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Botanic gardens and invasive alien species

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Cover Photo: Impact of Emerald Ash Borer on a stand of Ash trees in the USA (Andrew Gapinski)

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www.seascapedesign.co.uk

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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)20-37252692. 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

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United Nations Decade on Biodiversity 2011-2020

EDITORIAL:
Tackling invasive species

Tackling invasive species is a major global challenge. The CBD's Strategic Plan for Biodiversity 2011-2020 recognises that the impact of invasive species is one of the main underlying causes of biodiversity loss and has set a specific target that: *By 2020, invasive alien species and pathways are identified and prioritised, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment*. Botanic gardens and our networks are well placed to help implement this target and the related Target 10 of the GSPC. With the long tradition of growing introduced species, botanic gardens can and do test invasiveness and help identify the pathways of invasive species. Botanic gardens are also frequently involved in the eradication of invasive species both within their grounds and in natural areas.

Sharing information and resources is crucial for solving major environmental problems. The paper by Andrea Kramer and Abby Hird describes how BGCI is developing its databases to help share information on invasive species management between botanic gardens and how collaboration can be further strengthened. The paper by Peter Symes describes practical examples of collaboration between botanic gardens and plant health agencies in dealing with invasive plant pests and diseases. Voluntary codes of conduct, such as those described by Sarah Reichard and Vernon Heywood can remind botanic gardens of the steps they should take in relation to invasive species will be incorporated into the updated version of the *International Agenda for Botanic Gardens in Conservation*. While Quentin Groom and co-authors describe some examples of negative introductions from botanic gardens, Olivier Filippi and James Aaronson make the point that not all exotic plants introduced for use in gardens and amenity planting are bad.

BGCI is currently preparing an online Toolkit to support implementation of the GSPC. We will include the codes of conduct on invasive species along with other guidelines and practical case studies in the section on Target 10: *Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded*. We will be pleased to inform you when the Toolkit is available for review and welcome input from you to make this a successful resource for plant conservation around the world.

Managing natural areas that have been invaded by introduced species is time consuming and expensive but can be successful, as described by Christoph Kueffer for island ecosystems. Removal of invasive species is crucial for the conservation of threatened plants and more broadly for ecological restoration. In March this year a group of leading botanic gardens met with BGCI to plan the first steps towards a global Ecological Restoration Initiative. You can read more about this on BGCI's website. BGCI has agreed to coordinate this initiative as it develops. Botanic gardens have so much to contribute to restoring the damaged earth – tackling invasive species is an important part of the action.

Sara Oldfield
Secretary General, BGCI

Authors: Andrea Kramer and Abby Hird

BUILDING AN INTERNATIONAL SENTINEL PLANT NETWORK

Botanic gardens should be expanding their leadership role in addressing invasive species and a Sentinel Plant Network could facilitate this

Introduction

Invasive plants, pests and pathogens are among the greatest threats to the world's biodiversity and they pose a significant threat to global economic health (Pimentel *et al*., 2005), with estimated costs of US$350 billion annually (Sheppard *et al*., 2003). Botanic gardens play an important leadership role in protecting the world's plant diversity and minimizing the impact of invasive species. Many botanic gardens and arboreta work individually and collaboratively to address invasive species issues by: 1) educating visitors about invasive plant, pathogen, and insect species; 2) monitoring collections to evaluate the invasive potential of introduced plant species in new climates and sharing information with relevant stakeholders; 3) monitoring collections to identity potentially new invasive pests or pathogens; 4) working with relevant stakeholders to contain, control, and raise awareness about invasive species; and 5) helping public and private partners identify alternative non-invasive plant species. Given the scope and acceleration of invasive species problems, there is a need for botanic gardens to continue to expand their leadership role in addressing invasive species. Here, we describe how the formation of an International Sentinel Plant Network will facilitate this; share results of a worldwide survey to identify resources and expertise for a Sentinel Plant Network; and describe the steps that BGCI and the botanic garden community can take to move the idea of an International Sentinel Plant Network (ISPN) from a concept to a reality.

An International Sentinel Plant Network

It is estimated that 30-40% of known plant species are grown in living collections of the more than 2,500 botanic gardens and arboreta throughout the world. Often, species are maintained at gardens not in the country or even on the continent in which they are native. This presents a significant opportunity to understand and predict when and where species may become invasive pests, or when and where they may be susceptible to other pests (e.g. fungus and insects).

> *"An International Sentinel Plant Network has been proposed as a formal structure under which gardens can act individually and collectively to increase the predictive power of their collections, and to engage other partners who can use this information."*

Specifically, it has been proposed that botanic gardens and arboreta from around the world work together to form an ISPN, where living plant collections information is dynamically connected and capable of serving as an early warning system to predict, detect, and prevent the incursion of new invasive pests (insects, plant pathogens, or invasive plants). The idea of a sentinel network focused on invasive species is not new, and in a few cases model programs (such as New Zealand's expatriate plant pilot program) have been successfully implemented on a national scale (see Britton *et al*., 2010 and Box 1).

A clear example of why an ISPN could help mitigate environmental and economic costs via early detection and prevention of new pests comes from the 2002 discovery of the Emerald Ash Borer in Michigan, United States. The infestation of this beetle (native to Asia) was not identified in time to eradicate it and prevent its spread, and its range is now rapidly increasing throughout the United States and Canada. After only five years, over 53 million native ash trees (*Fraxinus* spp.) were killed by the beetle, and in the next ten years the infestation is predicted to cost an estimated $10.7 billion to treat, remove, and replace the more than 17 million planted ash trees likely to be killed in urban areas alone (Kovacs *et al*., 2010). In hindsight, if an ISPN had been in place, botanic gardens in Asia growing North American ash species potentially could have reported any unusual insect damage, and the extreme susceptibility of North American ash trees to the Emerald Ash Borer could have been predicted and measures put in place to monitor and eradicate occurrences before they became too large to control. Further, a monitoring network of gardens

Figure 1: Map of 146 institutions responding to the ISPN survey. Colors indicate whether institutions offer assistance with pest, pathogen or plant identification to visitors (yes = green, no = orange, gray = don't know). Ninety percent (90%) of responding institutions provide assistance on these topics.

and garden visitors in the United States may have helped detect the pest early enough to eradicate it.

Below, we present results of a recent global survey aimed at identifying current capacity to monitor for potentially new and invasive insects, plant pathogens, and plants in the botanical community, and discuss key steps botanic gardens and arboreta around the world can take to be a part of establishing an ISPN.

BGCI's International Sentinel Plant Network Survey

Support from the U.S. Department of Agriculture allowed BGCI to develop and carry out an electronic survey during the spring of 2011 to learn more about the relevant expertise and policies in place at botanical institutions around the world that could help form the basis of an ISPN.

This survey was available in English, Chinese, and Russian, was open for three months, and was advertised through email, list serves, and other websites and newsletters. In total, 204 respondents from 146 botanical institutions in 15 countries completed the survey (Figure 1). Results revealed a solid foundation of expertise, resources, partnerships and practices already in place to understand and address invasive species problems at individual institutions, but a need for more formal or regular training and enhanced communication and coordination among institutions in order to increase the power and impact of the network.

Survey Results

Policies and Programs

Sixty five percent (65%) of responding institutions have invasive species policies or programs in place to help minimize the risks posed by insect pests, plant pathogens, or potentially new invasive plants. An additional 29% don't yet have invasive species policies or programs in place, but would like to.

Monitoring

Nearly 96% of responding institutions monitor collections 'regularly' or 'whenever possible' for insect pests, while nearly 89% monitor for plant pathogens and 88% monitor for invasive plants (Table 1).

Staff and Resources

Some 57% of respondent institutions provide their staff with regular training about pests, pathogens and/or potentially new invasive plants. An additional 37% don't yet, but would like to. Many respondents said they had adequate staff and resources to identify insect pests (85.0%), plant pathogens (70.0%), and invasive plants (87.3%), but many could use more, particularly to identify plant pathogens (Table 2).

Many respondent institutions employ expertise to identify and address invasive species, including in the fields of horticulture (86.8%), plant taxonomy (74.3%), entomology (35.4%), plant pathology (29.2%), and mycology (16.7%) (Figure 2).

How often does institution monitor collections for:	Insect pests	Plant Pathogens	Invasive Plants
Regularly	62.80%	45.10%	51.80%
Whenever possible	32.80%	43.60%	36.70%
Never, but this is a future priority	0.00%	2.30%	6.50%
Never	2.90%	7.50%	2.90%
I don't know	1.50%	1.50%	2.20%

Table 1

Does institution have adequate expertise and resources to identify:	Insect pests	Plant Pathogens	Invasive Plants
Yes	41.00%	24.10%	59.70%
Yes, but we could use more	44.00%	45.90%	27.60%
No, we rely entirely on partners	12.70%	21.80%	9.70%
No, we don't identify these	1.50%	7.50%	5.20%
I don't know	0.70%	0.80%	0.70%

Table 2 ▲

▼ Table 3

Does institution utilize outside resources or partners to help identify:	Insect pests	Plant Pathogens	Invasive Plants
Yes	82.50%	82.00%	59.70%
No, but we want to	8.80%	11.30%	11.90%
No, we don't see a need for this	6.60%	6.00%	27.60%
I don't know	2.20%	2.30%	3.70%
Partner Type	**Insect pests**	**Plant Pathogens**	**Invasive Plants**
University researchers/staff/facilities	68.80%	66.00%	53.50%
Government agency staff/facilities	41.00%	35.40%	27.80%
Outside consultants/facilities	23.60%	21.50%	16.00%
Volunteers	11.10%	6.90%	9.00%

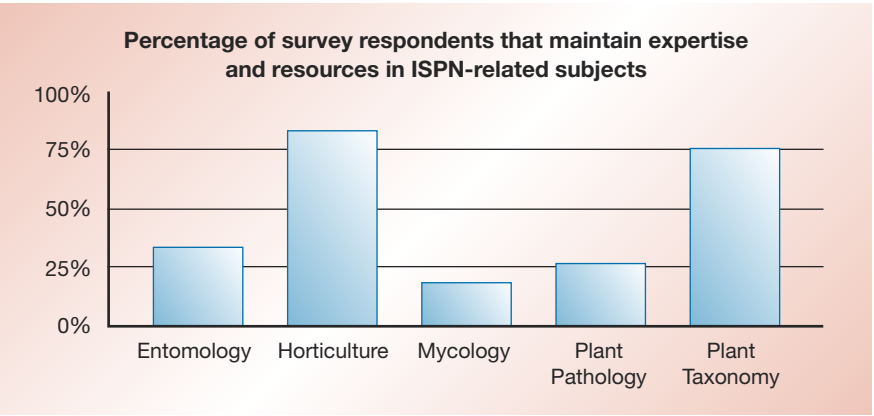
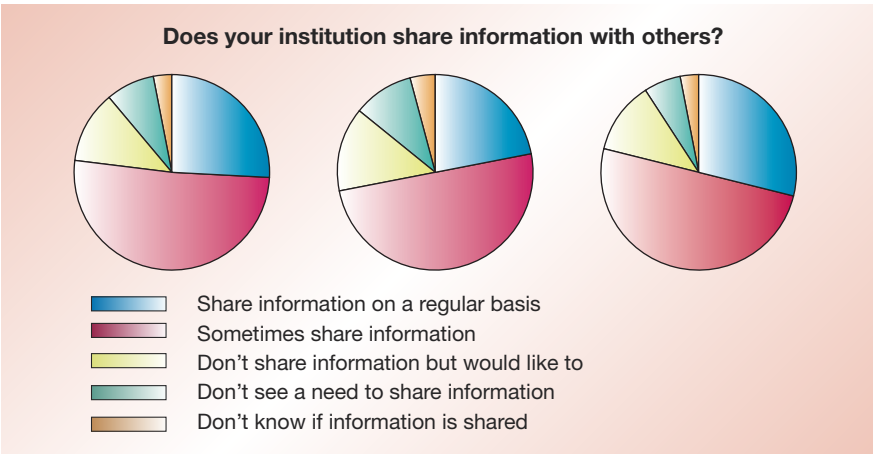


Figure 2 ▲

▼ Figure 3



Outside Resources and Partners
Most respondent institutions also utilize outside resources or partners to assist in identification of insect pests (82.5%), plant pathogens (82.0%), and invasive plants (59.7%). Many institutions partner with universities or government agencies for identification (Table 3); a few institutions utilize volunteers.

