta alongside National Plant Protection Organisations, Regional Plant Protection Organisations and plant health scientists.

To find out more about the IPSN, including how to get involved, please go to www.plantsentinel.org

References:

- Aukema, J.E., Leung, B., Kovacs, K., Chivers, C., Britton, K.O., Englin, J., Frankel, S.J., Haight, R.G., Holmes, T.P., Liebhold, A.M. and McCullough, D.G., 2011. Economic impacts of non-native forest insects in the continental United States. *PLoS One*, 6(9), p.e24587.
- Baker, R. H. A., Battisti, A., Bremmer, J., Kenis, M., Mumford, J., Petter, F., Schrader, G., Bacher, S., De Barro, P., Hulme, P. E., Karadjova, O., Lansink, A. O., Pruvost, O., Pyšek, P., Roques, A., Baranchikov, Y. and Sun, J.-H. 2009. PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union. EPPO Bulletin, 39: 87–93. doi: 10.1111/j.1365-2338.2009.02246.x
- Britton, K.O., White, P., Kramer, A. and Hudler, G., 2010. A new approach to stopping the spread of invasive insects and pathogens: early detection and rapid response via a global network of sentinel plantings. *New Zealand Journal of Forestry Science*, **40**: 109-114.
- Halmschlager, E. and Kirisits, T., 2008. First report of the ash dieback pathogen Chalara fraxinea on *Fraxinus excelsior* in Austria. *Plant Pathology*, **57**(6): 1177.
- Kenis M., Roques A., Sun J. H., Fan J. T., Kirichenko N., Baranchikov Y., Tomoshevich M., Yart A., Holmes K. & Péré 2011. PRATIQUE Enhancements of pest risk analysis techniques.
- Kowalski, T., 2006. *Chalara fraxinea* sp. nov. associated with dieback of ash (*Fraxinus excelsior*) in Poland. *Forest Pathology*, **36**(4): 264-270.
- Kramer, A. and Hird, A., 2011. Building an international sentinel plant network. *BGjournal,* **8***:* 3-6.
- MacLeod, A., Evans, H.F. and Baker, R.H.A., 2002. An analysis of pest risk from an Asian longhorn beetle (*Anoplophora glabripennis*) to hardwood trees in the European community. *Crop Protection*, **21**(8): 635-645.
- Pautasso, M., Aas, G., Queloz, V. and Holdenrieder, O., 2013. European ash (*Fraxinus excelsior*) dieback–a conservation biology challenge. Biological Conservation, **158**: 37-49.
- Tomoshevich, M., Kirichenko, N., Holmes, K. and Kenis, M., 2013. Foliar fungal pathogens of European woody plants in Siberia: an early warning of potential threats?. *Forest Pathology*, **43**(5): 345-359.
- Woodland Trust. 2016. https://www.woodlandtrust.org.uk/visiting-woods/trees-woods-and-wildlife/british-trees/native-trees/ash/ - accessed 10 January 2016.

Ellie Barham
Botanic Gardens Conservation International, 199 Kew Road, Richmond, TW9 3BW, UK
ellie.barham@bgci.org

Author: John Grimshaw

TREE HEALTH, IPSN AND THE YORKSHIRE ARBORETUM

The Yorkshire Arboretum has provided a test site for the International Plant Sentinel Network (IPSN) and is involved with other initiatives to monitor the spread of pests and diseases.

Introduction

In the face of current unprecedented threats to trees from novel pests and diseases, botanic gardens have a frontline role to play in monitoring their presence and spread. Collections are under regular scrutiny by staff, records are often detailed, and they form part of a wider scientific network. In addition, such gardens are often able to maximise possibilities for crowd-sourced data collection ('citizen science'), using their reputation to recruit volunteers while their facilities can be used for training or, importantly, public engagement. Occupying 48 ha of former parkland on the Castle Howard estate, North Yorkshire, UK, and with a satellite 10 ha woodland garden in Ray Wood adjacent to Castle Howard 1 km away, the arboretum was founded in 1979.

The collection comprises a wide range of hardy trees and shrubs including native species and the former forestry trees that were on the site previously. The garden in Ray Wood has a diverse collection in its own right, notably of *Rhododendron*. Approximately 35% of the total collection is of known wild origin.

Pests and diseases

In the North Yorkshire countryside several important tree diseases are easily observed: the continuing presence of Dutch elm disease *Ophiostoma ulmi* affecting regenerating elms *Ulmus* spp.; the seldom-mentioned *Phytophthora alni* causing massive die-off of alder *Alnus glutinosa* along watercourses; and Ash dieback *Hymenoscyphus fraxineus* which is becoming ever more established throughout the area. In addition there are

The Yorkshire Arboretum Director testing plant material for Dothistroma needle blight

usually non-fatal but damaging diseases such as poplar cankers, willow anthracnose *Drepanopeziza sphaerioides* and powdery mildew *Erysiphe alphitoides* on native oaks (*Quercus robur, Q. petraea*) that are so familiar that they no longer arouse comment. Dothistroma needle blight *Dothistroma septosporum* is well established, and the arboretum has had to fell many interesting but badly affected pines in consequence. *Phytophthora ramorum* has been found a few kilometres

away but fortunately has not yet appeared in the vicinity of the arboretum, where old larch plantations would be at risk. However the less familiar (and less problematic) *P. cambivora* and *P. plurivora* have both been found on beech within the collection.

In addition to these major and widespread diseases the arboretum hosts other organisms of interest and concern. European Mountain Ash Ringspot-associated Virus (EMARAV) is present on *Sorbus*, and has previously only been identified in the United Kingdom at RBG Kew and in the Highlands of Scotland. However, since its discovery in the arboretum it has now been looked for and found on *Sorbus* elsewhere in North Yorkshire, an example of how the more detailed observations possible in a collection can be used to stimulate investigation elsewhere. Dieback of branches of the St Lucia Fir *Abies bracteata* was eventually traced to the fungus *Allantophomopsis pseudotsugae*, but a slow decline leading to death in *Zelkova* species has yet to be identified. We have not suffered any novel problems with insect pests in the past four years, but it is worth mentioning that the greatest threat to the collection and successful establishment of many taxa comes from the Grey Squirrel *Sciurus carolinianus*, a reminder of the diversity of threats faced by trees.

International Plant Sentinel Network

Fera is located at Sand Hutton near York, only 13 km away from the arboretum, along with the UK Government's Animal and Plant Health Agency (APHA). Professor Nicola Spence, Chief Plant Health Officer, is a trustee of the Yorkshire Arboretum and through her, and by making contact with key members of the Fera tree pathology team such as Dr Charles Lane, Consultant Plant Pathologist, we have developed an excellent relationship with the plant health community there. Our diverse collection of trees makes the arboretum an ideal site for workshops and field studies, while also providing samples of pathogens of interest – the *Allantophomopsis* and *Zelkova* problems mentioned above being key examples.

One of the team based at Fera is Ellie Barham, an employee of BGCI who is the Coordinator for the International Plant Sentinel Network (IPSN), a three-year EUPHRESCO project funded by the UK's Defra. The IPSN aims to create links between botanic gardens and arboreta around the world and the wider plant health community. The network will utilise the many eyes of the botanic gardens' staff and volunteers to observe and report tree diseases present in collections. This information can be used by the plant health community to take prompt action to prevent pest and disease introduction and spread. In 2014, following previous contact through the OPAL Tree Health initiative (a UK Citizen Science project), Ellie asked us to become active members of IPSN and to take part in developing the reporting system.

> *"A number of workshops were held at the Yorkshire Arboretum with prototype recording sheets, resulting in refinements to the IPSN system."*

The end result, the IPSN Plant Health Checker (available for both broad-leaved and coniferous trees) provides a way of assessing a tree's state of health. It uses a two-step 'traffic light' system: green indicates normal health, amber a situation that requires follow-up and red is a warning that something is evidently very wrong (An example of the plant health checker can be found on page 33-36).

Step 1, the initial assessment, is intended to be undertaken by non-specialist volunteers who can give the tree an inspection, and flag up any obvious

issues using the traffic light system. The trial of the proforma with our volunteer teams revealed misunderstandings in terminology, and the need to ensure that volunteers are familiar with technical terms; knowledge cannot be assumed. If there are evident problems with the tree, the system escalates to Step 2, where a more experienced observer can undertake a more detailed assessment, perhaps leading to the submission of samples for diagnosis, or recognition of a known problem.

The person surveying the tree in Step 2 should ideally be familiar with the species and individual specimen. The importance of this became clear during the development work done at the arboretum. Assessment of a tree requires a reasonable understanding of healthiness as a baseline position, against which symptoms of ill health can be compared. Curatorial personnel will often have intimate knowledge of the specimen, together with an understanding of the conditions in which it is growing. Many symptoms of poor health do not have pathogenic origin. For example a late frost can kill new shoots; poor planting,

IPSN diagnostic training at the Yorkshire Arboretum

Fera mycologist and arboretum volunteer looking for signs of disease

compaction or waterlogged soil can cause unthrifty growth; deficiency diseases present frequently; some taxa struggle in unsuitable conditions, and glyphosate can have very unusual effects. Such curatorial experience can greatly aid understanding regarding a dubious symptom.

There remains the issue of what to do about a diseased tree. Amber on the Plant Checker System suggests watching and waiting, revisiting later in the season or the following year to monitor any development of problems, but when there is an evident critical problem, what should the curatorial decision be? The main objective of the IPSN is to know what pests and diseases are causing damage and thus are potential threats, so diagnosis should always be the next step. This is essential if we are to understand and tackle the problem of tree disease. Once a diagnosis has been made a decision needs to be taken on the infected tree's future. At the Yorkshire Arboretum we often have interesting discussions with our friends from Fera, who would like to study an infected tree for its 'nice' pathology, while our aim is to keep the collection as healthy as possible through its removal.

The major difficulty with the IPSN for us, and probably for other participating gardens, is finding the time and personnel to undertake the surveys amongst a busy workload and limited staff. Volunteers are one answer, but they require training and Step 2 requires staff input. Information on paper forms needs transcribing into the IPSN electronic record-keeping system, a labour intensive task. We are looking forward to trialling an electronic version of the Plant Health Checker, developed by CABI, which uses a tablet to enable direct recording in the field, downloadable direct to the IPSN database. This online form will also comprise guidance and help in order to support surveyors, which will also help ease the process.

Other initiatives and training

In collaboration with Fera and APHA the Yorkshire Arboretum has also been active in other areas of plant health science and public awareness. Our collection of *Dothistroma*-infected pines has been used as the basis of a volunteer project, trialling the GENIE system for rapid, in-field genetic tests, and as a pilot for spectroscopy tests measuring the coloration of infected and healthy trees as a rapid survey technique. An international group of nematologists visited last year, and fortunately found nothing of significance. In 2015 the arboretum was used to host training sessions of volunteers for the Observatree initiative, which uses citizen science through a nationwide cohort of observers who monitor woodlands for pests and diseases, with some notable successes to date. An APHA-led event during the October half-term holiday raised public awareness of tree health problems, especially through the deployment of realistic but gigantic insect models in the arboretum. This was well received by children and their parents – a similar event will be repeated this year.

Conclusion

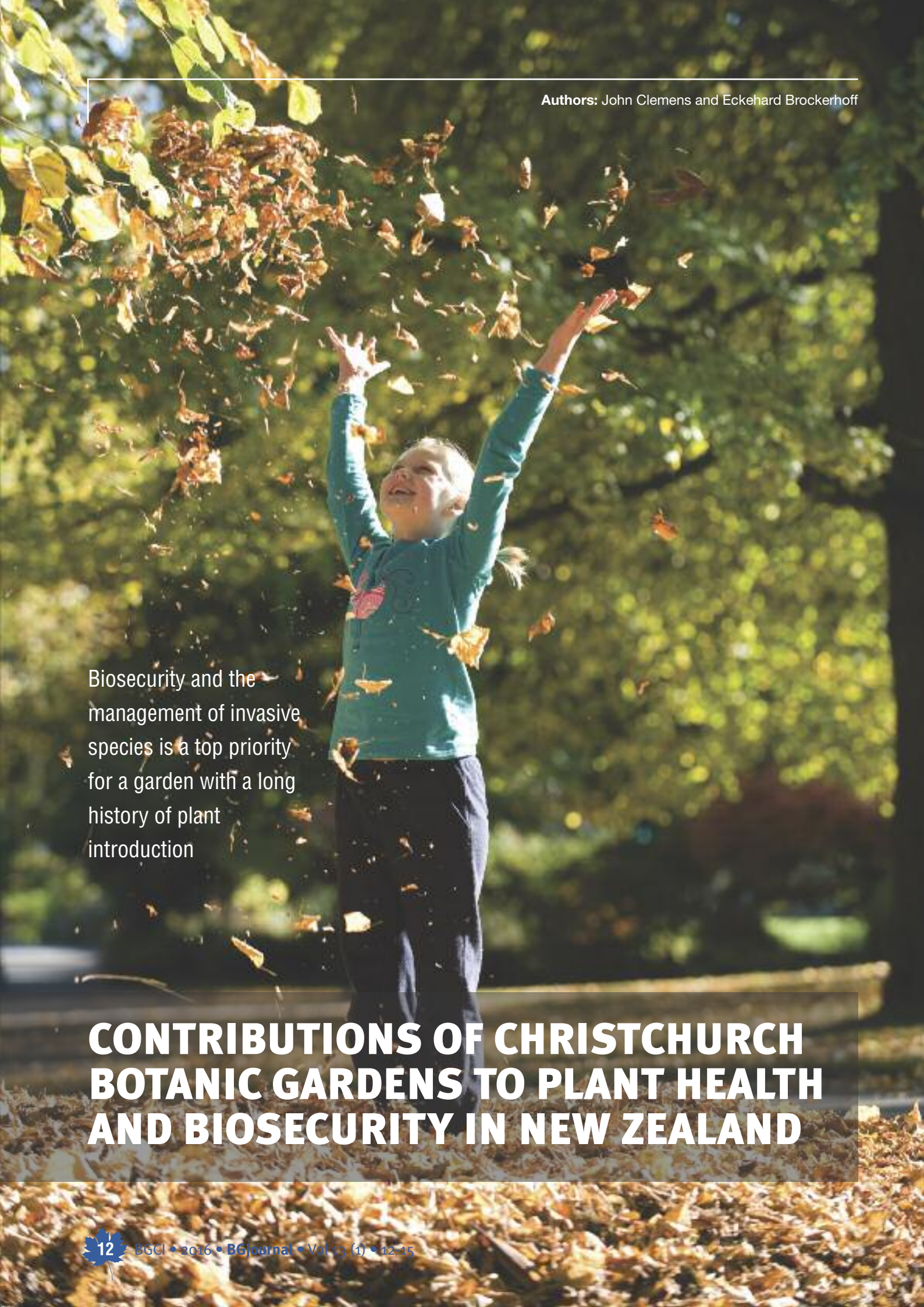
The IPSN has recognised that the staff and volunteers in botanic gardens, arboreta and other public collections are very well placed to undertake observations on tree health that can act as a warning to the wider world. This could enable action to be taken before a problem becomes too widespread; citizen science also has a hugely important role to play in tackling this international concern.

We see our connection with the IPSN and other initiatives as part of our scientific remit and an area in which we can make a contribution that is not overly taxing on an organisation with limited resources of either time or finances, but has a unique resource in its diverse collection of trees. We are all at the frontline in the battle with pathogens, and our collections should be used for the benefit of all. Not only can we monitor diseases, but we can also discover which trees are resistant or less susceptible, making diverse collections particularly important. For example, we have over thirty taxa of *Fraxinus* in the collection and monitoring these for health in the time of ash dieback may have significant consequences for the replacement of trees lost from the landscape due to this disease.

Botanic gardens have a huge role to play in stimulating public and governmental awareness of plant pests and diseases, which are at their most conspicuous when affecting trees. We can also mobilise citizen scientists to undertake monitoring of tree populations both on site and in the wider landscape, and engage with professional pathologists, which requires a coordinated approach. A further step might be the production of best practice guidelines for biosecurity in botanic gardens, or on how to deal with diseased plants present in a collection. As a community we could do a lot more.

Dr John M Grimshaw FLS
Director, The Yorkshire Arboretum
The Yorkshire Arboretum, Castle Howard, York YO60 7BY

Authors: John Clemens and Eckehard Brockerhoff



Biosecurity and the management of invasive species is a top priority for a garden with a long history of plant introduction

CONTRIBUTIONS OF CHRISTCHURCH BOTANIC GARDENS TO PLANT HEALTH AND BIOSECURITY IN NEW ZEALAND

Introduction

The 21 ha Christchurch Botanic Gardens is part of a 9,000 ha parks network throughout urban and wilder areas of Christchurch. In the past the Botanic Gardens have been the centre for numerous plant introductions, including the unintentional importation of some that might have become invasive plants, plant pests and pathogens. In recent decades the Botanic Gardens have worked with several other agencies to protect our biodiversity and to educate our visitors about conservation, care for the environment, and plant health in the city and beyond.

The primary goal of the Botanic Gardens is to help visitors appreciate and understand the plant world. As resources permit, we mount activities under the banners of display, education, research and conservation, guided by the targets of the Global Strategy for Plant Conservation. Biosecurity and the management of invasive species is therefore a top priority in a country that has a history of having to deal with past invasions and protecting against new ones (Allen & Lee, 2006).

The Botanic Gardens are in a strong position to address global challenges of conservation and biosecurity. Their governance means their influence extends outside the core 21 ha of its grounds into the wider city parks network. They have wide cultural and biological diversity, and the expertise of collaborators in universities and government research and biosecurity organisations nearby. In addition, the million plus visitors who visit the Botanic Gardens annually have the opportunity to learn about important biosecurity messages and potentially to contribute to biosecurity surveillance and response.

Plan of the 1887 arboretum (circled) within the Botanic Gardens in the shape of a 'pie chart'. Each "slice" was dedicated to trees of a different continent.

Many 'worlds' in one place

Botanic gardens cast in the colonial mould have typically brought together plants from many continents, not just to delight visitors, but to reflect civic pride and economic development. Such gardens were built on the translocation of indigenous plants from other lands (McCracken, 1997). In the 1880s, Christchurch Botanic Gardens had a "pie chart" arboretum with each slice dedicated to growing trees from a different continent (see image below).

Bringing plant worlds together and redistributing new plants to the colonial public was fettered only by the price and availability of propagating material. However, the seeds, cuttings, budwood, whole plants and soil in which they were grown, along with the mud on the boots of those transporting them brought pests, diseases and benign associates of other lands.

> *"Colonial gardens became not so much botanic decorations as intimate mixtures, microcosms of the world's biodiversity, synthetic ecosystems where the imported mingled with the local wildlife."*

A snap 24-hour survey in 2005 to raise public awareness of biodiversity (termed a BioBlitz) found around 1,200 different organisms living wild in our Botanic Gardens and the surrounding Hagley Park, over a third of which were introductions from overseas. The species list included 100 species of annelids, mites and insects, 300 bacteria, 100 algae, 23 freshwater invertebrates, almost 300 plant species, and 79 fungi. Although most of these are overlooked or unseen by the public, some of the fungi associated with introduced vegetation are favoured by local collectors. The most popular target is the cep or penny bun (*Boletus edulis*), introduced with oak trees by early settlers from the UK (Cooper, 2012).

Many fungi form beneficial associations with our plants, e.g. mycorrhizal species, or are needed for plant establishment and survival, e.g. fungi supporting the

Collaborating scientists work into the night alongside the public to identify plants during a BioBlitz. Drs Steve Wagstaff (seated) and Colin Meurk (standing).

indigenous potato orchid (*Gastrodia*), several species of which occur in the Botanic Gardens and locally (Macdonald *et al*., 2015). Other fungi lead to the decline and death of the introduced trees, such as the polypore fungus of beech, *Meripilus giganteus*, and *Armillaria, Ganoderma* and *Agrocybe* species.

It is a wonder that the plants, local and imported, managed to survive in this strange mixture of the world's biodiversity. It is likely that many introduced plants did not establish successfully in past decades or persist, but their absence today goes unnoticed.

The biosecurity setting

New Zealand is a trading nation. Its economy, enhanced by a growing tourism industry, is dependent on the movement across its borders of people, products and the materials needed for production. Although geographically isolated from other land masses by nearly 2,000 km of the South Pacific Ocean, movements of people and materials through its ports and airports pose a constant threat to the country's indigenous wildlife and primary industries.

Incursions of harmful pests and diseases can be costly for a small country of 4 million people; for example it cost $25m to eradicate a Queensland fruit fly incursion in New Zealand's largest city Auckland in 2015, and an imported bacterium of kiwifruit vines first detected in New Zealand in 2012 cost growers over $200m annually at the height of the infection. A tight regulatory system currently helps to minimise the risk of biological incursions like these (Acosta and White, 2011).

*A playful "jail" containing the caricature of a Most un-Wanted pest plant boneseed (*Chrysanthemoides monilifera *ssp.* monilifera*): part of an educational display on invasive plant eradication.*

Gum tree, Christchurch Botanic Gardens

The importation of most plants and other organisms is today strictly controlled, which is in stark contrast with the situation in earlier centuries. Māori cultivated the treasured kumara and other plants brought by their ancestors from elsewhere in the Pacific over 700 years ago. These were overshadowed by the >25,000 plant species that have been introduced and cultivated in New Zealand since European settlement in the mid-1800s (Gordon, 2012).

As well as providing the seeds of today's primary industries, landscapes and garden plantings, these plants - and their accompanying organisms - can pose a serious threat to economic, plant, human and environmental health (Goldson *et al*., 2015). Fruit trees and other edibles are increasingly being planted in urban parks and private gardens, adding to the abundance of plant species that could harbour pests and diseases to threaten crop production.

On the other hand, introduced plants in botanic gardens, arboreta, city streets and private gardens can provide unique opportunities for the early detection of pest and disease problems, and provide clues to their control. They also provide research opportunities and help us to educate the public about plant health challenges and good biosecurity practice.

Pest and disease surveillance

The New Zealand Ministry for Primary Industry (MPI) undertakes routine high risk sites surveillance (HRSS) of forestry and landscape plants throughout the country (Acosta and White, 2011). This determines which pests and diseases are already present, and if they are spreading. However, the main purpose of HRSS is to give authorities an early warning of new arrivals, to enable timely responses of incursions and to increase the probability of successful eradication (Brockerhoff *et al*., 2010). HRSS survey lines in the Christchurch Botanic Gardens are regularly surveyed by specialist consultants employed on behalf of MPI.

New Zealand has already accumulated hundreds of plant-feeding invertebrates, mainly since the mid-1800s, with aphids being by far the most common plant-feeding group with 110 recorded species (Martin and Paynter, 2014). However, until recently we had limited information on the abundance and feeding preferences of these aphids with respect to introduced plant species, some of which were threatened with extinction in their countries of origin (Arnet *et al*., 2015).

Working with the Forest Research Institute (Scion) and the University of Canterbury, we surveyed the abundance of aphid species on the 50 pine species and other conifers growing in the Botanic Gardens. The survey discovered new associations and, surprisingly, selectivity for different conifers among our aphids (Redlich *et al*., 2013). Research such as this can contribute to the effort of the International Plant Sentinel Network to alert the relevant national authorities to new potential threats. These might be insect pests in their own right, or vectors of asymptomatic diseases already present, that could threaten plantations and indigenous forests in New Zealand or in other countries where these trees or aphids occur.

> *"Studies in the Gardens have identified new host-pest associations."*

Managing potential invasions

There is little doubt that botanic gardens have been, at least partially, instrumental in the escape of invasive plant species in the past (Hulme, 2011). This is hardly surprising as they are virtually "training grounds" for the successful establishment of newly introduced species freed from the pests and diseases present in their native range. They are also typically located near cities and waterways that provide disturbed habitats for colonisation. They are also potential sources of propagules of species. Of course, a botanic garden is only one agent among many that have imported and distributed introduced plants. Nonetheless, city councils such as Christchurch's have active programmes to monitor, control and eradicate pest plant species emanating from whatever source.

Groom *et al*. (2011) described how a botanic garden can lead to the escape of species that grow well within its grounds, e.g. shade-loving species from a garden dominated by forest. At the Christchurch Botanic Gardens staff are well aware of the risk of releasing potential invaders of both open and forest habitats. The Botanic Gardens were founded in an area that did not contain any trees in the 1850s, and the indigenous species present at the time were predominantly those of

grasslands, wastelands, wetlands and other open habitats. These open habitats are still abound in Christchurch and the surrounding region, being especially prevalent since the 2010/11 earthquakes. However, the study of naturally colonising indigenous plants within the Botanic Gardens showed a move in recent years from species that favour open habitats to forest- and forest margin-loving species (Fig. 1).

Some potentially invasive plant species are kept and used in educational programmes that alert the public to the threats these plants can pose. No invasive species are propagated for wider distribution. We also cultivate close relatives of known invasive culprits but only when these are sterile or show no tendency to spread vegetatively. As always staff are alert to any change in the behaviour of plants in their care, detecting invasive tendencies before these get out of control.