Information Sharing
Most institutions reported sharing information on insect pests, plant pathogens, and invasive plants found in their living collections with others at least sometimes, while several institutions don't currently share this information, but would like to do so in the future (Figure 3).

How your institution can get involved

Locally
Be aware that identification of insect pests, plant pathogens, and invasive plants is an important and often limiting resource in invasive species work. Identify partners with complementary needs and resources and find ways to work together to address current invasive species problems in your community while predicting and preventing future invasive species.

Use your living collections to support research on invasive species if you have the resources to do so. If not, make your collections available to support the research of other collaborators and partners.

Regionally and Nationally
Become involved in current invasive species programs or consider starting a program with partners. Introduce yourself to your state/provincial agencies involved with invasive species monitoring and prevention, and communicate regularly with them on any suspicious insect, pathogen, or plant detected in your living collection.

Globally
Update your institution's collections information in PlantSearch to facilitate communication, collaboration and research using your living collections. It is quick, easy, and FREE. Every living collection, large and small, can help support collections-based research and collaboration for threatened as well as

BOX 1: Examples of what botanic gardens and networks are doing to address invasive species

Insect pests and plant pathogens

- With support from the US Department of Agriculture, the American Public Gardens Association is working with the National Plant Diagnostic Network to engage public garden professionals, volunteers, and visitors in the detection and diagnosis of high consequence pests and pathogens: www.publicgardens.org/content/sentinel-plant-network.
- The Morton Arboretum's online Plant Health Care Reports provide detailed monthly updates on the occurrence of pests and pathogens on their collections and in the Chicago area: www.mortonarb.org/tree-plant-advice/category/97/plant-health-care-reports.html.
- The Royal Botanic Gardens Melbourne has developed a Pest Database, Biosecurity Policy, and Weed Strategic Plan to provide principles and practices that reduce the risk of new pest introductions to and from its landscape: www.rbg.vic.gov.au/horticulture/environmental-management/biosecurity and p. 7-13 in this issue.

Invasive plants

- The European Botanic Gardens Consortium shares information and policy on potentially invasive alien plants in botanic gardens: http://plantnetwork.org/ebg-consortium/alien-plants/
- The Chicago Botanic Garden has endorsed the Voluntary Codes of Conduct for Botanic Gardens and is implementing the Codes as detailed in its invasive plants policy: www.chicagobotanic.org/research/conservation/invasive/policy.php.
- The Australian Botanic Gardens Weed Network was established in 2003 and includes 75 member institutions that developed common invasive plant policies and procedures, as well as a weed risk assessment procedure and management software (Spencer *et al*., 2006): www.bganz.org.au/resources.
- In the U.S., staff at the University of Washington Botanic Garden and Montgomery Botanical Center have partnered with others to develop a Weed Risk Assessment for botanic garden decision making: www.bgci.org/files/Dublin2010/papers/Husby-Chad.pdf.

invasive species by uploading a simple spreadsheet of taxa maintained in living collections to BGCI'S PlantSearch database. Additional instructions can be found here: www.bgci.org/usa/plant searchinstructions.

Use PlantSearch now to connect directly to other living collections managers on a species-by-species basis. For example, use PlantSearch's request function to ask other garden staff if they have detected certain pests on a specific plant, or if they have seen invasive characteristics in certain plant species in certain environments.

Finally, make sure your institution's GardenSearch profile is up-to-date (www.bgci.org/garden_search.php), especially if you maintain resources, expertise, and policies relevant to an ISPN (see Figure 2). Future updates to BGCI's databases will allow users to access information about specific resources, expertise, and eventually plant collections at gardens around the world. This information will help form the basis of an International Sentinel Plant Network, and allow us to deliver tools, information and updates to appropriate staff at botanical institutions.

Conclusion

There is a great need for action to prevent the economic and environmental impacts of future insect pests, plant pathogens, and invasive plants, and botanic gardens around the world have the resources and expertise to help. An International Sentinel Plant Network can make this work more coordinated and impactful by supporting and expanding current efforts to monitor and connect collections, share information, and collaborate at local, regional and global levels.

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Andrea Kramer
BGCI US at Chicago Botanic Garden
1000 Lake Cook Road
Glencoe,
IL 60022,
USA

Abby Hird
BGCI US at the Arnold Arboretum of Harvard University

RBG Melbourne staff removing Eryngium agavifolium - *a species noted for eradication from the Gardens due to observation of heavy recruitment in aquatic marginal environments (RBG Melbourne)*

BIOSECURITY
ROYAL BOTANIC GARDENS MELBOURNE

Author: Peter Symes

Increasing globalisation means that botanic gardens must set a priority agenda to develop biosecurity management, policy and practices to reduce the risk of introducing or spreading invasive species.

Introduction

Biosecurity describes the protection of living plant assets, environmental habitat, and industries from biological threats such as 'pests' that may cause damage or disease. The term pest is accepted as a generic definition (IPCC, 2011) for a biological threat that is detrimental to biodiversity, natural habitats, and plant health. Some examples include pathogenic micro-organisms, insects, mites, pest animals, and pest plants.

It is likely that every botanic garden around the world will have serious exotic pests to consider as threats to living plant collections. These risks should also be considered in the context of climate change that has the potential to create conditions suitable for new and emerging exotic pests. Furthermore, globalisation has increased the fluidity of world-wide transport systems, and subsequently, the chances of a serious pest finding purchase in another country, region or garden (Victorian Government, 2009). For example, seeds are often purchased over the internet and readily posted to a customer anywhere in the world, and these packages are not always intercepted by quarantine services. An international traveller with seed or pest-contaminated footwear could easily visit a botanic garden on their first excursion, and walk onto a garden bed to take a photograph.

Over the last decade, a greater emphasis has been placed on the protection of horticultural industries from pest incursions in Australia with Biosecurity Plans developed by Plant Health Australia in association with many agricultural industries and the Nursery and Garden Industry (PHA, 2008). For southern Australian botanic gardens, future serious exotic pests include Asian Gypsy Moth, Dutch Elm Disease (*Ulmus* spp.), Eucalyptus/Guava Rust (see Box 1),

Box 1: Eucalyptus/Guava Rust

In April 2010, Myrtle Rust (MR) *Uredo rangelii*, a member of the 'eucalyptus/guava rust complex' was detected for the first time in NSW, Australia. Myrtle Rust has been found infecting a wide range of both native and exotic plants belonging to the Myrtaceae family, including the familiar *Eucalyptus* spp., *Melaleuca* spp. and *Leptospermum* spp. Myrtaceae is an iconic plant family in Australia with many endemic species. The disease has spread rapidly along the eastern seaboard of Australia and is now found from Northern Queensland to Southern NSW in bushland, gardens and nurseries, (State of New South Wales, 2011) with some detections occurring only about 100 km from the Victorian border. Infections have already occurred in botanic gardens in NSW. As MR is severely infecting plants in natural areas as well as garden situations, it may lead to some species (which have not developed natural resistance against the disease) becoming threatened. The reduction or loss of plant species would also likely impact the natural ecology and life cycles of other organisms.

RBG Melbourne has implemented precautionary procedures and surveillance programs. However, rust fungi are easily spread by spores via the wind, on people's clothing or on vehicles, and it will be difficult (if not impossible) to eradicate. Containment and control is also a huge challenge as this mostly relies on frequent applications of full coverage chemical sprays which are unsustainable from an environmental and resource perspective.

In March 2011, the Australian National Botanic Gardens convened a National Myrtle Rust Workshop to consider the threats from Myrtle Rust to Myrtaceae in natural habitats, and in *ex situ* plant collections. More information can be found at the Council of Heads of Australian Botanic Gardens website. http://www.anbg.gov.au/chabg/myrtle-rust/index.html

CHABG, 2011.

Pine Pitch Canker and Sudden Oak Death. These threats highlight the need to be prepared for potentially devastating pest incursions.

At the Royal Botanic Gardens Melbourne (RBG Melbourne), the high plant diversity of about 10,000 species means that there are a great number of plants suitable for hosting serious exotic pests, especially when combined with close proximity to trade and travel pathways into Victoria.

Currently, biosecurity is included as a matter for attention within the RBG Melbourne Risk Management Plan. Pest incursions that result in significant damage to the living collections are ranked as a high strategic risk to the organisation. While RBG Melbourne has a responsibility to protect its living assets, it also recognises the magnitude of inadvertently spreading pests beyond its managed land that could damage natural biodiversity and plant-based industries.

Background

Early warning – Fireblight strikes!
In 1997, the RBG Melbourne had the unenviable position of Fireblight (*Erwinia amylovora*) being found on some *Cotoneaster* spp. (Rosaceae) by a visiting scientist (Jock *et al*., 2000). This was the first record of this serious exotic pathogen being found in Australia. Fireblight is a devastating disease particularly for the pome fruit industry (mainly apples and pears) and had very significant implications for international trade. The subsequent eradication program that removed the few infected plants, and a large number of potential host species also resulted in the loss of wild-collected plants from Rosaceae with irreplaceable plants from Southern China. Also removed were important landscape specimens including magnificent trees of *Pyrus pashia* which had been growing in RBG Melbourne for decades. Whilst the eradication program was successful, the importance of active monitoring and surveillance was highlighted and has resulted in heightened awareness, planning and precautionary measures in dealing with biosecurity matters within RBG Melbourne during the past decade. In the interim, hygiene and sanitation practices were implemented and a hygiene protocol document was developed to limit the risk of another undetected incident such as this occurring again or if it was to happen that there would be improved containment measures in place.

Invasive plants management
Prior to 2003, botanical staff had assessed the invasive potential of plants proposed for sale by the Growing Friends. However, there was no formal risk assessment or substantive process to address the weed risk of plants being introduced into RBG Melbourne's living plant collections. Early in 2003, horticultural coordinators at the Garden initiated a management project to develop a Weed Risk Assessment Process (WRAP). A working group was subsequently formed comprising both horticultural and botanical staff to assist with further development of the WRAP, and to develop a Weed Strategic Plan. RBG Melbourne also worked closely with staff from the Department of Primary Industries Victoria (DPI Victoria) to improve the risk assessment components. Strong interest in the process and valuable observations of plant invasiveness by horticultural staff also helped refine the WRAP. In 2004, the Nursery Coordinator developed an interim WRAP database to improve the processing and recording of weed risk

Front screen of the WRAP software package

'Asparagus' Phytophthora symptoms on Agave attenuata *(RBG Melbourne)*

assessment. An information resource '*Garden plants as environmental and agricultural weeds, resource and information pack*' was developed by botanical staff for botanic gardens and public education and made available as a download from the RBG Melbourne website (RBG Melbourne, 2011a).

Later in 2004, the then Weeds Cooperative Research Centre (Aust.) provided funding for an Australian Botanic Gardens Weeds Network (ABGWN) workshop which was held in Melbourne and led by RBG Melbourne botanical staff to confirm policy and the WRAP for adoption across Australia. In 2005, the Council of Heads of Australian Botanic Gardens (CHABG) endorsed a common Weed Policy for Australian botanic gardens, and this was followed by the development of a federally funded and customised software version of the WRAP which is a free download available from the Botanic Gardens Australia and New Zealand (BGANZ) website (BGANZ, 2011).

A scientific analysis of the WRAP was published in the journal Plant Protection Quarterly. The paper assessed the discriminatory power and potential cut-off scores for the test (Virtue *et al*., 2008). The potential for application of the WRAP to industry was noted in the paper and, in April 2011, an industry workshop was held at the Royal Botanic Gardens Sydney to discuss the adoption of the WRAP by the Australian Nursery and Garden Industry and to devise a programme for assessing 1,000 common ornamental plants available in the industry using the WRAP. A researcher has been employed by the industry and the result of the assessment should be known in about a year's time. (See also RIRDC, 2011).

The WRAP project that was initially derived at RBG Melbourne to reduce the risks of introducing or spreading invasive plants has now developed into a national initiative, receiving funding and being accepted by weed scientists and horticultural industries alike.

Pest Incursions - Case Studies

'Asparagus' Phytophthora

In September 2000, an undescribed *Phytophthora* aff. *megasperma* (Asparagus Phytophthora) was detected on Agavaceae in RBG Melbourne for the first time in Australia, and possibly the world. Within two months, about 70 plants from Agavaceae (particularly *Agave* spp.) were killed and or removed due to severe infection. This disease has been a continuing and significant problem to date with devastating impacts primarily on plants from Agavaceae. Over ten irreplaceable, wild-collected *Agave* spp. were killed outright by this disease. Interestingly, in 2005, this *Phytophthora* spp. was finally confirmed via DNA analysis as the same organism originally recorded in 1995 damaging culinary asparagus plants being grown over 40 kilometres to the east of the Gardens in Cranbourne (Cunnington *et al*., 2005). It is possible that the pest originally entered RBG Melbourne via soil supplies as Cranbourne is a common source for sandy loams used in landscapes all over Melbourne. RBG Melbourne had held fears that this disease may also infect Australian plants within natural habitats that had been classified within Agavaceae such as *Doryanthes palmeri* or *D. excelsa*. However, these plants appear to not be susceptible.

In October 2010, *Phytophthora* aff. *megasperma* was detected damaging *Bulbine vagans* – not a member of Agavaceae, but related in order through Asparagales. *Bulbine vagans* is native to northern NSW and Queensland, Australia. This raises the biosecurity issue of the risks for the diseases to spread to natural habitats of *B. vagans*.

To consider further, what would be the implications of a successful incursion of this pathogen into natural habitats of *Agave* spp. in Southwest USA?

Diplodia on Pines

In June 2010, unusual symptoms of dieback on *Pinus muricata* were submitted to Crop Health Services, DPI Victoria. Symptoms identified included stem cankers and dieback, needles dying and resin flow from affected branches. The initial diagnosis was reported as *Botryosphaeria* spp. This 'weakly' pathogenic pest is a common secondary disease in stressed plants and was relatively frequent around the RBG Melbourne due to over a decade of unprecedented drought. However, the RBG Melbourne sought further identification to species level. Further DNA sequence data established the identity of the pathogen as *Diplodia africana* and this was also later detected from a nearby *Pinus patula*. *D. africana* was first described as a new species in South Africa, where it was isolated from shoots of *Prunus* spp. However, this incursion on *Pinus* spp. in the RBG Melbourne appears to be the first record described anywhere in the world. Similarly to other *Diplodia* infections,

Blue staining of timber symptomatic of Diplodia *spp. infections (RBG Melbourne)*

Diplodia africana *on* Pinus muricata *(RBG Melbourne)*

it was thought that predisposing biotic or abiotic stresses were required to initiate infection. In this case symptoms seemed to be related to previous significant hail damage that occurred to trees in March 2010. The area was barricaded and a ban imposed on movement of *Pinus* material within and out of RBG Melbourne. From September 2010, further surveillance by Biosecurity Victoria did not detect *D. africana* in any *Pinus* spp. within or outside RBG Melbourne. Due to the possible risk to commercial pine plantations and amenity trees in general, it was decided to remove these trees to contain the disease as soon as possible under suitable conditions to reduce risk of spreading fungal spores (low wind speed, dry weather), even though pathogenicity had not yet been fully determined. In October 2010, the two infected trees were removed as a joint operation between Biosecurity Victoria

Table 1 - Selected new pest incursions to RBG Melbourne

Detection Date	Pest	Detected Hosts	Comments
May 1997	Fireblight *Erwinia amylovora*	Cotoneaster and Sorbus.	Significant loss of unique provenance and landscape specimens. Disease eradicated.
Sep 2000	'Asparagus Phytopthora' *Phytophthora aff. megasperma*	Mainly Agavaceae	Significant loss of unique wild-collected material and landscape specimens. Limited control achieved by applying phosphonate fungicides.
Jan 2004	Fusarium Wilt (Palms) *Fusarium oxysporum f.* sp. canariensis	*Phoenix canariensis*	One infected palm removed under quarantined conditions. No further infections detected to date
Jul 2004	*Phytophthora niederhauseria*	*Xanthorrhoea australis*	First record in Victoria. Plant removed. No further detections. Has since been found as records elsewhere in Victoria from taxonomic reviews.
Nov 2004	Mahonia Rust (*Cumminsiella mirabilissima*)	*Mahonia fortunei*	First known record in Victoria on *Mahonia* spp.
Jun 2010	*Diploda africana*	*Pinus muricata* and *Pinus patula*	First known record in the world infecting *Pinus* spp. Trees were removed under quarantined conditions. *Pinus muricata* was an only accession for RBG Melbourne.
Oct 2010	'Helleborus Black Death' [Helleborus Net Necrosis Virus (HeNNV)]	*Helleborus orientalis*; H X *sternii*	First known record in Australia, since been found in gardens to the east of Melbourne including symptomless plants. Research continuing with Biosecurity Victoria.

and RBG Melbourne staff under quarantined conditions. Subsequent pathogencity testing of *D. africana* completed in December 2010 ultimately found it to be less severe than the more common *D. pinea*. If further incursions of *D. africana* occur this is now considered to be a local management responsibility for RBG Melbourne.

This incident highlights the importance of avoiding assumptions about disease symptoms and or being satisfied with identifications to genus level (which is often influenced by testing costs). If the scenario had involved a more serious pathogen, and RBG Melbourne had not requested further identification, it is conceivable that an epidemic on *Pinus* spp. may have ensued, damaged commercial interests and opened RBG Melbourne to scrutiny and loss of reputation in the community.

These case studies and new incursions highlight the importance of biosecurity to protect botanical living assets, natural habitats and industries. The value of botanic gardens living plant collections and expert staff is emphasised in supporting the work of plant health agencies for detecting pest incursions early. Active surveillance, accurate identification, containment, and establishing pest pathogenicity and host range are vital lessons that were learnt.

Completion of Diplodia africana *eradication operation -disinfection processes underway (D. Smith0*

Relationships with Plant Health Agencies

RBG Melbourne has fostered highly collaborative relationships with plant health agencies both within and outside Australia. In particular, Plant Standards, Biosecurity Victoria has recognised the sentinel value of the diversity of RBG Melbourne's plant collections and are very responsive to notifications of unusual pest symptoms. Personnel will often make the effort to visit and take specimens for analysis at no cost. In 2006, Plant Standards undertook a Hazard Site Surveillance program that operated for two years to inspect large gardens and urban landscapes for serious exotic pests which included RBG Melbourne due to its proximity to the city. There have also been other collaborative projects with Biosecurity Australia in screening for particular exotic pests. Being able to provide current plant records and/or horticultural staff assistance to locate host plants improves the efficiency of the site surveillance, and is noted and welcomed by the personnel involved.

Removal of Pinus patula infected by Diplodia Africana (D. Smith)

In 2007, RBG Melbourne began assisting with the New Zealand (NZ) Expat Plants Project (Biosecurity New Zealand, 2011) which was a component of the Better Border Biosecurity (B3) program. The intent of this forward thinking project was to identify NZ plant collections growing overseas that could then be used as international sentinels of emerging pests that may threaten NZ flora. Some pest affected specimens from RBG Melbourne were collected by NZ researchers under phytosanitary conditions to consider for pest risk to NZ's natural resources. Communication has continued with the B3 program

Symptoms of Helleborus Black Death (HeNNV) on Helleborus *x hybridus (RBG Melbourne)*

when pests on NZ flora are identified. It is also understood that other BGANZ member Australian botanic gardens have assisted with this project.

Pest Database

In 2006, conceptual planning began for developing a system that would integrate recording, education and management of pest problems in RBG Melbourne. In 2008, a pest database was completed as a component of the RBG Melbourne's living plant collections database. It is now possible to produce comprehensive reports of particular hosts, known distribution, treatment history, images of symptoms, etc. This has become a valuable management tool toward improving pest management within RBG Melbourne. Being linked to the plant collections database also means that changes in plant nomenclature or location names are also readily updated.

International Course in Botanic Garden Management (BGCI)

Professional and Public Education

In March 2010, BGCI and BGANZ delivered the International Certificate in Botanic Gardens Management course in Singapore (BGCI, 2011) to a range of participants generally from SE Asia. Two of the modules under horticulture led by RBG Melbourne addressed biosecurity through management of invasive plants and pests.

A range of training is regularly delivered by horticultural staff and external experts for employees, friends and volunteers. Information relating to biosecurity and pest management has also been provided via the website (RBG Melbourne, 2011b).

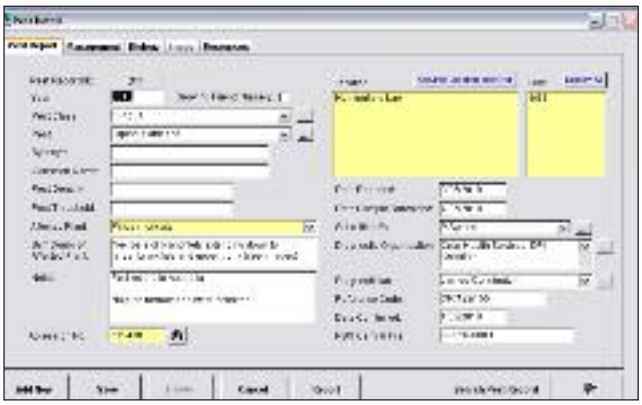
Policy and Procedures

In 2010, RBG Melbourne improved its biosecurity strategy in completing an organisational Biosecurity Policy and is currently reviewing the associated procedures. Within the policy, RBG Melbourne acknowledges the importance of the stewardship of its living assets to protect them from exotic pest threats, and also its responsibility to prevent pest threats to others. The organisation has adopted the philosophy that effective biosecurity includes the implementation of both border quarantine and internal pest management practices such as Integrated Pest Management (IPM) (see Figure 1).

Principles

Underpinning the RBG Melbourne Biosecurity Policy are eight principles:

1. Seek to prevent pest excursion, incursion and further spread.
2. Manage risk of transport of landscape materials across management boundaries.
3. Conduct regular surveillance.
4. Promote plant health according to the prevailing environmental and climatic conditions, and available resources.
5. Implement effective hygiene and sanitation practices.
6. Conduct regular employee training and visitor education programs.
7. Maintain and develop effective relationships with plant health agencies.
8. Continue to develop and improve procedures for effective monitoring, recording and managing pests.



Pest module from the Living Plant Collections Database

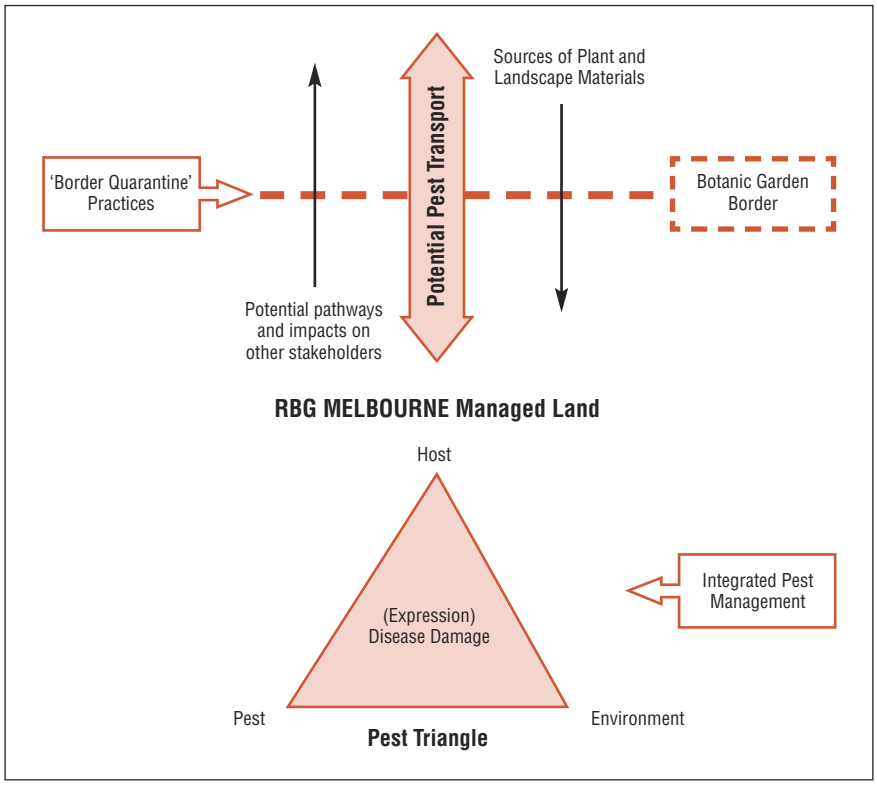


Figure 1- Border Quarantine and Pest Triangle Schematic
Pest Triangle adapted from (Agrios, 1988)

Conclusion

There is an increasingly vital role for botanic gardens to fulfil in protecting the biosecurity of natural environments, cultural landscapes and industries. Whilst the high plant diversity intrinsic to botanic gardens may be seen as a risk to biosecurity, it can actually provide an 'early warning' mechansim through sentinel plants to herald the incursion of a new invasive species. This early identification of pests provides greater opportunity for the success of containment and eradiction programs. World-wide, botanic gardens can readily share their expertise and observations from practitioner to scientist, to work with plant health agencies and produce a more robust surveillance network. Increasing globalisation also means that botanic gardens must set a priority agenda to develop biosecurity management, policy and practices to reduce the risk of introducing or spreading invasive species. Botanic gardens have readily demonstrated leadership through dedicated personnel in reducing the risk and impacts from invasive species upon biodiversity.