The future

The Christchurch Botanic Gardens, like others around the world, offer amazing opportunities for helping members of the public to understand biosecurity issues in engaging ways in a natural, non-threatening classroom. Behind the scenes, staff and science and governmental collaborators take advantage of the rich biodiversity to receive early warning of incursions and to study plant-insect and other associations. These two realms, the public and the expert, are complementary, with the public making a significant contribution towards detecting new organisms. While invasive threats are real and bear serious consequences, a future in which the public understands and is supportive of biosecurity measures is a bright one.

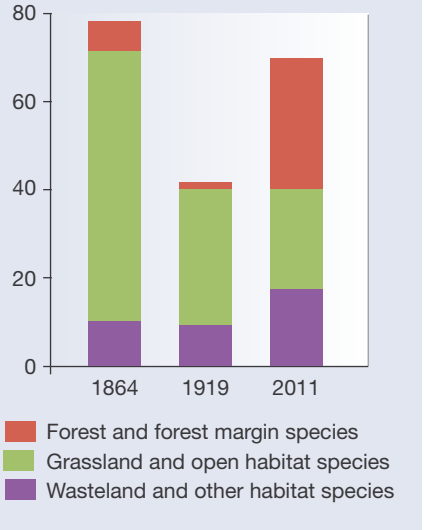


Fig 1: Numbers of forest and forest margin species colonising naturally in the Botanic Gardens have greatly increased in recent years.

Top: High risk sites surveillance (HRSS) survey lines (numerous dashed yellow/pink lines) within the Botanic Gardens (solid white line). From Acosta and White (2011, Map 16).

Acknowledgements

We wish to thank Rory McLellan and Paul Stevens (Senior Advisors, Plants Surveillance Incursion and Investigation, MPI Wellington) and Botanic Gardens staff who contributed helpful information for this article.

References

- Acosta, H. and White, P. 2011. *Atlas of biosecurity surveillance. 2011-May*. Wellington, New Zealand, Ministry of Agriculture and Forestry.
- Allen, R.B. and Lee, W.G. (eds.) 2006. *Biological invasions in New Zealand*. Springer, Berlin.
- Arnet, M., Santos, B., Brockerhoff, E.G., Pelser, P.B., Ecroyd, C. and Clemens, J. 2015. *Importance of arboreta for* ex-situ *conservation of threatened trees*. Biodiversity and Conservation **24**: 3601-3620.
- Brockerhoff, E.G., Liebhold, A.M., Richardson, B. and Suckling, D.M. 2010. *Eradication of invasive forest insects: concepts, methods, costs and benefits*. New Zealand Journal of Forestry Science **40**: S117-S135.
- Cooper, J. 2012. *Mycological Notes 11:* Boletus edulis *in Canterbury*. http://www.funnz.org.nz/node/78 [accessed 5 Jan 2016].
- Goldson, S.L., Bourdôt, G.W., Brockerhoff, E.G., Byrom, A.E., Clout, M.N., McGlone, M.S., Nelson, W.A., Popay, A.J., Suckling, D.M. and Templeton, M.D. 2015. *New Zealand pest management: current and future challenges*. Journal of the Royal Society of New Zealand **45**: 31-58.
- Gordon, D.P. 2012. *New Zealand inventory of biodiversity. Volume 3: kingdoms bacteria, protozoa, chromista, plantae, fungi*. Canterbury University Press, Christchurch, New Zealand.
- Groom, Q.J., Ronse, A. and Hoste I. 2011. *The reasons for exotic plant invasions and why botanic gardens are particularly vulnerable*. BGJournal **8**: 18-22.
- Hulme, P.E. 2011. *Addressing the threat to biodiversity from botanic gardens*. Trends in Ecology & Evolution **26**: 168–174.
- Macdonald, K.J., Lennon, Z.J., Bensemann, L.L., Clemens, J. and Kelly D. 2015. *Variable pollinator dependence of three* Gastrodia *species (Orchidaceae) in modified Canterbury landscapes*. New Zealand Journal of Ecology **39**: 208-213.
- Martin N.A. and Paynter Q. 2014. *Predicting risk from adventive herbivores to New Zealand indigenous plants*. New Zealand Entomologist **37**: 21-28, DOI:10.1080/00779962.2012.759308
- McCracken, D. 1997. *Gardens of empire: botanical institutions of the Victorian British Empire*. Leicester University Press, Leicester.
- Redlich, S., Clemens, J., Pendrigh, D., Godsoe, W., Bader, M., Teulon, D. and Brockerhoff, E.G. 2013. *Identifying new associations between aphids and Pinaceae using plant sentinels in botanic gardens*. [https://www.bgci.org/resources/3299 / retrieved 5 Jan 2016].

John Clemens
Manager Conservation and Sustainable Development
Curator Christchurch Botanic Gardens
Christchurch City Council
PO Box 73036, Christchurch 8154, New Zealand

Eckehard G. Brockerhoff
Principal Scientist
Scion (New Zealand Forest Research Institute), PO Box 29237, Christchurch 8540, New Zealand

Author: Hui Dong

MORPHOLOGICAL AND MOLECULAR IDENTIFICATION OF COMMON NURSERY AND LANDSCAPE PESTS IN SHENZHEN, CHINA

Fairylake Botanical Garden's approach to building an online digital interactive Pest Guide in a new Chinese megacity

Introduction

Inventory, phenological recording, digitization, and online management of cultivated and wild plants are key components of the conservation efforts in botanical gardens. Since its establishment in 1983, Fairylake Botanical Garden, Shenzhen & Chinese Academy of Sciences (abbreviated as FLBG below) has emphasized its conservation work. Among 21 special collection areas across the garden, the cycad collection is of most importance and is where the National Cycad Conservation Center is based. It holds approximately 240 species in *ex situ* cultivation, representing nearly 80% of the world's cycad species. There are also approximately 700 species of ferns in the fern nursery, representing more than one third of China's native fern species. Furthermore, the garden has national leading collections of Gesneriaceae, *Magnolia*, bryophytes, Acanthaceae, *Hoya, Begonia, Plumeria*, Palm, *Bougainviellea*, aloe, aquatic plants, Araceae, and shade plants.

The documentation and identification of pests and invasive species is critical to the garden's management. The past decade has seen an increased interest in pests of nursery and landscape plants, largely in response to the accidental introduction of several invasive species in recent years, such as the coconut leaf beetle (*Brontispa longissima*) and the Erythrina gall wasp (*Quadrastichus erythrinae*). These species have caused significant damage to landscaping plants locally, affecting the horticultural industry by reducing the quantity and quality of nursery plants. Identification of common nursery and landscape pests currently depends on taxonomical literature. More specifically, it relies on the comparison between the specimens and the reliable collections which have been previously identified by experts. However, few such collections exist.

In order to fill that gap, FLBG initiated the current project in 2013; building an online digital interactive pest guide of common nursery and landscape pests in Shenzhen. The main objective is to assemble a "digital reference" in the form of a collection of datasheets, images, distribution data, molecular data (DNA barcodes) and bibliography. This set of information will serve as a basic on-line reference collection and will facilitate current and future projects on nursery and landscape pests in Shenzhen.

SZCIQ's Plant Post-Entry Quarantine Center

Background

The location of Shenzhen, near Hong Kong, has been a site of human habitation for a few centuries. It was designated as a Special Economic Zone in 1979, as it has one of the first international trade ports in China. In 34 years, the population of Shenzhen grew explosively from about 300,000 to 10.63 million (UN DESA 2012) and the urban area increased from 64,625 ha in 1996 to 84,115 ha in 2004 (Li *et al*. 2010). Presently, Shenzhen is categorized as one of the first-tier cities in China, along with the three other biggest cities; Beijing, Guangzhou and Shanghai, based on population and economic power (Ye *et al*. 2012).

Shenzhen has 218 parks and 5,000 hectares of scenic forests (van Dijk 2009). The number of native plant species in Shanghai fell by 43-53% during a period of urban development (1980-2000) (Yang *et al*. 2002; Xu *et al*. 1999). However, in Shenzhen during a similar period (1985-2001) the number of plant species increased 406% (from 58 to 294) for both native and non-native species (Ye *et al*. 2012). Non-native species have been introduced mainly from Hong Kong and other countries due to the explosive growth in trade and urban development.

> *"FLBG is the most important integrated botanical research institute in Shenzhen, and provides horticulture and landscape support to urban greening efforts."*

The Plant Protection Laboratory in FLBG which was established in 1988, is one of the laboratories which belong to the Key Laboratory of Southern Subtropical Plant Biodiversity. It is devoted to the monitoring, identification and documentation of Shenzhen's nursery and landscape pests, playing an important role in plant protection at FLBG and municipal parks of Shenzhen.

Pest investigation and digitalization

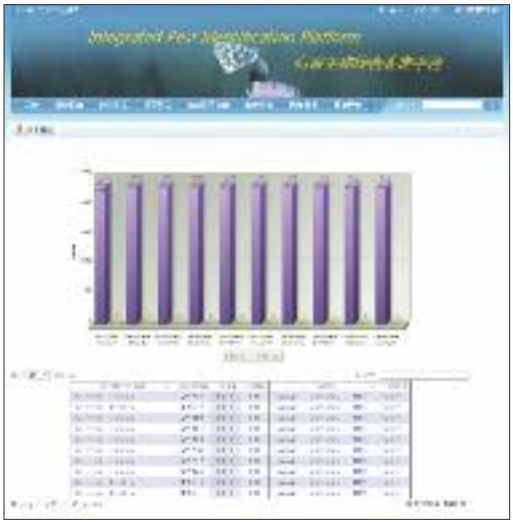
The need for accurate data on the pests of landscaping plants in Shenzhen has resulted in several pest surveys (Table 1), undertaken by FLBG and university researchers. A project supported by Botanical Gardens Conservation International (BGCI) and the International Plant Sentinel Network (IPSN) entitled 'Studies into Chinese longhorn beetles in the Shenzhen region and investigation into the *Plagionotus* genus in China' was launched by FLBG in 2015. This study used literature studies and on-site surveys to increase knowledge and understanding of longhorn beetles in Shenzhen. 108 longhorn beetle samples were collected in Shenzhen, belonging to 45 morphological species. Results from the above studies have supplied important information for the decision-making process in pest control at Shenzhen (Feng 1998; Feng *et al*.; 2000; Liu *et al*. 2015).

So far, 2,102 specimens (damaged plant specimens, pinned-specimens, fluid-preserved specimens, slides) of common nursery and landscape pests in Shenzhen have been digitalized, with each specimen being given an individual barcode for reference. Two hundred and twelve pest datasheets have been developed, including 200 insects, 10 mites and 2 nematodes. The datasheets comprise fully referenced sections on

Pest monitoring through an Android app

Title of Project	Lead Researchers	Year	Insects	Disease	Weeds	Total
Research on pests and controlling method of landscape plants in Shenzhen	FENG Hui Ling	1998	389	347	10	739
An Enumeration of Landscape Plant Pests, Diseases and Weeds in Shenzhen	FENG Hui Ling *et al*.	2000	288	202	9	499
Checklist of Major Landscape Pests in Shenzhen	DONG Hui and CHEN Shenghu	2013	180	155	9	344

Table 1. The surveys of landscaping plant pests in Shenzhen



Barcode library available online

taxonomy and nomenclature, diagnostic features, host plants, biology, images and distributional data. This set of records is freely available at http://ipip.csdb.cn/.

Pest monitoring and forecasting

Monitoring for pests and diseases is a fundamental step in creating a proper Integrated Pest Management (IPM) program. There are many methods employed to monitor the pests and diseases of landscape plants and pests of the herbarium at FLBG, such as sticky traps, pheromone traps, malaise traps and light traps. A solar insect monitor is set up in the garden to track the presence and population development of key pests. The monitor uses light traps to collect nocturnal insects and the captured insects are killed and dried by infrared ray and preserved separately. The pest monitoring function has also been developed as an application of the living plant collection database for FLBG to gather and organize field data, which can be managed on remote Android devices (Fig. 2). Information collected is used in research projects and, together with output from pest forecasts developed at FLBG, is delivered to the horticultural department monthly. Those for the Shenzhen City are published on FLBG's website monthly (www.szbg.ac.cn).

"Monthly pest forecasts are delivered to the horticulture department."

Pest identification using digital keys and DNA barcoding

Pest identification and classification is time-consuming work requiring expert knowledge. In order to facilitate garden and urban pest management, FLBG developed an online digital interactive pest guide of common nursery and landscape pests in Shenzhen. This project is developed in collaboration with Shenzhen Greening Administration and the Computer Network Information Center, CAS (CNIC). The aim of this study was to establish morphological and molecular identification systems to facilitate remote detecting and monitoring of landscaping pests to prevent them from further spreading in FLBG and Shenzhen city. The main tasks are as follows:

1. Providing digital keys that facilitate the identification of common garden pests.
2. Establishing applications of molecular identification of common garden pests based on mtDNA COI gene fragment (DNA barcodes).