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Peter Symes
Curator, Environmental Horticulture
Royal Botanic Gardens Melbourne
(Private Bag 2000)
Birdwood Avenue
South Yarra
Australia 3141
Tel: + 61 3 9252 2347
Fax + 61 3 9252 2348
Email: Peter.Symes@rbg.vic.gov.au

Author: Christoph Kueffer

PREVENTING AND MANAGING PLANT INVASIONS ON OCEANIC ISLANDS

Figure 1: On oceanic islands, high elevation heather formations are among the very few habitats not yet heavily invaded. With climate change, increased disturbance and the introduction of new non-native species this resistance may decrease and preventive measures should be a priority (Eva Schumacher)

The impacts of alien invasive species are particularly severe on islands, but efforts are underway to address this threat.

Introduction

Oceanic islands are infamous for the extent and impacts of invasions by non-native species. Globally, hundreds of different invasive plant species have invaded island ecosystems and threaten native biodiversity, and the same is true for other groups of non-native organisms (e.g. Caujapé-Castells *et al*., 2010; Kueffer *et al*., 2010a). Management of invasive plants on islands is confronted with the challenges of (i) preventing further introduction of potentially invasive non-native species, (ii) containing the spread of already introduced non-native species, and (iii) mitigating the impacts of established invasive species. Comprehensive documents that treat these different management phases specifically for islands are readily available on the internet (e.g. "*Guidelines for Invasive Species Management in the Pacific*"[1] or Kueffer and Loope, 2009) and I will therefore in this article only focus on selected aspects that are in my view particularly relevant for an effective prevention and management of plant invasions on oceanic islands.

If not botanic gardens, who else?

On islands, botanic gardens have a particular responsibility for invasive plant management because they are often the only organisations with substantial specialised botanical expertise and related international connections.
A reliable taxonomy of established non-native plants and a rapid identification of new introductions are the basis of effective prevention and management of plant invasions. Many botanic gardens

[1] *http://www.sprep.org/att/publication/000699_RISSFinalLR.pdf*

on islands maintain a continuously updated database of the native and non-native flora (for a compilation of examples of such online databases see Caujapé-Castells *et al*., 2010, pp. 113).

As key players in the horticulture sector, botanic gardens should be role models of good practice, and the St. Louis Codes of Conduct[2] can serve as a guideline. The example of the *Conservatoire Botanique National de Mascarin (CBNM)* illustrates how botanic gardens can take on a leadership role in education, awareness building and policy formation. The CBNM was for instance a leading organisation in the preparation and implementation of the invasive species management strategy of La Réunion[3]. As the following paragraphs highlight, the involvement of botanic gardens in invasive species management can include a broad range of activities such as the promotion of the use of native plants, *ex situ* propagation of native plants, restoration of invaded habitat, networking actors, and outreach to the general public.

"Botanic gardens have the necessary expertise and networks to be key players in controlling invasive species."

Although plant protection is not the focus of this article, it is also important that botanic gardens act responsibly with respect to the prevention of new introductions of plant diseases and pests, which can spread rapidly across small islands and affect the majority of the individuals of a vulnerable native plant species in a short period of time (Caujapé-Castells *et al*., 2010).

Most non-native plants are friends not foe, and sometimes they are both at once

While some non-native plants are indeed an important threat to island biodiversity, most of them are not problematic. In fact, the presence and abundance of many non-native plants on islands are due to past anthropogenic habitat destruction or the result of deliberate planting for forestry, restoration of degraded land or landscaping, rather than an active invasion of undisturbed natural areas.

Many non-native plants remain important for agriculture, forestry and daily life on islands, and some of them have become allies of nature conservation; for instance by stabilising soils, preventing invasions by other and potentially more problematic non-native plants or providing food to native fauna (Kueffer *et al*., 2010b). Managers and scientists on islands increasingly recognize the beneficial role of non-native plants in heavily altered "novel ecosystems". Sometimes the same non-native plant species can play a beneficial role in one habitat and yet have major negative impacts in a neighbouring habitat, thus posing new challenges to invasive species management. Non-native cinnamon (*Cinnamomum verum*) for instance is beneficial in the Seychelles for biodiversity management in mid-elevation forests (Kueffer *et al*., 2010b) but is a major problematic invader of nearby montane cloud forests.

Prevention – pragmatic solutions and innovations are needed

It is generally believed that the prevention of new introductions of potentially invasive non-native organisms is more effective than the later management of problematic invasions. Indeed, eradication or containment of a spreading non-native species and the management of established invasive species is very difficult and costly. However, prevention is very challenging too and new innovative biosecurity solutions and continuous learning to improve existing good practice approaches are needed. Above all, preventative measures need to be simple and take the limited financial and human resources of island societies into consideration.

"Few, if any, oceanic islands have yet implemented an effective biosecurity system that is able to substantially reduce the rate of new introductions of non-native organisms."

Increased travel and transport mean that introduction rates of new organisms to islands have become so high that effective control at borders is almost impossible. Daily, non-native organisms are transported to islands around the world and inevitably some of these species will not be detected at borders. How prevention can work in an increasingly globalised world is not evident. A solution may lie in developing multi-layered biosecurity systems based on shared responsibilities among many agencies and citizens, with post-introduction detection as a second important filter after border control.

Figure 2: The native plant ex situ *collection at Barbarons Biodiversity Center on Mahé, Republic of Seychelles (Eva Schumacher)*

[2] *http://www.centerforplantconservation.org/invasives/DownloadPDF/bga.pdf*
[3] *http://www.cbnm.org/component/docman/doc_download/93-strategie-de-lutteinvasives*

Possible invasive non-native species that pass through border control must be detected as early as possible after introduction while they are still localized and eradication is still feasible (Kueffer and Loope, 2009). This will require regular systematic early detection surveys as exemplified by the Hawaiian example (Kueffer and Loope, 2009) but depends also on the collaboration and awareness of other agencies – e.g. those involved in road maintenance, landscaping, forestry and agriculture – and the general public.

Partnerships with stakeholders are of pivotal importance

An important lesson learnt is that stakeholder concerns and expertise should be built into invasive species prevention and management from the very beginning. In Hawaii, for instance, a weed risk assessment system with the aim of predicting potentially invasive non-native species that should be prevented – the Hawaii-Pacific Weed Risk Assessment system (HP-WRA[4]) – was at first developed relatively independently of stakeholders, especially the plant industry, and consequently acceptance by stakeholders was low. Thanks to committed representatives of the plant industry a more participatory process was later initiated, which significantly increased the acceptance of weed risk assessments and preventative measures among industry partners (Kueffer and Loope, 2009).

Figure 3a: Bris de fer forest Mauritius, heavily invaded by invasive Psidium cattleianu *(Claudia Baider)*

In the Hawaiian archipelago it was also particularly effective to setup a separate Invasive Species Committee (ISC) on each of the different islands (Kueffer and Loope, 2009). These island-specific ISCs allow preventative measures: early detection, monitoring, awareness building and outreach to be tailored to the specificities of the individual islands. For instance, on a small island such as Molokai, where everyone knows everyone, effective approaches are different to those required on a highly urbanised island such as Oahu, or a large and sparsely populated island such as the Big Island.

Prevent future invasions, don't fight the ghost of past invasions

There is a tendency in invasive species management to invest most resources on the management of those islands and habitats that are already heavily affected by invasions. Once a problem is experienced, money flows. But prevention is only effective if it is one step ahead. The most problematic future invasions will likely happen in areas that are not yet badly invaded. In contrast to already invaded areas, un-invaded ecosystems offer open ecological niches that are not yet filled and native biodiversity is not yet impacted through earlier invasions. Ecosystems situated in less developed, remoter or less disturbed regions or islands may thus require particular attention (Fig. 1). For instance, the expansion of ecotourism onto new islands or into new habitats may be a reason for concern and should be accompanied by preventative measures, increased early detection survey activities and awareness building. With environmental change and the introductions of new types of non-native plants through land use changes, those habitats that have been resistant to invasions in the past may become vulnerable too.

Promote native and non-invasive alternative plants

A particular important strategy to support the prevention of new introductions of potentially invasive non-native plants is formulated in the St. Louis Code of Conduct cited above as follows: "5. *Promote non-invasive alternative plants or, when possible, help develop non-invasive alternatives through plant selection or breeding*". Environmental degradation related to fire, droughts, deforestation, and erosion is for instance a major environmental management challenge on many oceanic islands. To combat erosion, even today non-native *Acacia* species, which are known invaders, are introduced to new islands. To stop such deliberate introductions that pose a severe invasion risk, alternative ways of restoring degraded sites with native or non-invasive, non-native species have to be urgently developed. For the development and promotion of native plants for use in restoration – as well as, for instance, in landscaping, horticulture or forestry, botanic gardens play a key role. Many botanic gardens on islands do already invest heavily in native plant *ex situ* propagation programmes (Figure 2).

Resurrection of native biodiversity after invasion can happen

Even in the case of heavily invaded island ecosystems, there is hope. Removal of invasive plants and exclusion of invasive animals from conservation management areas, either through mechanical or biological control measures, can have rapid and dramatic positive effects on the recovery of native plants and other biodiversity. This has for instance been shown for intensively managed conservation areas in Hawaii (Kueffer and Loope, 2009) and Mauritius (Baider and Florens, 2011; Florens *et al*., 2010), or native regeneration after biological control of *Miconia calvescens* in Tahiti (Meyer and Fourdrigniez, 2011). A striking example has recently been reported from Conservation Management Areas (CMA) in Mauritius (Western Indian Ocean) (Fig. 3). Ten years after weeding of sites formerly infested with *Psidium cattleianum*, juveniles of two presumed extinct, three critically endangered and four endangered native plant species were

[4] www.botany.hawaii.edu/faculty/daehler/wra

Figure 3b: Bris de fer today following successful weeding and rehabilitation into native species dominated forest, including vigorous re-growth of rare species (Claudia Baider)

recorded, together with vigorous regeneration of many other native species (Baider & Florens, 2011). The same positive trend was also found for butterfly species (Florens *et al*., 2010). Island ecosystems still harbour surprisingly high levels of relict native biodiversity, but this is probably only due to a time lag effect ("extinction debt") and much of this biodiversity may go extinct without immediate active management intervention. Exclusion of invasive species from intensively managed conservation areas is one such emergency measure.

Acknowledgements

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Christoph Kueffer
Institute of Integrative Biology
Plant Ecology,
ETH Zurich,
Switzerland
kueffer@env.ethz.ch

Authors: Quentin J. Groom, Anne Ronse and Ivan Hoste

THE REASONS FOR EXOTIC PLANT INVASIONS AND WHY BOTANIC GARDENS ARE PARTICULARLY VULNERABLE

The problems caused by alien invasive plants are related to many aspects of human activity. Botanic gardens, with their experience in cultivating exotic species, are central in helping to address such problems.