The morphological identification system uses traditional dichotomous keys including high-quality illustrations and/or photographs. In addition to providing an image gallery of landscaping pests, an automatic identification system for identifying insects based on images of certain groups (such as butterflies) will be developed in the future.

The molecular identification system serves as a workbench with management, quality assurance, and analysis of barcode data. It is a system with flexible security, web based delivery, and full interface with molecular sequence databases, such as GenBank, BOLD (Ratnasingham & Hebert, 2007), ITIS, and so on.

Collaboration on plant biosecurity

FLBG has been collaborating closely with the Shenzhen Entry-Exit Inspection and Quarantine Bureau (SZCIQ) on invasive species monitoring, pest identification, isolated inspection and quarantine. Plants from abroad, introduced to FLBG through international exchange programs, are quarantined at SZCIQ's Plant Post-Entry Quarantine Center before being planted in the nursery of FLBG. There are 16 isolation rooms in SZCIQ for plant quarantine, including common isolation rooms, advanced isolation rooms and risk simulation rooms.

The collaboration between FLBG and SZCIQ also covers weed identification and fruit fly (Diptera: Tephritidae) monitoring. The botanists of FLBG Herbarium have joined several weed investigations in Shenzhen-Hong Kong Ports and fruit fly traps are set up in FLBG every April to November.

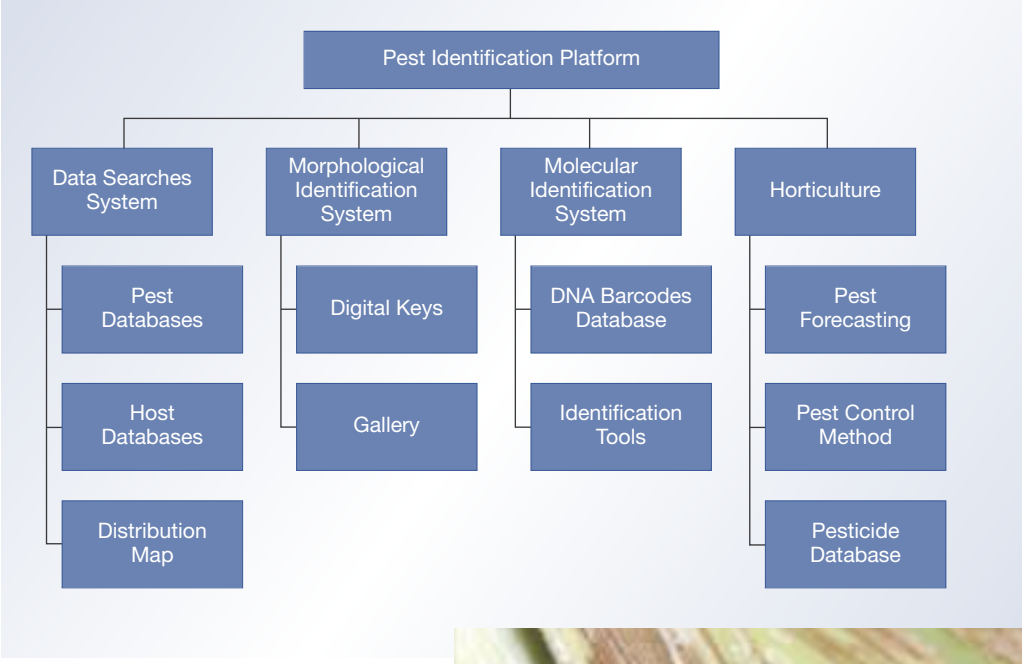
Education and training

FLBG serves as the biodiversity research base for local universities, including Hong Kong Baptist University, Sun Yat-Sen University, South China Agricultural University, Shenzhen University and Shenzhen Polytechnic. In addition,

IPSN workshop hosted by Fairylake Botanical Gardens

Light trap

FLBG provides a diverse range of formal and informal education programs for people of all ages and at all levels. The IPSN workshop 'The Identification and Diagnosis of Longhorn Beetles in China and nearby Countries' was successfully held in FLBG on March 26-27, 2015. The course was supported by BGCI and organized by FLBG. Twenty four participants from 17 institutions, including staff from botanical gardens, students from universities and government officials from Shenzhen Quarantine Bureau and Hong Kong Agriculture, Fisheries and Conservation Department attended this workshop.



Pest identification in Fairylake Botanical Gardens

A non-native beetle identified by FLBG scientists

Reference

- Feng, H.L. 1998. Research on pests and controlling method of landscape plants in Shenzhen. (Project report)
- Feng, H.L., Xie, H.B., and Li, Z.L. 2000. An Enumeration of Landscape Plants Pests, diseases and Weeds in Shenzhen. Fairylake Botanical Garden. pp. 1-74.
- Li, T.H., Li, W.K., and Qian, Z.Z. 2010. Variations in ecosystem service value in response to land use changes in Shenzhen. *Ecological Economics*, **69**: 1427–1435.
- Liu, D.M., Liang, Z.Y., Dong. H., He, F., Yi, Q.F., Xu, Y., and Xing, F.W. 2015. Technical Code for Pest Control in Urban Green Land. Quality and Technical Supervision Bureau of Shenzhen.
- Paiero, S.M., Marshall, S.A., McPherson, J.E. & Ma, M.S. 2013. Stink bugs (Pentatomidae) and parent bugs (Acanthosomatidae) of Ontario and adjacent areas: A key to species and a review of the fauna. Canadian Journal of Arthropod Identification No. 24, 1 September, 2013. Available online at http://www.biology.ualberta.ca/bsc/ejournal/pmmm_24.html
- Ratnasingham, S., & Hebert, P.D.N. 2007. BOLD: The Barcode of Life Data System (http://www. barcodinglife.org). *Molecular Ecology Notes*, **7**(3): 355-364.
- van Dijk, M.P. 2009. Citing online sources: Ecological cities, what are we heading for and are new towns examples of ecological cities? Available from http://naerus.net/web/sat/workshops/2009/Rotterdam/pdf/vanDijk_Meine.pdf [accessed 10 October 2015].
- Xu, B.S., Ou, S.H., and Yang, B.S. 1999. Flora of Shanghai. Shanghai Scientific and Technology and Document Press, Shanghai, China. pp 1-953. Shanghai Scientific and Technology and Document Press. Location is Shanghai.
- Ye, Y.H., Lin, S.S., Wu, J., Li, J., Zou, J.F., and Yu, D.Y. 2012. Effect of rapid urbanization on plant species diversity in municipal parks, in a new Chines city: Shenzhen. *Acta Ecologica Sinica*, **32**: 221–226.
- Yang, Y.C., Da, L.J., and Qin, X.K. 2002. A study of the flora on Dajinshan Island in Shanghai. *Journal of Wuhan Botanical Research*. **20**: 433–37.

Hui Dong
Fairylake Botanical Garden, Shenzhen & Chinese Academy of Sciences
160 Xianhu Road, Luohu District, Shenzhen, GD, P.R.China, 518004
fishdh@gmail.com

Authors: Daniel Stern and Rachel McCarthy

THE SENTINEL PLANT NETWORK:

ENHANCING BIOSECURITY BY LEVERAGING THE CAPACITY OF PUBLIC GARDENS TO SUPPORT EARLY DETECTION OF AND RAPID RESPONSE TO INVASIVE ALIEN PESTS

Colorado beetle (Shutterstock)

Invasive alien pests represent a significant threat to agriculture, forests and the vital ecosystem services that they provide. With the volume of international trade increasing by about five percent per year since 2000, the risk of introduction continues to grow. Although prevention is the preferred mode of invasive species management; both preclearance (port of export) and exclusion (port of entry) inspections are costly and, as a result, typically restricted to a small sample of incoming cargo. In addition, pests present in plant material or products (e.g. wood packaging) can easily be hidden or in an unidentifiable stage at the time of inspection and thus go unnoticed.

While important, these prevention tactics are not sufficient. Early detection strategies are imperative for biosecurity because the longer an invasive species goes unnoticed, the more difficult it becomes to eradicate or control. But, in order for early detection to work, it must be coupled with rapid and effective response techniques. As such we also need regulatory agencies and the work that they do to eradicate or limit the spread of invasive alien pests. Public gardens need to take a leadership role in combatting invasive alien pests. Partnerships like the Sentinel Plant Network illustrate how their capacity can be leveraged to support early detection and rapid response efforts along several fronts.

Launched in 2011 with financial support from the U.S. Department of Agriculture – Animal and Plant Health Inspection Service (USDA – APHIS), the Sentinel Plant Network is a collaborative partnership between two organizations with complementary resources and a shared commitment to plant conservation.

The first is the American Public Gardens Association, which was founded in 1940 and has grown to include more than 585

Sentinel Plant Network Workshop

institutions, spanning all 50 states, the District of Columbia, Canada, and 24 countries. The Association advances the field by encouraging best practice, offering educational and networking opportunities, equipping public garden professionals with the tools they need to celebrate and preserve plants creatively and sustainably, and advocating on behalf of its members and public gardens worldwide. The capacity that the Association brings to the early detection of serious plant pests and diseases includes:

- Hundreds of gardens who maintain detailed records in their stewardship of tremendously diverse taxonomic collections and natural areas;
- Thousands of front-line horticulturists and garden volunteers who observe the plants under their care daily;
- Millions of people that visit member gardens annually who can learn about serious pests and diseases, act as citizen scientists and support rapid response and regulatory action.

However, in a 2011 BGCI survey of botanical institutions around the world, most respondents indicated that their organization relied entirely on external partners for insect pest and pathogen identification or that their organization had some in-house expertise but could use more help (Kramer and Hird, 2011).

This expertise is brought to the partnership by the National Plant Diagnostic Network (NPDN), a branch of the USDA's National Institute of Food and Agriculture. NPDN was established in 2002 to enhance security in agricultural and natural ecosystems in the U.S. Pooling the collective efforts of professionals at Land Grant Universities, federal agencies, state departments of agriculture and other stakeholders.

NPDN has grown into an internationally respected consortium of laboratories that are engaged in diagnostics, training and communication. The capacity that NPDN brings to the Sentinel Plant Network includes:

- A nationwide network of diagnostic expertise and laboratory infrastructure;
- A national database where diagnostic results are recorded and available for review by a variety of stakeholders;
- A cohesive chain of communication that ensures that any observations of pests or diseases with potential quarantine significance are reported immediately to appropriate regulatory officials and decision makers responsible for responding to and mitigating new outbreaks.

The Sentinel Plant Network contributes to plant conservation by engaging public garden professionals, volunteers and visitors in the early detection of serious plant pests and diseases. Since its launch in 2011, the program has grown to include more than 200 gardens across North America.

Public garden staff and volunteers are well positioned to contribute observational data that improves our understanding about the distribution of serious plant pests and diseases and help identify emerging threats because they are intimately familiar with and maintain detailed accession records about the diverse plants under their care.

The Sentinel Plant Network enhances this capacity by providing training and resources on monitoring for pests and diseases and engages front-line horticulturists to survey their collections. Since 2011, the Network has conducted 16 regional workshops to train public garden staff in basic plant diagnostics, significant pests and diseases in their region, potential threats, and best practices for monitoring their collections. These events, which have served 420 individuals from 170 different public gardens to date, have also provided a valuable opportunity for the Sentinel Plant Network to build relationships between the public garden community, diagnosticians and regulatory officials so they can work together more effectively on the front lines of early detection.

In addition to in-person training, the Sentinel Plant Network provides member gardens with monitoring tools (e.g. camera-equipped dissecting scopes) so they can efficiently communicate with diagnosticians and get timely and accurate identification of pest and disease problems. The Network also engages its members year-round through geo-targeted pest and disease alerts. These alerts contain actionable information about what garden staff should be on the lookout for, phenological cues, host plants, common symptoms, and links to the program's threat-specific monitoring checklists and visual aids.

"Public gardens have a unique capacity to educate the public about the impact of serious plant pests and diseases and encourage their support of regulatory control measures."

Public gardens provide immersive experiences with nature that can help visitors make the connection between the urban landscape and the forest.

When a plant in the garden captures a visitor's interest, it also presents a unique informal learning opportunity to engage that person on subjects related to forest health and plant conservation. The Sentinel Plant Network capitalizes on this opportunity by developing eye-catching interpretive signage and plant labels featuring high-consequence pests and diseases. At a glance, visitors can learn about the threat and its impact, steps the public can take to help prevent its spread, and the importance of early detection, rapid response and regulatory action. Each of these pieces also bears a quick response (QR) code which, when scanned with a smartphone, takes the garden visitor to a threat-specific landing page on a mobile-friendly website where they can learn more. To date, over 500 of these pieces have been deployed at more than 50 Sentinel Plant Network gardens across North America.
Public gardens can engage new audiences to get involved in early detection efforts as citizen scientists.

Sentinel Plant Network workshop

Besides reaching visitors as they walk through their plant collections, public gardens also serve as centers for formal education in their communities. The Sentinel Plant Network leverages this capacity by providing member gardens with curriculum materials to encourage class participants to get more involved by becoming a certified member of NPDN's First Detector Network. To date, Sentinel Plant Network gardens have delivered this content to thousands of program participants.

The American Public Gardens Association's participation in the Sentinel Plant Network falls within the Association's Plant Protection Program, which encompasses a variety of activities and resources that engage public gardens in forest health protection and plant conservation. The Plant Protection Program also includes Plant Heroes, the Association's youth education program. The vibrant Plant Heroes activity books, comics, field guides and other materials available at www.plantheroes.org are great for public garden professionals, parents and teachers looking for innovative ways to educate young learners about the importance of plants and involve them in protecting forests from the threat of invasive species.

Real Impact

"The cool thing is that my volunteers were trained to look for [viburnum leaf beetle], and I had also sent out VLB fact sheets (alerts to watch out for) to all of our horticulturists recently; the Sentinel Plant Network training helped make these early finds possible."
Tom Tiddens, Plant Health Care Supervisor, Chicago Botanic Garden

There have been numerous early detections by Sentinel Plant Network gardens over the past five years, but the recent events at one member garden in particular truly epitomize the full capacity that public gardens play in early detection and rapid response efforts. In early 2014, Sentinel Plant Network garden, Bloedel Reserve, submitted a plant sample to their state's NPDN lab that was subsequently diagnosed as positive for *Phytophthora ramorum*, a waterborne pathogen of quarantine significance. Instead of being paralyzed by this devastating diagnosis, the news launched the Bloedel Reserve into action. The garden worked closely with officials from the Department of Agriculture to conduct a delimitation survey to identify all additional infected plants on garden grounds so that they could be destroyed. The garden also implemented soil steaming treatments in affected areas, and assisted with a "trace-back" investigation to find the source of infection. The garden continues to train their staff and educate visitors on sanitation practices to mitigate the spread of the pathogen. In addition, the garden leveraged the local publicity to enroll more community members in First Detector trainings at the garden.

References

- Kramer, A., A. Hird. 2011. *Building an international sentinel plant network*. BGjournal **8**(2): 3-6

Support for the Plant Protection Program comes from the USDA Animal and Plant Health Inspection Service and the USDA Forest Service – Forest Health Protection Division. For more information about the Plant Protection Program, Plant Heroes or the Sentinel Plant Network visit http://publicgardens.org/programs/plant-protection-program. For more information on the National Plant Diagnostic Network and their First Detector Network, visit http://npdn.org/.

Daniel Stern is the Manager of the American Public Gardens Association's Plant Protection Program and coordinates the Association's participation in the Sentinel Plant Network. Daniel can be reached at dstern@publicgardens.org.

Rachel McCarthy is a Training and Education Coordinator for the National Plant Diagnostic Network and coordinates their participation in the Sentinel Plant Network. Rachel can be reached at rachel.mccarthy@cornell.edu.

Authors: Marek Barta, Peter Ferus and Peter Hoťka

BIOSECURITY OF WOODY PLANT COLLECTIONS IN MLYŇANY

A section of North American flora in the arboretum (Juraj Kuba).

The Mlyňany Arboretum manages the largest living collection of non-native trees and shrubs in Slovakia. The trees are regularly monitored for the presence of native and alien pests and pathogens in order to identify organisms that could present a potential risk to tree health.

Introduction

Botanic gardens and arboreta worldwide face the issues of protecting living plant collections, biodiversity and natural habitats from various biological threats that may cause plant damage or disorders. These issues are a result of human-caused global environmental changes and globalisation of trade that create conditions appropriate for new and emerging non-native pests, diseases, and weeds. Botanic gardens and arboreta usually manage large and diverse plant collections which offer an excellent opportunity to monitor, understand, and predict new potential biological threats to plant health and the biodiversity of natural habitats. The present legislation surrounding biodiversity protection in Slovakia does not provide adequate provisions to tackle the ca. 40% of vascular and ca. 16% of non-vascular plants that are estimated to be endangered in the country (Government of the Slovak Republic, 2013). In 2013, the updated National Strategy for Biodiversity Protection to 2020 was adopted by the Slovak government with the aim to halt biodiversity loss and the degradation of ecosystems by 2020. Biosecurity and the fight against invasive alien species were both highlighted in this national strategy.

The Mlyňany Arboretum is the only botanic garden exclusively specialised in collecting exotic woody plant taxa in Slovakia. It is situated in south-western Slovakia in one of the warmest and driest areas of the country with an

Escaped from the Mlyňany Arboretum into the adjacent black locust forest (Peter Ferus).

Research on biology of invasive seed bug Leptoglossus occidentalis *in the arboretum.*

average annual temperature of 9.86°C and an average annual rainfall of 577.94 mm. The arboretum manages the largest living collection of non-native trees and shrubs in Slovakia and houses one of the richest collections of such species in Central Europe.

> *"This high plant diversity means an abundance of potential host species for harmful exotic pests and diseases."*

This also means there is an increased potential for non-native plants to become invasive in a new environment. At present, the Mlyňany Arboretum does not possess a risk management plan that would encompass a detailed policy framework on how to predict, identify, and manage potential biological threats.

However, the issue of biosecurity is included as a matter of attention within the arboretum's General Management Plan for Living Collections. Mlyňany Arboretum currently collaborates with the National Plant Health Agency (the Slovak Central Controlling and Testing Institute in Agriculture) focusing on the issues of plant propagation, plant protection, and internal and external quarantine. The collaborative relationship between the Agency and plant growers is anchored in national legislation, but also has an element of voluntary participation through consultation and advisory services available to growers.

Mlyňany Arboretum – a rich collection of non-native woody plant taxa in Slovakia

The Mlyňany Arboretum, founded by a Hungarian noble Dr. István Ambrózy-Migazzi in 1892, houses the most unusual collections of trees and shrubs in Central Europe. Dr. Ambrózy-Migazzi and his followers adopted a neglected piece of land, turning it into a beautiful park visited by scientists, students and the public. An enthusiastic naturalist, Dr. Ambrózy-Migazzi, often visited the Mediterranean area and, impressed by the local evergreen flora, decided to establish a collection of evergreen plants in the continental climate at the southern foothills of the Carpathian Mountains. In 1892, he began creating his idea of an "evergreen park", and evergreen species were planted into an oak-hornbeam forest of ca. 40 ha (98.84 acres). Soon after the initial plantings, he and his assistant Josef Mišák, a qualified gardener, succeeded in building an extraordinarily rich assortment of approximately 250 evergreen and semi-evergreen taxa - the most abundant plant collection of such species in Central Europe at that time. Contemporary botanists and professional gardeners disputed that such a park was possible as it was the first garden in the area to try and acclimatise evergreens under continental climate.

In 1953, the Slovak Academy of Sciences took over the Mlyňany Arboretum with the ambition not only to preserve the

An aerial view of the Mlyňany Arboretum (BTV Blučina).

A side view of the mansion from the rose garden (Marek Barta).

evergreen park, but also to extend the plant collection to grow as many exotic trees and shrubs in this climate as possible. After 1967, extensive collections of non-native woody species were planted in new sections. The plants were arranged aesthetically according to phytogeographical principles, i.e. plants were established in groups which were based on the differing ecosystems of their native habitats. In total, a new area of 27 ha (66.72 acres) was established to grow East-Asian (19.5 ha – 48.18 acres) and North-American woody species (7.5 ha – 18.53 acres). Besides these two large collections, other smaller ones were established for North-Korean flora, native flora and a rose garden. Nowadays, the Mlyňany Arboretum manages the largest park in Slovakia, almost 67 ha in extent. Visitors can find here more than 1,930 woody taxa, approximately 1,100 of them are wild species and more than 600 are cultivars. The plant collection is represented by more than 1,300 deciduous, 273 evergreen or semi-evergreen, and 327 coniferous taxa (Hoťka and Barta 2012).

Exotic woody plants harbour exotic pests

Over the last few years, a number of plant pests and diseases have been found in Europe for the first time and have caused significant damage to either the native flora or to commercial crops. These threats have increased due to the globalisation of trade and with climate change. New emerging pests and diseases can also cause significant damage to living collections of botanic gardens and arboreta. It is likely that every botanic garden around the world has already had serious exotic pests considered as threats to its plant collections. Therefore, it is vital that biosecurity measures form a substantial component of plant management plans in botanic gardens.

Introduction of new exotic plant species is generally thought to be linked with an increased risk of the introduction of new (invasive) pests and diseases. Biosecurity research in the Mlyňany Arboretum dates back to as early as 1967 when the Institute of Dendrobiology was established and a project of plant pests was initiated under the direction of Prof. František Benčat. The main aim was to study mutually beneficial relationships between introduced plant hosts and their parasites, focusing on identifying new introductions in connection with the arrival of exotic plant species to the arboretum.

"Many new plant parasites have been detected and studied in the arboretum's collections."

During the past 15 years more than 400 taxa of exotic woody plants have been evaluated and numerous species of parasitic fungi were found on assimilative organs (280 species) or branches (226 species) (Juhásová 2002a, 2002b, 2004).

Undisputedly, among the most aggressive fungi observed during the survey was *Cryphonectria parasitica* (Murr.) Barr responsible for sweet chestnut blight and bark cancer. This fungus is a typical example of an invasive plant parasite with a huge impact on tree vitality. In the Mlyňany Arboretum, a severe infection of an experimental plot by this invasive

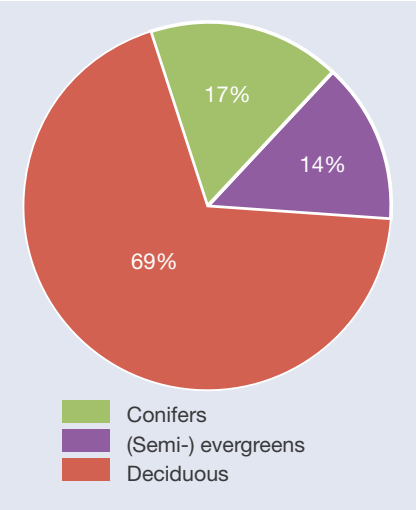


Figure 2. Categories of trees and shrubs growing in Mlyňany Arboretum in 2012 (Hoťka and Barta 2012).

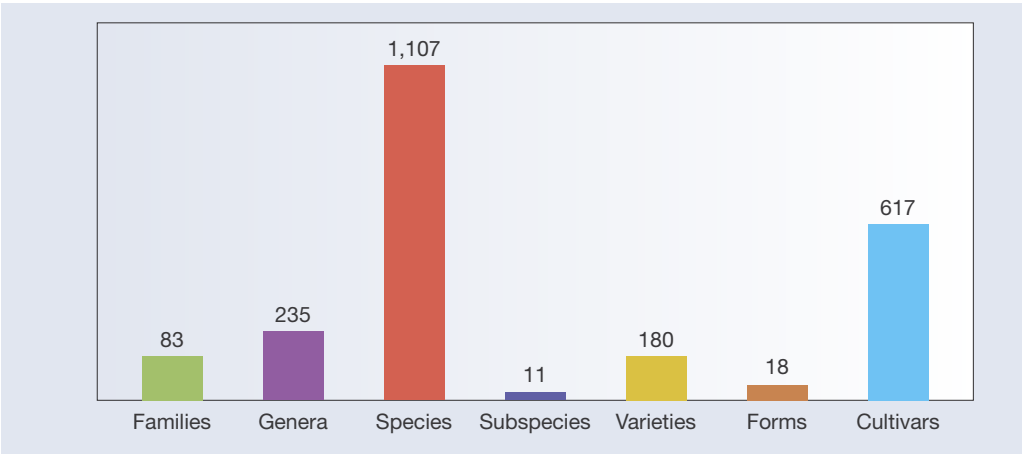


Figure 1. Taxonomic profile of the living collections of the Mlyňany Arboretum in 2012 (Hoťka and Barta 2012).