Cardamine corymbosa *(Ivan Hoste)*

Introduction

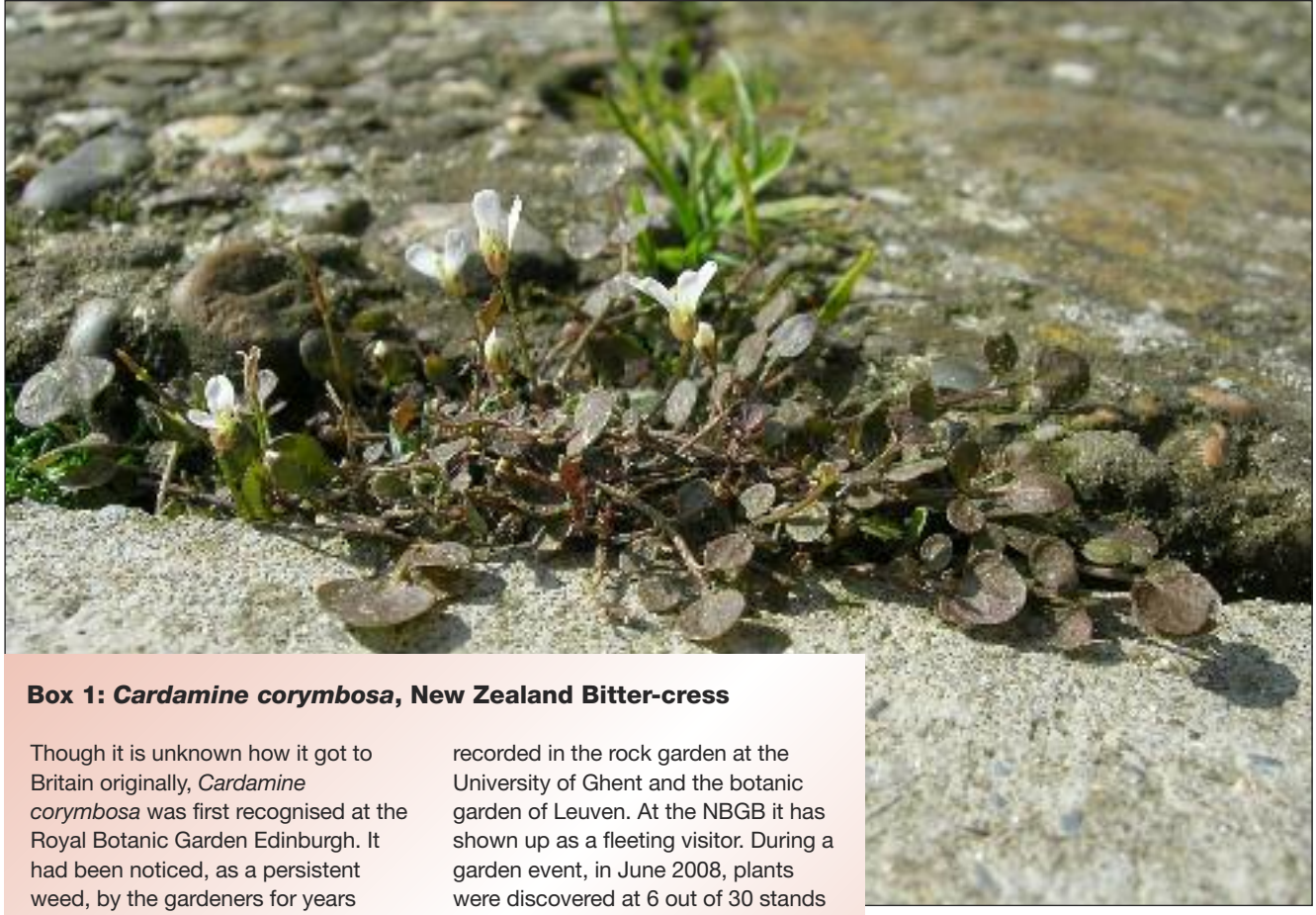
Botanic gardens need to be constantly alert to the possibility of introducing new invasive species. Even gardens with a high awareness of the problem may have conditions that make them prone to losing control of the plants they grow. Many of mankind's activities can result in invasive plants, yet there are good ecological and evolutionary reasons why botanic gardens are particularly liable to causing new invasions. Facon *et al*., (2006) wrote a simple synthesis of the primary reasons for biological invasions. In their paper they reduce the causes of invasions to three basic scenarios: migration change, environmental change and evolutionary change. Here we show, with reference to the National Botanic Garden of Belgium (NBGB) and other northern European gardens, how botanic gardens can actively contribute to each of these scenarios.

Migration

The range of some species is only restricted by their ability to disperse. Such species will survive in new areas, but they are unable to reach such areas by natural spread (Sax and Brown, 2000). Botanic gardens are skilful at growing introduced species, yet not all these species escape cultivation. One explanation is the hypothesis of propagule pressure (Simberloff, 2009). This hypothesis suggests that a minimum rate of propagule import is required to ensure that founder populations of aliens can establish in a novel location. Below this minimum, alien species are unlikely to find suitable habitat and will have insufficient genetic diversity to survive. This acts as a barrier to potentially invasive species, favouring those species that are more frequently imported.

"A minimum rate of propagule import may be necessary for an alien to establish."

It is clearly not only botanic gardens that import alien plants. Plant propagules are imported for all sorts of reasons, particularly for food. Today it is no doubt the horticultural industry that imports the largest range of species, either specifically for propagation and sale, or as stowaways. By piggybacking on the activities of mankind, plants can easily breach once insurmountable barriers to dispersal (see box 1).



Box 1: *Cardamine corymbosa*, New Zealand Bitter-cress

Though it is unknown how it got to Britain originally, *Cardamine corymbosa* was first recognised at the Royal Botanic Garden Edinburgh. It had been noticed, as a persistent weed, by the gardeners for years before it was first identified as an alien, rather than a native *Cardamine* spp. (Braithwaite, 1991). Its explosive ripe fruits, its preference for plant pots, combined with the constant flux of container plants through extensive horticultural networks in Europe create ideal conditions for its dispersal (Hoste *et al*., 2008). It has since spread all over Britain and by the early 21st century had reached the Netherlands and Belgium, where it has been recorded in the rock garden at the University of Ghent and the botanic garden of Leuven. At the NBGB it has shown up as a fleeting visitor. During a garden event, in June 2008, plants were discovered at 6 out of 30 stands selling plants, yet fortunately it hasn't established in the Garden as a result. Often, it only requires a short residence time in a garden centre for seed to disperse from one pot into neighbouring containers or between paving stones. The ease with which it proliferates puts *C. corymbosa* in the company of other ill-reputed pot contaminants such as *Cardamine hirsuta, Sagina procumbens* and *Oxalis corniculata*. (Photo: Ivan Hoste)

While the removal of dispersal barriers by human activity can explain the migration of invasive species, it does not explain why invasive plants are often more successful than native species. The enemy release hypothesis suggests that one of the reasons for the success of invasive plants is that they are released from the stress of pests and diseases that occur in their native ranges (Keane & Crawley, 2002). One of the observations consistent with this hypothesis is that:

"invasive alien species have fewer pests and diseases in their invasive ranges."

This is certainly consistent with our observations at NBGB. Although there are only about 350 wild native species compared to 7,000 cultivated taxa growing outdoors in the garden, of 100 pests and diseases recorded in the garden, only 10 occur only on alien species (Groom, 2011). While enemy release is unlikely to be the sole reason for the success of invasive species, it seems likely that it is a contributing factor in some cases.

Environment

A large number of invasive species occur in places disturbed by human activity, such as in urban environments, on agricultural land and by roadsides (Lozon, 1997). This may, in part, be explained by the creation of novel habitats. The proximity of botanic gardens to large urban areas, full of novel, unexploited habitats, certainly raises the risk of new invasions being initiated by garden escapes.

The now classical tale of how *Senecio squalidus* spread in Britain from Oxford University Botanic Garden along the railways in the late 19th century, usually does not tell that it was already "very plentiful on almost every wall in Oxford" at the end of the 18th century (Kent, 1956, 1960). Furthermore, it was naturalized in other distant towns, well before Oxford was connected by railway. In at least three cases it had escaped from gardens where the seed had originally been taken from Oxford as a botanical novelty (Kent, 1956). One can see the same influences of botanic gardens, novel habitats, disturbance and horticultural novelty in the introduction histories of many species (Hulme, 2011).

It will come as no surprise that species which escape into the neighbourhood of botanic gardens are those that thrive in the habitats of that area. Thus a garden surrounded by wall, as in the case of Oxford Botanic Garden, exports *S. squalidus* that grows on walls. Likewise, a forest garden is likely to export shade-loving species and a desert garden will export xerophytes (Marco *et al*., 2009). In the NBGB we have found that many of the most persistent and invasive escapes are woodland plants whose seeds are spread by birds (Box 2; Ronse, 2011). This is inevitable, since nearly half of the area of the garden consists of woodland.

Box 2: *Diospyros lotus*

Diospyros lotus (Ebenaceae) is a tree from south-east Europe and south-western Asia that produces edible fruits called date plums, dispersed by birds. Hundreds of seedlings of this species have had to be removed and were found up to one kilometre away from cultivated trees at the NBGB, some of them growing in wooded, undisturbed areas of the Garden (Ronse 2011).

D. lotus is not a particularly attractive tree and will only produce seed if both male and female tree are present. Therefore botanic gardens, rather than private gardens, are much more likely to be the source of escapes, at least in Northern Europe.
(Photo: Paul Borremans)

Poa annua *f.* purpurea *(RHS/Barry Phillips)*

Evolution

It has been argued that a species, when liberated from the competition, environmental stress and pests and diseases of its native habitats, can evolve to reallocate its resources from protective mechanisms into traits which confer greater invasive potential (Blossey & Notzold, 1995). While such evolution is generally suggested to occur in wild populations there is certainly also unconscious selection occurring in botanic gardens (Enßlin, Sandnera & Matthiesa, 2011). It is likely that unconscious selection for improved survival in a garden may also mean selection for traits that encourage weediness.

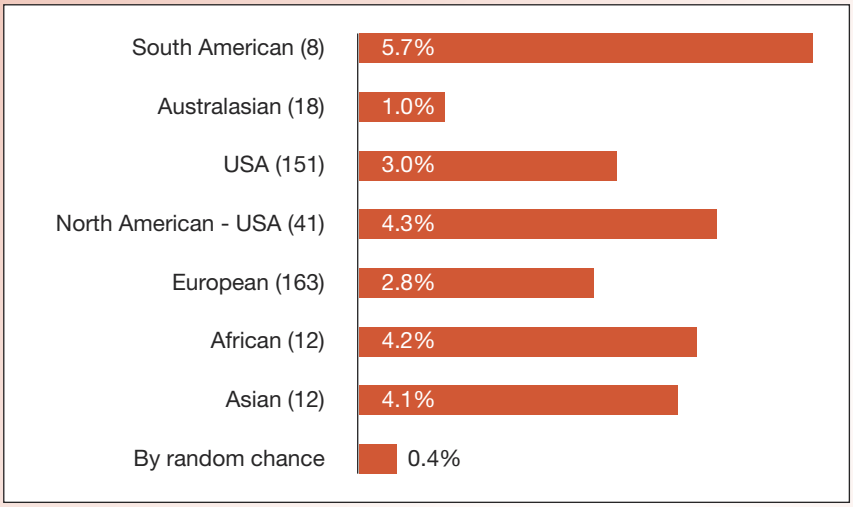
> *"Selecting individuals that grow well may result in selecting for weediness."*

A recent example is the case of *Poa annua f. purpurea* M. L. Grant (Grant, 2003). Hand-weeding in gardens has apparently selected for this purple-leaved form of a practically ubiquitous weed. Its dark cryptic colouration makes it more difficult to see against dark coloured soil than the normal green *P. annua*.

Though unconscious selection will predominantly act on annual and other short-lived species, there is also a filtering process in the acquisition of plants. Dead plants are continually replaced until a species or variety is found that persists. In our own garden an accession of *Oenanthe pimpinelloides*, originally from Bulgaria, has escaped cultivation even though *O. pimpinelloides* is usually considered too cold sensitive to develop persistent populations in Belgium (Ronse, 2011).

In addition, the pool of introductions to a garden is not unbiased. Botanic gardens often produce a list of seeds for exchange with other gardens, know as an *index seminum*. A random survey of these lists showed that several invasive species were listed, presumably because of their high rate of seed production (Aplin & Heywood, 2008). All these processes combine to favour invasive species in gardens, indeed the result can be seen in the inventories of many gardens (Box 3; Hulme, 2011). Hybridisation has been implicated in the evolution of invasive plants (Ellstrand & Schierenbeck, 2000). Examples are *Casuarina* ssp. in Florida (Gaskin *et al*., 2009); *Fallopia* ssp. in Belgium (Tiébré *et al*., 2011); *Senecio squalidus* in the UK (Abbott *et al*., 2000) and *Spartina anglica*

Box 3: Botanic gardens are biased towards invasive species



The average percentage of 455 invasive plants grown at 406 botanic gardens, split by continent. The number of gardens included from each continent are shown in parenthesis. Only gardens with more than 100 species in the database were used and seed banks were excluded. Synonymies of species names were corrected, but not exhaustively.