*Black cherry (*Prunus serotina *(Ehrh.) Borkh.) and Oregon grape (*Mahonia aquifolium *(Pursh) Nutt.)*

pathogen killed all 262 trees of intraspecific *Castanea sativa* × *C. sativa* and interspecific *C. sativa* × *C. crenata* crosses established in 1981-1982 within just a short period of five years (2009-2014). Much work has been done on *C. parasitica* as it seriously endangers crop production of sweet chestnut. Biological control of the disease by hypovirulent strains has been intensively studied in laboratory and field experiments (Juhásová *et al*. 2005). Over 300 insect species were found in trophic association with exotic woody plants in the arboretum including mostly new records of alien phyllophagous lepidopterans like *Cameraria ohridella, Phyllonorycter platani, P. robiniella, P. leucographella, Parectopa robiniella, Coleotechnites piceaella, Argyresthia trifasciata, A. thuiella* and *Cydalima perspectalis* (Hrubík, 2002; Barta, 2009; Barta & Konôpková, 2013). Recently, selected non-native pest species have been studied to understand their life history, host spectrum, and local dispersal (e.g. *Leptoglossus occidentalis, Megabruchidius tonkineus, Cameraria ohridella, Chloropulvinaria floccifera*) (Barta & Ferus 2014; Barta, 2015). Since the plant health monitoring was initiated in the arboretum, many first records of mostly fungal and insect species parasitizing on exotic trees and shrubs have been published. However, no direct link between incursion of new pests and intentional introduction of plant species has been observed.

Meeting in the arboretum's mansion to disseminate actual information on invasive plant species.

When introduced plants become weeds

If non-native plants are grown over a long period of time, they stand a better chance of naturalizing, which is the first step to becoming an invasive problem. Of course, not all exotic species will become invasive, and they are considered to be invasive only when they cause harm. In Slovakia, 126 species of invasive and 79 potentially invasive vascular plants have been recorded (Government of the Slovak Republic, 2013). Invasive plants possess a set of specific traits that characterize their invasive potential. The naturalization of exotic woody plants is carefully watched in the Mlyňany Arboretum and the botanical staff has assessed the invasive potential of "problematic" species. From a biosecurity point of view, capacity of these species for self-expansion is a very dangerous trait. Therefore seedlings of spontaneously 'escaped' exotic plant species from cultivation need to be localized, identified, quantified and then effectively eradicated. Surveys on spontaneous escape of woody plants outside the arboretum's fence started relatively recently, and the first of them was carried out at the end of the last century (Tomaško, 1999). Focusing only on a specific area of black locust (*Robinia pseudoacacia* L.) forest, situated on the south-western side of the arboretum, the presence of exotic woody species was analysed with increasing distance from the arboretum's border. The following seven species were found; *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Fraxinus pennsylvanica* Marsh., *Prunus laurocerasus* L., *Ilex aquifolium* L., *Mahonia aquifolium* (Pursh) Nutt. and *Paulownia tomentosa* (Thunb.) Steud. Thirteen years later, a similar analysis was repeated in the black locust forest, but the study area was extended to an abandoned apple orchard located along the arboretum's east border and also to a thin belt of wild vegetation along the outside border of the arboretum. Altogether, 27 exotic woody taxa were reported with a predominance of East Asian species, though North American species dominated, including black cherry (*Prunus serotina* (Ehrh.) Borkh.), red ash (*Fraxinus pennsylvanica* Marsh.), and Oregon grape (*Mahonia aquifolium* (Pursh) Nutt.), which were most likely distributed by birds and/or wind. According to the National Regulation No. 24/2003 (Government of the Slovak Republic, 2003), land owners are obliged to eradicate listed invasive plant species, however, in reality, this is very rarely practised. Therefore the arboretum's ambition is to provide knowledge transfer and danger alerts on invasive plant species to local farmers, foresters, and local authorities.

Meetings and training is delivered by the arboretum's staff, external experts, and representatives of the national regulatory body for employees, land owners, horticulturists, students, and visitors to disseminate information on invasive plant species and the necessity of their effective management.

Research on invasive plants has been the focus of the arboretum for several years. Recently, a cooperation with the Taipei botanical garden (Taiwan) and Multidisciplinary Institute of Plant Biology in Córdoba (Argentina) has started to assess the prospects for bioregulation of the invasive tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle) in Central Europe and to explain changes in honey locust (*Gleditsia triacanthos* L.) preceding its switch to invasive behaviour. The arboretum also participates in the "European information system for alien species" (European COST action TD 1209) which aims to contribute to early warning tools and the development of rapid response protocols.

Conclusion

In 2015, the Mlyňany Arboretum updated its Plant Management Strategy and incorporated biosecurity measures. Prevention rather than cure is the emphasis of plant biosecurity in the arboretum, since there are many pests that can only be controlled to a limited extent and not eliminated.

"Regular surveying of plant collections, application of sanitation practices, conducting employee training and effective monitoring of imported seeds and plant material are fundamental measures implemented in the biosecurity strategy."

Since early identification of pests provides a greater chance for success of control or eradication programmes, we regularly monitor the occurrence of native and alien pests and pathogens of plants with the aim to identify organisms that could present a potential risk to tree health. The arboretum works together with local universities (Slovak Agricultural University and Constantine the Philosopher University) and forest diagnostic laboratories (the National Forest Centre) for plant pests and pathogens identification. As a member of Botanic Gardens Conservation International and the International Plant Sentinel Network, the arboretum has a chance to collaborate with other member gardens on building an early warning system for new pest risks. Worldwide, botanic gardens and arboreta can effectively and relatively quickly share their data on incursion of new invasive species and thus produce a strong global network as a tool of early warning system.

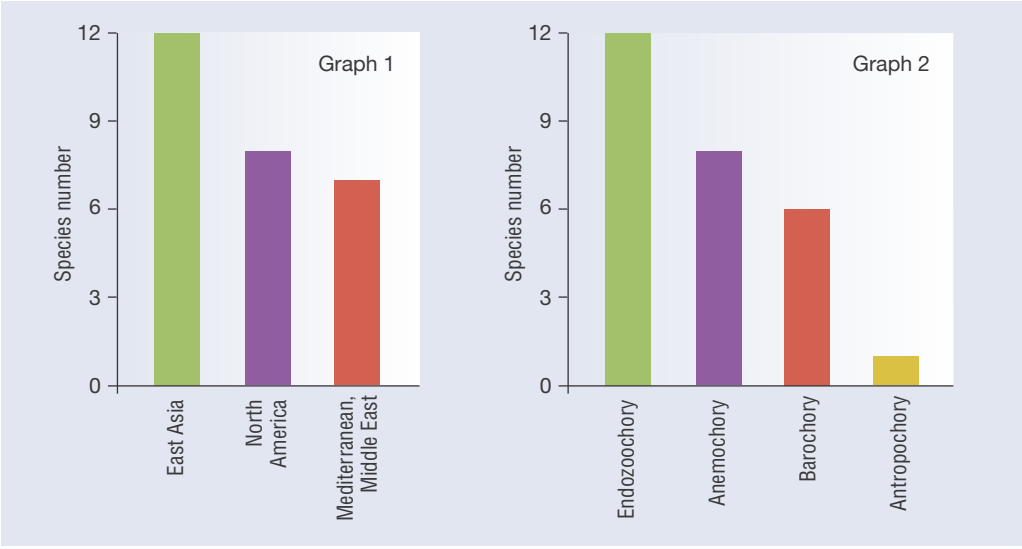


Figure 3. Geographical origin (Graph 1) and dissemination mode (Graph 2) of non-native woody species detected behind the arboretum's fence in 2012.

References

- Barta, M. 2009. Occurrence of pests on introduced woody plants under conditions of Arboretum Mly any SAS during 2007-2009. Proceedings of papers *Dendrological Days in Mlyňany Arboretum SAS 2009*, p. 32-40.
- Barta, M. 2015. Biology and temperature requirements of the invasive seed bug *Leptoglossus occidentalis* (Heteroptera: *Coreidae*) in Europe. J. Pest. Sci. DOI 10.1007/s10340-015-0673-z
- Barta, M. & Konôpková, J. 2013. Important pests of evergreen woody plants in Mlyňany Arboretum SAS. Proceedings of papers *Woody plants in public greenery*, p 215.
- Barta, M. & Ferus, P. 2014. Potential spatial distribution modelling of non native bruchid beetle *Megabruchidius tonkineus* in Slovakia. Proceedings of papers *Dendrological Days in Mly any Arboretum SAS 2014*, p. 15 23.
- Hoťka, P. and Barta, M. 2012. Inventory of Living Collections of the Mlyňany Arboretum SAS. VEDA, Bratislava, 136
- Hrubík, P. 2002. Results and current issues on exotic woody plant protection in Slovakia. Proceedings of papers *Growing and protection of exotic woody plants in Slovakia* p. 40-49.
- Juhásová, G. 2002a. Vulnerability of exotic woody species by parasitic fungi. Proceedings of papers *Growing and protection of exotic woody plants in Slovakia* p. 50-60.
- Juhásová, G. 2002b. The most important fungal diseases on semperviren ornamental woody plant species. Proceedings of papers *110 years of Arboretum Mlyňany*, p. 60-65.
- Juhásová G. 2004. *Results of phytopathological research of woody plants in Arboretum Mlyňany*. Proceedings of papers *Introduction and acclimatisation of trees in conditions of central Europe* p. 235-241.
- Juhásová G., Adam íková K., and Robin, C. 2005. *Results of biological control of chestnut blight in Slovakia*. Phytoprotection **86**: 19-23.
- The Government of the Slovak Republic, 2003. Regulation of the Ministry of Environment of the Slovak Republic for the implementation of the Law no. 543/2002 On nature and landscape protection.
- The Government of the Slovak Republic, 2013. Updated National Strategy for the Protection of Biodiversity to 2020.
- Tomaško, I. 1999. Invasive dendrotaxa of Arboretum Mlyňany. Invasions and invasive organisms 2, SNK SCOPE & SEKOS, Bratislava, p. 183-190.

Marek Barta, Peter Ferus and Peter Hoťka
Institute of Forest Ecology SAS
Mlyňany Arboretum
Vieska nad Žitavou, Slovak Republic

Authors: Rachel Warmington and Katie Treseder

SURVEYING, MONITORING AND QUARANTINING FOR NOTIFIABLE PESTS AND DISEASES AT THE EDEN PROJECT

Aerial shot of the Eden Project

Introduction

The Eden Project is a botanic garden, educational charity and visitor attraction in Cornwall, which has been open to the public since March 2001. It was designed to celebrate the interdependence of plants and people, and to educate people about the need to care for the world. Located in an old china clay pit at Bodelva, the 105 hectare site consists of the outer estate (car parks, wetland, grassland, copses and an orchard), outdoor gardens (separated into themed areas such as the outdoor Mediterranean, crop production and wild Cornwall) together with two large geodesic biomes that provide a humid tropical environment (the Rainforest biome), a warm temperate environment (the Mediterranean biome) and the

The Eden project has experience of managing a wide range of pests and diseases associated with large-scale planting and the unique environments of its biomes.

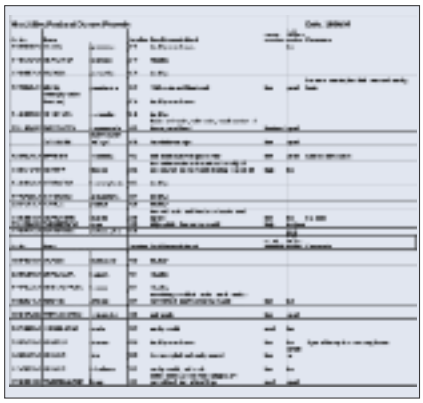
nursery. Nearly two million individual plants make up Eden's collection, with over 1,000 species being located in the Rainforest biome.

Pest and disease management

In the fifteen years since opening, there have been many pest and disease management challenges following the first plantings in the rainforest biome. Even at the early stages, when a small team of horticulturists started procuring and growing plants from around the world in preparation for the biomes, it was realised that there was a significant risk of importation of invertebrate pests. This was despite ensuring that all plants were imported with their relevant plant passports and phytosanitary certificates. Indeed, many of the pest and disease management issues faced today at the Eden project can be attributed to the large scale planting which occurred in the early years, as well as the unique environments created in the biomes.

Despite ensuring that all imported plants had the relevant documentation, and working closely with the local Plant Health Inspector and the Central Science Laboratory (now Fera), many non-indigenous pests were accidentally introduced into the gardens, but in particular the rainforest biome. These include *Pentalonia nigronervosa* (banana aphid), *Aleurotrachelus atratus* (palm infesting whitefly), *Nipaecoccus nipae* (coconut or spiked mealybug), *Opogona sacharri* (banana borer) and *Coccus viridis* (green coffee scale). These pests are the subject of a containment notice from DEFRA, meaning we are obliged to monitor pest populations and maintain an integrated pest management programme to control them. In addition, the notice also stipulates that strict measures must be taken to ensure that these pests are not allowed to escape from the rainforest biome, restricting the plant material that can be removed from the biome and requiring inspection of any plant cuttings or seeds that do leave. Furthermore, all seeds and cuttings are grown on in our quarantine facilities to ensure they are free from pests and diseases before they are placed with other plants from our collection.

The nursery and quarantine facilities are based at Pentewan, approximately six miles away from the main Eden site at Bodelva. This site enables the quarantining of all new plants, and any cuttings or plants being moved from temporary displays, away from the main collection. The quarantine area is divided into separate areas for temperate and tropical plants, with strict protocols on



Example of a pest and disease check sheet

how long a plant needs to be in quarantine before it can either be planted at Bodelva, or be placed with other stock plants at the nursery. A minimum of 1 month of quarantine is given for temperate plants compared to 3 months for tropical plants. For new plant material a Plant Risk Assessment is carried out which helps to highlight any particular issues which will impact the length of quarantining time required, i.e. the potential presence of pests with cryptic life stages. The quarantined plants are checked weekly by members of the Plant Health team, who record all their findings on Eden's plant database, reporting any issues to be dealt with to the nursery staff, as well as advising when plants can be moved out either to be planted at Bodelva, or held at the nursery. Numerous pests and diseases have been identified on new plants in quarantine, sometimes resulting in plants being disposed of if there is no suitable treatment available, particularly if viruses are identified or suspected.

Pest Identification

In addition to quarantining plants in the facilities at our nursery site at Pentewan, we also have to continually monitor the main site at Bodelva, including the outer estate, which is achieved by both passive and active monitoring. Passive monitoring is carried out predominately by the horticultural team whilst they are performing other tasks around the site (watering, weeding, pruning etc), but often other members of the Eden team will also report to the Plant Health team anything that requires attention. For active monitoring in the rainforest biome the horticultural team use pest check sheets in weekly inspections, which are then passed to the Plant Health team. These use specific plants which act as sentinels to enable pest populations to be surveyed for and assessed. The team also report on any additional problems, such as dieback, fungal growth, leaf spots and nutrient deficiency symptoms, providing photographs and samples when the symptoms are high up in the tree canopy.

Large bamboo plants arriving as part of the first plantings

> *"A combination of passive and active monitoring ensures that plants at all sites are regularly monitored."*

In the outdoor gardens, Mediterranean biome and the wider estate a combination of general monitoring by the horticultural team and tree surveys (which are carried out as part of the Tree Safety Policy) help to highlight problems. The Plant Health team also check all the bulbs which are purchased each year for planting in both the Mediterranean biome and the outdoor gardens. These checks are carried out to prevent diseased bulbs being planted (which has resulted in poor flowering occurring in the past). This also links with our general quarantining and inspecting procedures, which specify that all organic matter must be checked by a member of the Plant Health team before being brought into the gardens. In 2015 more than fifty thousand bulbs were checked before planting, with basal rots, aphids and gummosis being just some of the problems identified on the bulbs which were then discarded or returned to suppliers. All problems found on the bulbs, as well as the number of bulbs discarded, are recorded for future reference.

Disease Identification

Previously *Phytophthora ramorum* has been found in the gardens and as a result we routinely use lateral flow device kits (LFDs) to test any host plants with symptoms. LFDs use the same technology as home pregnancy testing kits, using antibodies to detect antigens which are produced by all species of *Phytophthora*. A small piece of diseased plant material is crushed in a buffer

solution, and a few drops of the resulting mixture are pipetted onto the lateral flow device. Any *Phytophthora* antigens present will react with the antibodies in the device, causing a line to appear. If a positive result is found we call in our local Plant Health Inspector to obtain a formal diagnosis.

Starting in May 2015, a project was carried out by an intern with the Plant Health team which extended our monitoring to surveying for and recording of symptoms of notifiable diseases on the Eden Project site. The whole site at Bodelva, including the outer estate, was divided into 25 sections of approximately 200 x 200 metres. For each section any host trees of the pathogens *Phytophthora ramorum, P. kernoviae, Hymenoscyphus fraxineus*, and *Ceratocystis platani* were identified and mapped using our plant records database. They were then visually identified on the ground, together with any hosts not listed in our database; the GPS-location and, if known, the accession number was recorded. All trees were scored on a scale from 1 to 5; 1 being 'dead/dying' and 5 being 'very healthy'. Scores were based on the overall appearance of the tree and any disease-specific symptoms were recorded separately. In addition, all trees and shrubs showing any symptoms of *P. ramorum* were tested using a lateral flow device. Fortunately all of the plants tested during this project were negative for *Phytophthora*. The results of this project provide a baseline data set for future monitoring, and have highlighted a number of trees which are showing some potentially concerning symptoms. These specific trees will be assessed by the Plant Health team who will decide on further action required.

Our laboratory facilities, based at the nursery site, enable the Plant Health team to carry out microbiology work for identification of pathogens by microscopy. When required we will also send pest and pathogen samples to universities or Fera for molecular characterisation. In addition to looking at pathogens in the laboratory we also conduct our own testing of soil pH and conductivity, which can be useful when determining whether symptoms seen on a plant are caused by disease or by nutrient deficiency. The temperatures in our compost heaps are also monitored and recorded by the Plant Health team to ensure that they reach sufficiently high temperatures for a long enough period to safeguard against pests and pathogens being inadvertently spread around the gardens where the compost is used.

The Eden Project team

All of the plant health operating procedures we have in place at Eden Project require everyone on the Horticulture team to work together.

The Eden Project biomes

Plants being brought into the rainforest biome as part of the first plantings

The horticulturalists out in the gardens and working at the nursery report potential problems to the Plant Health team, as well as completing the plant movement records. These records are managed by a dedicated Plant Records Scientist, using the database application BG-BASE, and they provide all the details required by the Plant Health team to operate the quarantine facility effectively. This includes the date plants arrived in quarantine, the original provenance of plants, where the plants were before on the Eden site (if not new plants) and any pest and disease issues previously identified in quarantine. Once armed with all of this information the Plant Health team is able to advise on control measures as required, plant movement around site, notifiable diseases and integrated pest management programs.

The on-going use of quarantining, restrictions on plant movements and the inspection of organic materials entering the gardens will help to safeguard our valuable plant collection for the future.

Rachel Warmington & Katie Treseder
Eden Project, Bodelva, Cornwall, PL24 2SG
rwarmington@edenproject.com

RESOURCES

In the framework of the IPSN, BGCI has developed a number of resources over the last few years aimed at building capacity and capability in the area of plant health and biosecurity amongst botanic garden and arboretum staff.

All resources are available to IPSN Member Gardens through the 'Members only' area on the IPSN website. IPSN membership is completely free and open to all botanic gardens and arboreta. To find out more please go to: http://www.plantsentinel.org/get-involved

IPSN Plant Health Checker

Available for broadleaf (pg 33-34) and conifer trees (pg 35-36), this form allows users to assess, monitor and record damage on infected trees in a standardised format.

It is accompanied by a comprehensive guide detailing how to use the forms and providing details, including images, of common signs and symptoms to be aware of. It also helps to identify when a problem should be escalated both internally, e.g. to senior staff/different department, and externally, e.g. to seek help diagnosing a problem or to report any quarantine/organisms of statutory concern to the relevant authority.

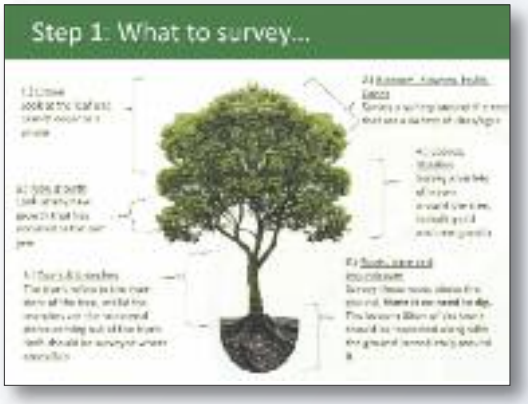
IPSN Guides

Plant Biosecurity in Botanic Gardens and Arboreta: this guide provides principles of good biosecurity; precautionary steps aimed at reducing the risk of introducing and/or spreading harmful organisms. This is particularly important for botanic gardens and arboreta as they move plant material regularly and have valuable/rare plant collections to protect.

Plant Health Governance: this guide introduces the structure of organisations that govern plant health policy. Botanic gardens and arboreta have a legal and moral responsibility to carry out good biosecurity; knowing and understanding relevant plant health policy is therefore important and can aid day-to-day working.

Submitting Physical Samples: this guide provides help on how to submit a diagnostic sample and how procedures change depending on what type of material is being sent. This may be important to ensure a diagnosis of a particular pest or disease outbreak, and helps to save time, money and resources that would otherwise be lost due to samples being submitted wrongly.

Taking Photographs for Diagnostic Purposes: this guide provides information on how to take photos which will enable diagnosticians to make an initial assessment of signs and symptoms (or for the garden's own record to monitor damage).
Photos will not be used to diagnose a plant pest or pathogen, but can be used to determine whether a physical sample is required for further investigation.



IPSN Posters

The IPSN has produced a series of posters detailing new and emerging pests and diseases of iconic UK tree species; including English oak (*Quercus robur*), European ash (*Fraxinus excelsior*), and *Pinus* spp. The organisms included all have the potential to enter the UK, either through trade or via natural spread, in the near future and are known to have a damaging effect on these species. Making UK botanic gardens and arboreta aware of these organisms could help in their early detection - should they be introduced – an important step in stopping their establishment and spread. A template has been designed in order to allow other countries to create their own poster series.

Similarly, the IPSN has developed a poster for *Xylella fastidiosa*, a bacterium causing damage worldwide due to its effects on various important plant species including grapes (Pearce's disease) and olives.

Targeted surveys

The IPSN has been developing a number of materials for supporting botanic gardens and arboreta in carrying out targeted surveys for specific organisms. These are designed to collect valuable information for plant health scientists, addressing knowledge gaps for known damaging and potentially invasive organisms. This information will be used to support the development of Pest Risk Analyses (PRAs) and management techniques.

International Plant Sentinel Network

Plant Health Checker - Step 1

Name of Botanic Garden / Arboretum:	
Country:	
Address:	
Name of IPSN contact:	

Survey details

Survey carried out by:	
Date of survey:	
Best description of season:	

Main reason for surveying this particular individual:

Plant details

Species (Cultivar):	
Accession number:	
GPS	
Country/region species is native to:	
Age/amount of time plant has been present in gardens:	

General Comments:

General description (please tick)

Generally healthy	✓	Some damage	✓
Dying	✓	Dead	✓

Any recent changes in health or overall look:

General description of environment

Any management issues (e.g. irrigation, soil pH, sun bleaching) or any recent use of pesticides/ fungicides/ herbicides:

Description of environment (focusing on recent changes and individuals in close proximity):

For each section of the plant give it a rating dependent on how healthy it appears:

Red (R) = In very poor health and of imminent concern due to significant damage potentially resulting in death of individual

Orange (O) = Not currently a concern but could develop; should be checked frequently to monitor progress

Green (G) = As would be expected on a 'healthy plant'

Black (X) = Absent/not applicable

Where an **orange or red** rating is given, ensure you give a description of why you've given it this rating in notes.

1.) Crown

R ✓ O ✓ G ✓ X ✓

2.) Cones

R ✓ O ✓ G ✓ X ✓

3.) New growth

R ✓ O ✓ G ✓ X ✓

4.) Needles / Leaves

R ✓ O ✓ G ✓ X ✓

5.) Trunk & branches

R ✓ O ✓ G ✓ X ✓

6.) Base and Roots (if exposed)

R ✓ O ✓ G ✓ X ✓

Notes:

What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)*						Reference/file name of any photographs taken:	
1.) Is a re-survey required?	✓	2.) If yes, in what timeframe **(include a suggested date)**		3.) Should this be escalated to an appropriate staff member to carry out STEP 2?	✓	4.) Name of person escalated to *(if applicable)*:	5.) Date:

Conifer trees

Accession number:_____ Survey completed by:_____ Date:_____

Plant Health Checker – Step 2

Please read: This section should be completed if escalation is specified by STEP 1. It should be carried out by an appropriately trained staff member who has the relevant knowledge concerning the plant's history and/or pest and pathogen identification skills.

Tick all signs/symptoms that are at abnormal levels or are unexpected for the individual, and are thus cause for concern (e.g. are out of the ordinary/new to the plant). Give a description and an indication of severity/abundance in the **notes**, plus note anything else of importance or interest.