The BGCI's PlantSearch database contains almost a million records of plants grown at the world's botanic gardens. This database was compared with a list of 455 of the most invasive plant species from the ISSG's Global Invasive Species Database (http://www.issg.org/database, 2011). All but 6% of these invasive species are grown in at least one botanical garden.

If one assumes a garden's plants are chosen randomly from the pool of all the species grown, then these invasive plants should occur as 0.4% of collections. However, on average, these invasive species represent 3.0% of collections. Though it should be mentioned that some of this over-representation of invasive plants comes from plants being grown in greenhouses in temperate countries, where they are unlikely to become a garden escape.

The USA was analysed separately from the rest of North America, because many gardens from the USA follow the voluntary codes of conduct of the St. Louis declaration on invasive plants. The smaller percentage of invasive species in gardens in the USA might be a result of these codes. The greater awareness and regulation of invasive species in Australia and New Zealand has undoubtedly helped Australasia have the lowest value.

These values should only be taken as a guide. They are biased by the availability of digitised collections; by the overall size of collections; by uncorrected synonymy and by the list of invasive species used. Nevertheless, we can conclude that the collections of botanic gardens are biased towards invasive species. However, it is encouraging that these results suggest that a greater awareness of the issue is likely to reduce the problem.

Based on the PlantSearch and GIS Databases 2011.

across Europe (Thompson, 1991). While horticulture was not the cause of hybridization in all of these taxa, the close proximity of closely related taxa in gardens undoubtedly presents an opportunity. In the NBGB we have witnessed the *in situ* generation of the potentially invasive hybrid *Oenothera x fallax* from its two parents *O. biennis* and *O. glazioviana*. Similarly seedlings of *Hyacinthoides* x *massartiana* are increasingly found within the park, both in the collections and in semi-wild areas. This is the hybrid between the native *H. non-scripta* and introduced *H. hispanica* which have both been cultivated in the garden for more than forty years.

Despite there being little research on this subject, it seems likely that a combination of unconscious selection, hybridization between genotypes and the filtering out of feeble taxa may all contribute to the evolution of invasiveness in gardens.

Conclusion

There are many hypotheses for why we have an alien invasive plant problem. However, for each hypothesis, the cause relates either directly or indirectly from the activities of humankind. We have created a small, interconnected world, and botanists, horticulturists, and botanic gardens have eagerly cooperated in the process. We need to continually assess how we can benefit from this, while avoiding the drawbacks. Botanic gardens are a small but significant part of the invasive plant problem. Yet botanic gardens are also leaders in good practice for horticulture and conservation and can play an important role in educating the public. While significant steps have been made to address the problem of invasive plants in botanic gardens, there is still work to be done and a clearer understanding of the mechanisms that result in problem situations is important.

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Quentin J. Groom, Anne Ronse and Ivan Hoste
National Botanic Garden of Belgium, Domein van Bouchout, Nieuwelaan 38, 1860, Meise, Belgium
Tel: +32(0)2 260 0920
Fax: +32(0)2 260 0945
E-mail: qgroom@br.fgov.be

Clearing invasive Hedgchium garderianum *from a hillside in the Azores (BGCI)*

Author: Sarah Reichard

CODES OF CONDUCT

TO REDUCE THE THREAT OF INVASIVE SPECIES INTRODUCTION AND SPREAD THROUGH BOTANIC GARDENS

Are botanic gardens sufficiently addressing the issues of invasive plants and can Codes of Conduct help to focus attention?

There is increasing knowledge of the environmental and economic harm caused by invasive species to native species and ecosystems (Mack *et al*., 2000, Pimental *et al*., 2000). Those who place a high value on the protection of wild lands are concerned that introduced plants are causing those areas to be irreversibly altered. While many agricultural weeds have arrived accidentally, the majority of invasive plants invading natural areas were introduced for horticultural purposes (Gordon and Thomas, 1997, Reichard, 1997, Reichard and White, 2001). Plant exploration and introduction is part of many botanic gardens' missions, and collection displays are important to all gardens.

> *"Botanic gardens share the responsibility of ensuring that our activities do no harm to wild lands."*

Recently, botanic gardens have been criticized for their contributions to the introduction and spread of invasive plants. Dawson *et al.* (2008), using a garden in Tanzania as a case study, theorized that tropical gardens were responsible for the distribution, naturalization, and spread of non-native plants. Botanic gardens were also found to play a "*considerable role in the synanthropic flora of Central Europe in the last 200 years*" (Galera and Sudnick-Wójcikowska 2010). Hulme (2011) implicates gardens for the early introduction and cultivation of invasive plants throughout the world. While all of these papers can be examined for flaws in methods, and an argument can be made for including potentially invasive species in botanic garden collections for a variety of reasons, including education about their invasiveness, (see Sharrock in press for more), it is a subject that should be examined by gardens individually and discussed collectively.

Hulme (2011) points out that while efforts have been made to develop voluntary Codes of Conduct, or best management practices for horticultural interests, including botanic gardens, these Codes have been ineffective. He measures their effectiveness, in part, as the number of United States (U.S.) gardens that have formally endorsed the codes. There are many gardens that are actively implementing measures consistent with the Codes that have not formerly endorsed them, but it is hard to argue that botanic gardens are sufficiently addressing their role in the introduction and spread of invasive plants. This is an area of conservation that deserves more of our attention.

In 2001 there was a workshop at the Missouri Botanical Garden to develop Codes of Conduct for several horticultural interests, including botanic gardens. The process of developing them is discussed in Reichard (2004) and the attendees were largely from the U.S., but included representatives of Australia, New Zealand, and Great Britain. The codes were endorsed by the American Public Garden Association and several individual gardens. Gardens began implementation, using a broad group of stakeholders from within and outside the institution. Most found the framework the Codes provided to be a helpful way to address practices throughout the institution, not just the collections. The codes are summarized in Table 1, but can be read in entirety, along with the workshop proceedings in Reichard *et al*. (2002).

In the United Kingdom, the Department of Environment, Food, and Rural Affairs (DEFRA) later published similar Horticultural Codes of Practice (DEFRA, 2005). While many of the Codes of Practice were similar to the Codes of Conduct developed in the U.S., they did not focus on botanic gardens and only a few of the practices specifically included 'botanic collections' as their targets. However, despite this, some of the practices that did not name botanic gardens as a target are still relevant and some did specify they were relevant to all horticultural interest groups.

The Council of Europe has also developed Codes of Conduct for the horticultural industry (Heywood and Brunel, 2008) but specifically stated that, while the recommendations may be relevant to botanic gardens, the codes were not addressing gardens. They point

Lantana camasa *invading* Butea monosperma *relict forest in Pakistan (Joachim Gratzfeld)*

out that many European gardens are already working in partnerships and some relevant guidelines exist, including the International Plant Exchange Network's (IPEN) guidelines on non-commercial exchanges of plant material, although the purposes of IPEN are much broader than invasive species[i].

The guidelines from the three Codes of Conduct mentioned above are summarized in Table 1.

It is recommended that all gardens should visit the sites and documents listed as resources and consider implementing the Codes of Conduct that are appropriate to their institution. The reward will be a deeper involvement in global conservation and the knowledge that once again, botanic gardens are educating the public about the importance of responsible stewardship of our Earth.

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i Codes of Conduct for botanic gardens in Europe are presently under development. See Heywood, p. 26-28 of this issue. For further information about IPEN, visit: http://www.bgci.org/resources/ipen/

Summarized Code	1	2	3	4
Assess risk of new species prior to introduction	X			
Identify current invaders, remove when appropriate	X		X	X
Identify & promote safe alternative species	X			X
Become partners with other organizations and stakeholders to prevent and manage invasions	X			X
Education – public and professional outreach & formal education	X			X
Participate in early warning & monitoring programs to detect new invaders	X			
Enforce and respect legislation, help create when appropriate	X	X	X	X
Examine collection policies, as well as do an institution wide-assessment	X			
Control invasive plants in natural areas managed by the garden using best practices	X	X	X	
Exchange invasive plants for non-commercial purposes with caution	X			*
Beware of hitchhiking organisms on plants and soil, use good production practices		X	X	X
Ensure correct labeling of names and potential harm to the environment			X	X
Know the invasive ability of what you are specifying in landscapes, books and articles			X	
Dispose of plant waste responsibly		X	X	X
Know what you are buying			X	
Avoid planting invasive plants in large scale public plantings				X
Beware of potential distribution changes due to future climate change				X
**The Council on Europe considers this addressed by the IPEN*				

Table 1. Summarizing the United States (1), Great Britain – Botanical Collections (2), Great Britain – All (3) and Council of Europe General Codes (4). The goals and audience of the three efforts were not identical; complete agreement is not expected.

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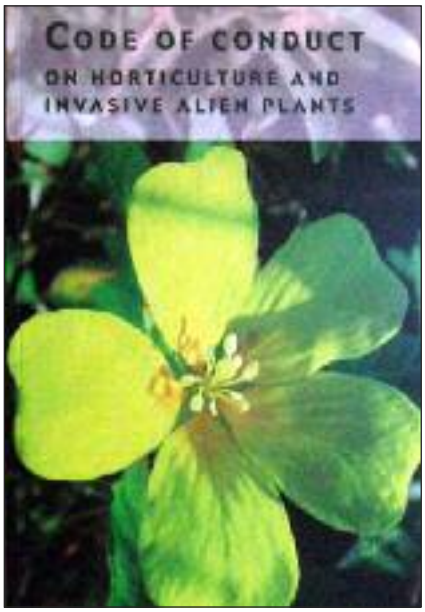
Sarah Reichard, Ph.D.
University of Washington Botanic Gardens
University of Washington,
Box 358010, Seattle
Washington 98195-8010
United States of America
Email: reichard@u.washington.edu

Interpretation sign at the Chicago Botanic Garden (BGCI)

Author: Vernon H. Heywood

A CODE OF CONDUCT
ON INVASIVE ALIEN SPECIES FOR EUROPE'S BOTANIC GARDENS



Voluntary codes of conduct are a valuable tool in dealing with the threats of invasive species and should be widely adopted by botanic gardens. A code for European botanic gardens is being prepared by the Council of Europe and BGCI.

Introduction

It is widely recognized that ornamental horticulture has been the main pathway of plant invasions and that most invasive plants have been introduced by nurseries and botanic gardens or by individuals (Reichard and White, 2001). Botanic gardens, especially those located in tropical countries, have often been implicated as the source of such invasions (Dawson *et al*., 2008; Hulme, 2011) although it is not always easy to establish the full facts (Galera, H. and Sudnik-Wójcikowsja, 2010). Given that Invasive Alien Species (IAS) are widely regarded as one of the main threats to biodiversity today, it is incumbent on botanic gardens to consider what actions they can take to prevent such invasions or to deal with existing ones. Amongst the tools that may be deployed to combat IAS are voluntary codes of conduct.

The desirability of preparing a code of conduct for botanic gardens and invasive alien species has been raised at several meetings, most recently at EuroGard V in Helsinki (2009) where a resolution was passed recommending *inter alia* that botanic gardens should 'develop and implement guidelines, Codes of Conduct, and appropriate practices to prevent the spread of alien species'. Separately, as part of its work in promoting actions to avoid the intentional introduction and spread of alien species and prevent their accidental introductions and to build an information system the Bern Convention Group of Experts on IAS of the Council of Europe had plans to prepare a code of conduct for botanic gardens. A collaboration between the Council of Europe and BGCI was therefore proposed and work is now in hand for the two organizations to prepare jointly a Code of Conduct for Botanic Gardens and Invasive Alien Species. BGCI is liaising on this with the European Botanic Gardens Consortium, and the IUCN Species Survival Commission Invasive Species Specialist Group (ISSG) has also been invited to participate in the drafting of the Code.

Existing codes of conduct

A number of codes of conduct for dealing with IAS have been published both in Europe and elsewhere. In Europe, the Council of Europe in collaboration with the European and Mediterranean Plant Protection Organization (EPPO) has produced *a Code of Conduct on Horticulture and Invasive Alien Plants* (Heywood and Brunel, 2009, 2011[1]), aimed at governments and the horticultural industry and trade (importers, traders, nurseries, garden centres, aquarists, landscape architects, managers of public or private areas. The aims of the Code are (1) to enlist the co-operation of the horticultural industry and trade in raising awareness of this topic among professionals; (2) preventing the spread of invasive alien species already present in Europe; and (3) preventing the introduction of possible new invasive alien species into Europe. Some countries have prepared codes of conduct for IAS such as the United Kingdom's *Horticultural Code of Practice* aimed at preventing the spread of alien invasive species (DEFRA, 2005), a code of conduct for gardeners and designers that has also been developed in Germany[2] and a national code for the horticultural sector that is under development in Belgium[3].

> *"Very few codes of conduct on IAS specific for botanic gardens have been prepared."*

In Europe, a German-Austrian Code of Conduct for the cultivation and management of invasive alien plants in botanic gardens has been developed (Kiehn *et al*., 2007) and the National Botanic Gardens of Ireland has a draft Code of Conduct on the management of actual or potentially invasive species. In the United States, a Voluntary Code of Conduct for Botanic Gardens and

[1] *EPPO / Council of Europe Workshop 'Code of conduct on horticulture and invasive alien plants' 2009-06-04/05, Ski (NO) http://archives.eppo.org/MEETINGS/2009_conferences/conf_codeofconduct.htm#pres*
[2] *Zentralverband Gartenbau (2008): Umgang mit invasiven Arten. Empfehlungen für Gärtner, Planer und Verwender. Zentralverband Gartenbau (Berlin), 37 S.*
[3] *AlterIAS (IAS for Invasive Alien Species) is a communication project which aims at educating the horticultural sector on the invasive plants issue: http://www.alterias.be/.*

Arboreta (and one for Nursery Professionals) arose out of a workshop 'Linking Ecology and Horticulture to Prevent Plant Invasions' that was held at the Missouri Botanical Garden in St. Louis in December 2001 (Fay *et al*., 2001). A follow-up workshop was held in 2002 at Chicago Botanic Garden (Fay *et al*., 2002). Several US botanic gardens have endorsed the Voluntary Codes. A detailed review of how Canada, Mexico, and the United States are confronting the challenges posed by invasive plants was the theme of the Weeds Across Borders (WAB) 2010 conference (Rindos, 2011).

The context

In Europe, it has been estimated that 80 per cent of invasive alien plants are introduced for ornamental and agricultural purposes (Hulme, 2007). On the other hand, although the biological, economic and social threats posed IAS are now widely recognized by the conservation community, in Europe there is a general lack of perception of these threats and even a certain degree of scepticism about their significance (Brundu *et al*., 2011). There is no European level regulation on invasive alien plants although the EC adopted a Communication presenting policy options for an EU Strategy on Invasive Species in December 2008.

Likewise at national level in Europe, the situation regarding the regulation of IAS is extremely diverse. In the various European countries a complex, fragmented and continually developing network of legislative instruments and regulations is in operation aimed at preventing or prohibiting the introduction and spread of non-native species that pose a threat to native species and ecosystems and to agriculture, fisheries, forestry and horticulture (Miller *et al*., 2006).

Preparing the Code

It would be relatively simple to prepare and agree a list of actions and good practice to be followed by botanic gardens in dealing with IAS but we have to take into account the very wide range of perceptions and experience in Europe's botanic gardens. While some gardens are well informed of the issues and actively engaged in policies and actions to prevent their introduction and diffusion and are engaged in control measures, in others, although there may be a general awareness of the problems of IAS, few if any policies are in place. Consequently the background and raison d'être of the precepts of the proposed Code will need to be given and guidance provided on where further information and explanations can be found. The relevant international and national legislation and initiatives that botanic gardens need to be aware of are many and varied and so it would be naïve to assume that such knowledge is widespread. The challenge will be to address these points and get the balance right.

"A Code of Conduct must be suitable for implementation by all gardens, regardless of size and resource base."

How to make it work

Publication of a Code is only the first step in a process. For it to be successfully implemented, a strategy for promoting it will be needed as in the case of the Council of Europe/EPPO *Code of Conduct on Horticulture and Invasive Alien Species* (Burundu *et al*., 2011) which was endorsed by the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats in November 2008 with the recommendations that the contracting countries draw up national codes of conduct on horticulture and invasive alien plants taking into account the European Code of Conduct. A dialogue was created with the stakeholders through workshops and other approaches. The Botanic Gardens Code will likewise be submitted for approval to the Standing Committee and it is expected that the implementation strategy at the garden level will be developed by BGCI and the European Botanic Gardens Consortium.

The proposed Code for botanic gardens will be voluntary in the sense that the parties adopting it will not have to sign up to any legislation; rather, they will follow the principle of self-regulation and it is hoped that most European botanic gardens will sign up to the actions and recommendations made in the Code. This does not mean, however, that voluntary codes such as this will have no legal implications or lack effective means of enforcement (Webb, 1999). There is some evidence to suggest that such high-level 'soft law' instruments can be effective (Shine *et al*., 2010). On the other hand, such codes or guidelines have no specific targets or time-frame and their effectiveness depends largely on how well they are promoted (Dehnen-Schmutz and Touza, 2008). Moreover, a system that is built on voluntary undertakings by member states and voluntary codes of conduct would only be as effective as the weakest link in a chain (Kettunen *et al*., 2008).

The preparation of the Code of Conduct should provide botanic gardens with a stimulus to develop their education and outreach policies on invasive alien species so as to better inform the public of the issues surrounding these species and the risks they pose to biodiversity.

Carpobrotus *invasive at Cap de Favaritx, Menorca, Spain (V. H. Heywood)*

Botanic gardens are uniquely suited to spread such a message and it goes without saying that compliance with the Code would be a necessary basis from which to start.

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The Code is available in English, French and Spanish, in hard copy and on the Internet:

http://www.coe.int/t/dg4/cultureheritage/nature/Bern/IAS/default_en.asp [English]

http://www.coe.int/t/dg4/cultureheritage/nature/bern/ias/default_FR.asp [French]

http://www.coe.int/t/dg4/cultureheritage/nature/bern/ias/CODIGO%20HORTICULTURA%20MAIL.pdf [Spanish]

Czech and Polish versions have also been prepared.

Vernon H. Heywood
Emeritus Professor
School of Biological Sciences
University of Reading, UK
Email: v.h.heywood@rreading.ac.uk

Authors: Olivier Filippi and James Aronson

USEFUL BUT POTENTIALLY INVASIVE PLANTS IN THE MEDITERRANEAN REGION: WHAT RESTRICTIONS SHOULD BE PLACED ON THEIR USE IN GARDENS?

Gardens and other amenity plantings are expanding rapidly throughout the Mediterranean region - a simple protocol, based on relevant information, may help determine which plants should be used, and which should be avoided.

Introduction

In the Mediterranean region as a whole, rising standards of living and expanding urbanisation are leading to rapid extension of land areas devoted to gardens and other planting areas. This entails complex environmental and cultural consequences that should be studied carefully since gardens and other amenity planting areas have both environmental and cultural functions. Whereas they are perceived by the general public as places of 'Nature', they can be seriously harmful for the environment because of their heavy consumption of water and the widespread application of pesticides, fertilisers, and weed killers. They can also be the starting point for the dissemination of exotic invasive plants involving risks for human health, and economies, as well as for native fauna, flora, biotic communities, and ecosystems. Decisions regarding the choice of plant material to be used in gardens and amenity areas are therefore a growing cause for concern. Consideration of both the positive and the negative aspects of the various plant species that can be used horticulturally is required.

*Figure 1: An Ice plant (*Carpobrotus *spp.) invasion on a coastal dune in Corsica (O. Filippi).*

What is an invasive plant?

According to Richardson *et al*. (2000), invasive species are exotic species that overcome successive barriers limiting their reproduction, naturalization, and dispersal, allowing them to spread in their new area of introduction. However, the term itself of invasive species is confusing: a species can never be invasive in and of itself; only *a population* of a species can be invasive, in a given place and at a given time (Colautti & MacIsaac, 2004). For some plants deemed invasive, there may also be uncertainty, at the local level, regarding the status of species or subspecies considered "native" (Beisel & Lévêque, 2009), especially in the context of the Mediterranean Basin with its complex history of intermingling flora and fauna, much influenced and mediated by human choices and activities. This sometimes hinders conservationists and ecologists seeking to dialogue with gardeners, horticultural professionals and landscapers in order to define which invasive plants to avoid when planting.

Indeed, in order to limit the spread of noxious invasive plants, such as Ice plant (*Carpobrotus* spp., Aizoaceae; Figure 1), many lists of species have been created in different countries of southern Europe.

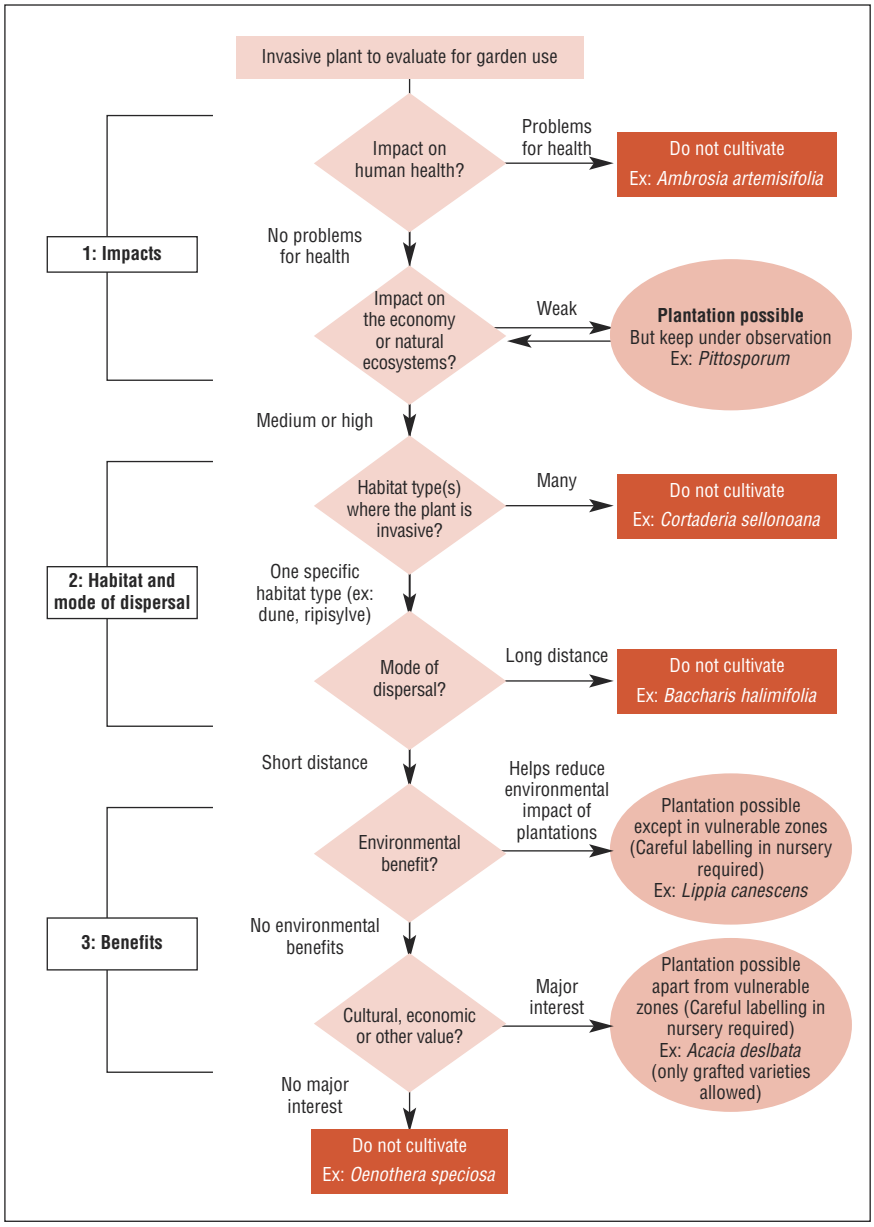

Figure 2: A decision-making protocol to help determine which types of restriction to impose for any given non-indigenous species under consideration for use in gardens or amenity plantings.