1. Crown

Thin /sparse		Notes:	
Yellow needles			
Dead wood			
Brown patches of needles/leaves			
Size	1-2cm (½-1in)	Single patch	
	3-4m (10-14ft)	Multiple patches	

2. Cones

Dead		Notes:	
Malformed			
Swollen			

3. New Growth

Dead		Dieback	
Wilted		Malformed	

Notes:

4. Needles/leaves

Dead		Malformed	
Discoloration		Rust	

4. Needles

Dieback of needles along branch			
Age of needles affected (year 1,2,3,4 etc.)			
Approx number of needles effected (%)			
Discoloration (spots/bands) on needles			
Light green / yellow		Single bands	
Brown / red		Numerous	
Approx number of needles effected (%)			

Notes:

5. Trunk & Branches

Canker or lesion		Approx. number	
Dry		Gummy/sticky	
Approx. height of canker from ground (m)			
Galls		Approx. size (m)	
Trunk bleeding ('weeping patches')			
Approx. height of bleed from ground (m)			
Approx. number of bleeds over trunk (m)			
Vertical bleeds (in a line up the trunk)		Horizontal bleeds (around the trunk)	
Loose Bark / bark flaking / comes off easily			

Notes:

6. Base and Roots (if exposed)

Bootlaces/black strands *(1-2mm wide)*			
Fungal mycelium/white strands			
Mushrooms/toadstools on plant			
Damage by mammals		Notes:	
Decay / Rotting			
Wet		Dry	

7. General pest damage

		Location (e.g. leaf)
Insect galleries under loose bark		
Insect eggs		
Chewing damage		
Insect webbing		
Insect mines		
Frass		
Bore holes *(circle below)*		
<5mm / 5-10mm / >15mm		

Notes:

8. Pest sightings

(give an indication of how sure you are of this identification)

		Location (e.g. leaf)	Photo (File name)

9. General Observations and Additional Notes

Reference/file name of any photographs taken:

What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)*		1.) Is a re-survey required?		2.) If yes, in what timeframe *(include a suggested date)*	
3.) Should this be reported to the local diagnostic laboratory - a physical sample may be required *(this is only if symptoms are severe or if a pest of concern)*		3.) Date reported:		4.) Should this be escalated to local National Plant Protection Organisation (NPPO)? *(as advised by local diagnostic laboratory)*	5.) Date reported:

International Plant Sentinel Network

Plant Health Checker - Step 1

Name of Botanic Garden / Arboretum:	
Country:	
Address:	
Name of IPSN contact:	

Survey details

Survey carried out by:	
Date of survey:	
Best description of season:	

Main reason for surveying this particular individual:

Plant details

Species (Cultivar):	
Accession number:	
GPS	
Country/region species is native to:	
Age/amount of time plant has been present in gardens:	

General Comments:

General description (please tick)

Generally healthy	✓	Some damage	✓
Dying	✓	Dead	✓

Any recent changes in health or overall look:

General description of environment

Any management issues (e.g. irrigation, soil pH, sun bleaching) or any recent use of pesticides/ fungicides/ herbicides:

Description of environment (focusing on recent changes and individuals in close proximity):

For each section of the plant give it a rating dependent on how healthy it appears:

Red (R) = In very poor health and of imminent concern due to significant damage potentially resulting in death of individual

Orange (O) = Not currently a concern but could develop; should be checked frequently to monitor progress

Green (G) = As would be expected on a 'healthy plant'

Black (X) = Absent/not applicable

Where an **orange or red** rating is given, ensure you give a description of why you've given it this rating in notes.

1.) Crown

R ✓ O ✓ G ✓ X ✓

2.) Flowers / Fruits *(circle)*

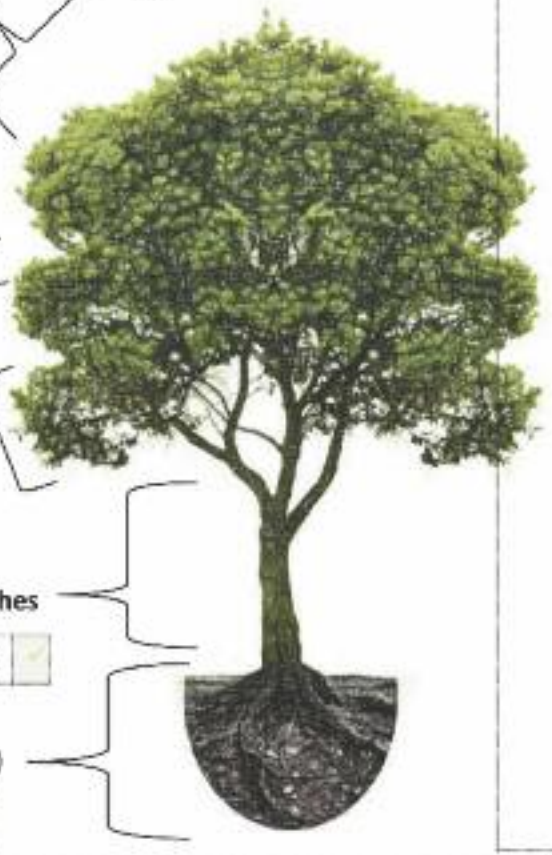
R ✓ O ✓ G ✓ X ✓

3.) New growth

R ✓ O ✓ G ✓ X ✓

4.) Leaves

R ✓ O ✓ G ✓ X ✓



5.) Trunk & branches

R ✓ O ✓ G ✓ X ✓

6.) Base and Roots (if exposed)

R ✓ O ✓ G ✓ X ✓

Notes:

What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)*						Reference/file name of any photographs taken:	
1.) Is a re-survey required?	✓	2.) If yes, in what timeframe **(include a suggested date)**		3.) Should this be escalated to an appropriate staff member to carry out STEP 2?	✓	4.) Name of person escalated to *(if applicable)*:	5.) Date:

Deciduous trees

Accession number:_____ Survey completed by:_____ Date:_____

Plant Health Checker – Step 2

Please read: This section should be completed if escalation is specified by STEP 1. It should be carried out by an appropriately trained staff member who has the relevant knowledge concerning the plant's history and/or pest and pathogen identification skills.

Tick all signs/symptoms that are at abnormal levels or are unexpected for the individual, and are thus cause for concern (e.g. are out of the ordinary/new to the plant). Give a description and an indication of severity/abundance in the **notes**, plus note anything else of importance or interest.

1. Crown

Thin /sparse		**Notes:**
Yellow leaves		
Dead wood		

2. Blossom/Flowers

Dead		**Notes:**
Malformed		
Swollen		

3. New Growth (Shoots and Buds)

Dead		Dieback	
Wilted		Malformed	

Notes:

4. Leaves

Dead		Malformed	
Smaller than expected (stunted)		Mosiacs / mottled / variation in colour	
Sticky		Galls	
Rust		Mildew	

4. Leaves continued (leaf spots)

Single		Numerous	
Present only at the edge		All over leaf	
Only on old growth		Only on new growth	
Yellowing (chlorotic leaves)		Brown/blackeing (necrotic leaves)	

Notes:

5. Trunk & Branches

Canker or lesion		Approx. number	
Dry		Gummy/sticky	
Approx. height of canker from ground (m)			
Galls		Approx. size (m)	
Trunk bleeding ('weeping patches')			
Approx. height of bleed from ground (m)			
Approx. number of bleeds over trunk			
Vertical bleeds (in a line up the trunk)		Horizontal bleeds (around the trunk)	
Loose Bark / bark flaking / comes off easily			

Notes:

6. Base and Roots (if exposed)

Bootlaces/black strands *(1-2mm wide)*			
Fungal mycelium/white strands			
Mushrooms/toadstools on plant			
Damage by mammals		**Notes:**	
Decay / Rotting			
Wet		Dry	

7. General pest damage

		Location (e.g. leaf)
Insect galleries under loose bark		
Insect eggs		
Chewing damage		
Insect webbing		
Insect mines		
Frass		
Bore holes *(circle below)*		
<5mm / 5-10mm / >15mm		

Notes:

8. Pest sightings

(give an indication of how sure you are of this identification)

		Location (e.g. leaf)	Photo (file name)

9. General Observations and Additional Notes

Reference/file name of any photographs taken:

What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)*		1.) Is a re-survey required?		2.) If yes, in what timeframe *(include a suggested date)*	
3.) Should this be reported to the local diagnostic laboratory - a physical sample may be required *(this is only if symptoms are severe or if a pest of concern)*		3.) Date reported:	4.) Should this be escalated to local National Plant Protection Organisation (NPPO)? *(as advised by local diagnostic laboratory)*		5.) Date reported:

Please join Botanic Gardens Conservation International (BGCI) and help us to save plants from extinction

Membership Benefits

BGCI's INSTITUTIONAL MEMBERSHIP

Members receive numerous benefits:

- A membership pack, including a Certificate of Membership
- BGCI's publications, including *BGJournal* and *Roots* (hard copy or digital)*
- Eligibility for BGCI's Twinning Scheme
- Eligibility for BGCI project funding
- Eligibility for subsidized BGCI training courses
- Eligibility for BGCI prizes and awards
- Botanic Garden technical support and advisory services
- Access to PlantSearch botanic garden accession data (opt in option)
- Use of the BGCI website to promote your events and news
- Eligibility for substantial discounts on attendance of BGCI Congresses.
- Permission to use BGCI's logo and name
- Eligibility for BGCI's Featured Garden Promotion

Established in 1987, BGCI links more than 500 botanic gardens and conservation organizations in 115 countries, working together to save Plants for the Planet.

Patron and Principal Members have additional access to special privileges and events:

- Membership of BGCI's International Advisory Council
- Preferential funding and project development activities
- Speaking opportunities at BGCI Congresses
- BGCI special event invitations
- BGCI website articles and features
- Office space and office support when visiting London
- Eligibility for BGCI's Featured Garden Promotion

Institution Membership		£ Stlg	US $	€ Euros
A	BGCI Patron Institution	5,500	8,500	7,500
A/B	Principal member	1,900	3,000	2,275
B	Institution member (budget more than US$2,250,000)	1,100	1,650	1,325
C	Institution member (budget US$ 1,500,000 - 2,250,000)	600	990	770
D	Institution member (budget US$ 750,000 - 1,500,000)	440	715	550
E	Institution member (budget US$ 100,000 - 750,000)	240	385	310
F	Institution member (budget below US$100,000)	110	165	130

BGCI's INDIVIDUAL MEMBERSHIP & DONORS

support BGCI's global network for plant conservation, and are connected to it through our publications and events. Members receive regular publications of *BGjournal, Roots* & *Cultivate* and invitations to BGCI congresses and discounts on registration fees

Individual Membership		£ Stlg	US $	€ Euros
J	Conservation donor	275	450	375
K	Individual member	80	125	100

*Many of these publications have been translated into Chinese, French and Spanish. Please contact us for more details.

❑ **I wish to apply for BGCI's INSTITUTION / INDIVIDUAL membership (circle one).**

Institution Name (if applicable) .....

Contact Name ..... Title .....

Address .....

.....

Telephone..... Fax .....

E-mail .....

Website .....

Membership category (A-K) ..... Annual rate .....

Please clearly print your name (or the name of your institution) in English on all documentation.
An official invoice will be issued outlining the various payment methods when your membership application has been accepted.

Please contact info@bgci.org for further information.

This publication is supported by

Department for Environment Food & Rural Affairs

Euphresco

BGCI
Plants for the Planet

Botanic Gardens Conservation International

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

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

Printed on 100% recycled paper

ISSN 1811-8712

CONSERVATOIRE ET JARDIN BOTANIQUES GENÈVE

VILLE DE GENÈVE

CICG
CENTRE INTERNATIONAL DE CONFÉRENCES GENÈVE

26th - 30th June 2017

6th Global Botanic Gardens Congress

Les Jardins botaniques dans la société : Visions pour l'avenir

Botanic Gardens in Society : Visions for the Future

Hosted by the Conservatory and Botanical Garden of the City of Geneva, Switzerland, at the International Conference Centre of Geneva (CICG).

The scientific programme will explore the role and relevance of botanic gardens in today's society. The congress, a forum for the exchange of ideas on future opportunities as well as potential challenges faced by botanic gardens, aims to explore creative and innovative ways to engage botanic gardens and their expertise with and for society. The main themes of Science and society, Plant conservation, Education and outreach, Capacity building and Management challenges for botanic gardens in the future, will be complemented by workshops or discussion sessions on specific topics.

Information on the congress programme and registration will be made available, via the BGCI website, in July of this year.

BGCI
Plants for the Planet