> *"Gardens and amenity plantings can be the starting point for dissemination of exotic invasive plants."*

Unfortunately, many of these lists, even those created by official environmental protection agencies, are based on inconsistent criteria (Heywood & Brunel, 2009), thereby contributing to confusion and preventing well-meaning recommendations from being implemented. Moreover, these lists are often elaborated at different spatial scales, e.g. national or regional, which may generate conflicting recommendations. The confusion of species genuinely noxious and those that have as their main defect that they are not considered "native" (Gould, 1997), may inflate the lists of unwanted or forbidden plants in gardens and amenity plantings and unleash negative reactions from horticulture and landscape professionals. To progress on these sensitive issues – which are sometimes strongly marked by emotional and subjective dimensions (Webb, 1985; Wilcove *et al*., 1998) – particular attention should be paid to the choice of targeted species and how decisions are made (Ewel *et al*., 1999; Parker *et al.*, 1999). In the following section, a protocol is described to aid in decision-making regarding which plant species to use freely - or to avoid at all costs - in gardens and amenity plantings across a range of situations.

Decision-making protocol

To classify invasive plants for use or not to use in gardens and amenity plantings, we offer a decision-making protocol (Figure 2) with the following steps: a candidate species' potential negative impacts in the introduction zone are studied followed by an assessment of the risk of the species spreading outside of the planting site; then the species' potential positive aspects in a horticultural setting are also considered. For each candidate species, answers to these successive questions can result in three types of decisions: 1) use of the plant should be proscribed regardless of the planting site (dark grey in Figure 1); 2) the species can be grown in any zone, but the plant should remain under observation in case conditions change (e.g. due to global warming) and lead to a revision in status (light grey); 3) the species can be grown only outside of the zones at risk defined for this species (white).

1) Evaluation criteria of invasive plants

Invasive plants can have several types of negative impacts (Heywood & Brunel, 2009), including those impinging directly on human health, those affecting economic activities and those affecting native biodiversity and the functionality of natural or semi-natural ecosystems. Albeit no tool has yet been internationally recognized for the assessment of the negative impact of invasive species on native biodiversity and ecosystems, several approaches have been suggested (Vitousek *et al*., 1987; Hulme *et al*., 2007; Parker *et al*., 1999). Here we adopt the Belgian protocol for measuring the impact of invasive plants (ISEIA, 2007) (see Figures 3 and 4).

> *"When evaluating invasive plants, we suggest focusing on the positive and negative aspects of the species rather than on place of origin."*

In which cases should a potentially invasive plant species be subject to complete, or partial, proscription? In case of partial proscription, which uses can be allowed, without entailing any environmental risk? In order to evaluate

the risk of invasion by a cultivated plant that might 'escape' from the site where it is intentionally planted, we first consider in what type of environment the plant is potentially invasive. In other words, is it a "generalist invasive" or a "specialist invasive" (Barbault & Teyssèdre, 2009)? A generalist invasive species is able to colonize many different environments, including natural, semi-natural, or human-dominated (e.g. Uruguayan Pampas grass, *Cortaderia sellowiana* (Schult. & Schult. f.) Asch. & Graebn. (Müller, 2004). A specialist invasive by contrast only colonizes one particular type of ecosystem, such as coastal dunes or riparian forests – both of which are in fact among the most sensitive ecosystems to invasive plants in the Mediterranean region (Chytry *et al*., 2009; Vilà *et al*., 2008).

If it is, or suspected to be, noxious, the planting of a generalist invasive plant should be proscribed in all cases, since all – or almost all - gardens constitute zones at risk from which such invasive species can escape. In contrast, for specialist invasive plants, the definition of zones at risk where the planting should be proscribed depends on the ecological connectivity between the planting site and the environment where the plant is potentially invasive. This notion of ecological connectivity, which can be structural and/or functional (Metzger & Décamps, 1997; Tichendorf & Fahrig, 2000), refers to the likelihood that a species with invasive potential may succeed in migrating from one ecosystem type to another within a given landscape (Taylor *et al*., 2006) (Figure 5).

Figure 3: Hyparrhenia hirta*, which is considered native in France, is deemed exotic and potentially invasive in Spain (O. Filippi).*

Regarding the positive aspects of a horticultural plant, whether it is native or exotic, our protocol calls for analyzing how best to use the plant in order to take advantage of its attributes in order to reduce the ecological footprint of traditional gardens and amenity plantings where the plant may be used. This can be done according to three parameters, namely water consumption, chemical inputs required (fertilizers, weed killers, insecticides, and fungicides, etc.), and fuel consumption related to maintenance operations requiring engine tools: mowers, hedge-trimmers, brush cutters, waste removal, etc.

Figure 4: Medicago arborea*, a highly ornamental but colonizing Mediterranean shrub, is expanding its range from east to west and is now considered a* planta non grata *by some conservationists in southern France (O. Filippi).*

2) Bibliographic database on plant species

Another tool is required for using this decision-making protocol to help identify and gather the necessary information in one standardized evaluation document, consisting of a database on the risks and advantages of invasive, or potentially invasive, plants used in gardens and amenity plantings. In order to reduce the risk of errors related to an overly narrow perception (Pyšek *et al*., 2009), we suggest that the database should be established by an interprofessional group including scientists and landscape professionals. This database should identify its different sources (bibliographies, experts' interviews or authors' personal observations). The European Botanic Gardens Consortium for example, could and should play a major role in developing, updating, and implementing this database. Head gardeners,

Figure 5: Pennisetum villosum *and* Oxalis pes-caprae *have long distance propagation modes, enabling them to escape readily from planting sites (O. Filippi).*

horticulturists, and botanists of botanic garden staff are perhaps the most knowledgeable experts anywhere and should participate in all collective efforts undertaken to evaluate potentially invasive species in an holistic fashion (Figure 6).

"As the ecological footprint of amenity planting is increasing rapidly in the Mediterranean region, the choice of well-adapted exotics can be very useful."

Discussion

Following test application on twenty exotic species used horticulturally in the Mediterranean region (Filippi & Aronson, 2010), our decision-making protocol clearly allows candidate species to be classified according to which of the three types of use restrictions to recommend. However, the reliability of this protocol should be validated with many more examples. The decision-making protocol can establish, at least for some specialist invasive plants with a short-distance spreading mode, the possibility of planting in low-risk areas. The process of demarcating the areas where planting these species might be possible should be given special attention, in order to avoid the plants at issue spreading into areas or ecosystems where they may become noxious.

Conclusions

Prevention and precaution remain vital to help limit the environmental risk related to the introduction of invasive plants (Ewel *et al.*, 1999; Hulme *et al*., 2007; Gasso *et al*., 2009). We hope that the new tool we offer will contribute to the debate on the issue of holistic assessment of invasive plants, some of which may be valuable for Mediterranean horticulture. We assert that a comprehensive analysis is required to lead to collective decisions, based on a consistent method. Only in this way will it be possible to bring together gardeners, nurserymen, landscape planners and botanic gardens, rarely consulted in this regard and yet key players, in search of a consistent policy aimed at limiting the spread of noxious invasive plants. We emphasize that there is a real risk of seeing these players reject outright any recommendations – or even legislation – which may seem arbitrary or lacking in a robust scientific basis.

Concurrently, the protocol we propose has potential use in the broader context of ecosystem management, conservation ecology, and restoration ecology. Happily, botanical gardens around the world are getting much more active in these areas (Hardwick *et al*., 2011) and the new list of Targets of the Global Strategy for Plant Conservation (http://www.cbd.int/gspc/targets.shtml) also suggests that the development of a holistic, decision-making protocol concerning invasive and potentially invasive plants is timely.

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Figure 6: Phyla canescens *is a cosmopolitan ground-cover species that is considered exotic in France. However, the use of this plant allows savings in irrigation water, herbicides and mowing (O. Filippi).*

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O. Filippi (Corresponding author)
Pépinière Filippi
R.D. 613
34140 Mèze
France
olivier.filippi@wanadoo.fr

J. Aronson
Centre d'Ecologie Fonctionnelle et Evolutive (C.N.R.S.-UMR 5175)
Montpellier, France and
Missouri Botanical Garden, USA
james.aronson@cefe.cnrs.fr

RESOURCES

Invasive and Introduced Plants and Animals
Human Perceptions, Attitudes and Approaches to Management.

Editors: Ian D. Rotherham and Robert A. Lambert

This book addresses the broader context of invasive and exotic species, in terms of the perceived threats and environmental concerns which surround alien species and ecological invasions. As a result of unprecedented scales of environmental change, combined with rapid globalisation, the mixing of cultures and diversity, and fears over biosecurity and bioterrorism, the known impacts of particular invasions have been catastrophic. However, as several chapters show, reactions to some exotic species, and the justifications for interventions in certain situations, including biological control by introduced natural enemies, rest uncomfortably with social reactions to ethnic cleansing and persecution perpetrated across the globe. The role of democracy in deciding and determining environmental policy is another emerging issue. In an increasingly multicultural society this raises huge questions of ethics and choice. At the same time, in order to redress major ecological losses, the science of reintroduction of native species has also come to the fore, and is widely accepted by many in nature conservation. However, with questions of where and when, and with what species or even species analogues, reintroductions are acceptable, the topic is hotly debated. Again, it is shown that many decisions are based on values and perceptions rather than objective science. Including a wide range of case studies from around the world, this book raises critical issues to stimulate a much wider debate.

'An interesting and much-needed book that tackles an important aspect of invasive alien species: how they are perceived, valued and judged by humans. The volume draws together a broad range of fascinating case studies and is very thought-provoking. A must for any serious invasion ecologist.'
(Robert A. Francis, King's College London, and Secretary of the British Ecological Society Invasive Species Special Interest Group).

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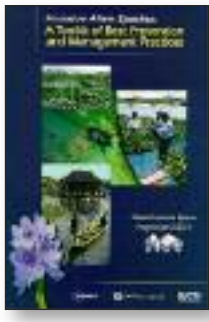
Native Alternatives to Invasive Plants (Brooklyn Botanic Gardens Guides for a Greener Planet)

Author: C. Colston Burrell; Editors: Janet Marinelli and Bonnie Harper-Lore.

The biggest enemy of any garden is not a pest, disease, or poison. It's any plant with tougher survival skills than the plants it competes with. This book provides a guide to the native plants that can replace the top 100 most unwelcome perennials, grasses, vines, shrubs, and trees in the USA. While replacing the invaders, the beautiful, hardy native plants described here also attract native birds and butterflies. Word-and-picture guides provide tips on care and maintenance, while helpful, "at a glance" boxes depict shapes, sizes, best locations, and most attractive features of each native alternative.

ISBN: 978-1889538778
Published by: Brooklyn Botanic Garden, 2011
www.bbg.org

Invasive Alien Species: A Toolkit of Best Prevention and Management Practices



Edited by R Wittenberg, and M.J.W. Cock

Human activities have contributed to the distribution of many plant, animal and microbial species to parts of the world where they are not native. This spread of alien species can have devastating consequences on native biodiversity. Examples include alien mammals consuming native vegetation and alien insects spreading viruses, as well as plants such as water hyacinth, which has caused major problems to waterways when introduced from South America. CABI's goal is to improve prevention and management of biological invasions, and this book represents a key outcome. It has been assembled by a team of international experts. Features include: case studies from around the globe, with some emphasis on islands, a focus on biodiversity, but with some consideration of traditional agriculture and forestry, advice on national management plans, including risk analysis.

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CABI - Invasive Species Compendium

An encyclopaedic resource that draws together scientific information on all aspects of invasive species.
Invasive species are a major threat to the global economy and the environment, costing billions of dollars to control each year. The Invasive Species Compendium is an online, comprehensive encyclopaedic reference work covering recognition, biology, distribution, impact and management of the world's invasive plants and animals.

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Content is derived from thousands of peer-reviewed expert contributors, backed up by existing compilations of knowledge and research on invasive species. It offers extensive global coverage of all invasive species, from every taxonomic group (excluding human pathogens), with fast and easy navigation between text, images, maps and databases.

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The ISC is a constantly developing encyclopaedic resource containing:

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The Global Invasive Species Database

The Global Invasive Species Database (GSID) aims to increase awareness about invasive alien species and to facilitate effective prevention and management activities. It is managed by the Invasive Species Specialist Group (ISSG) of the Species Survival Commission of the IUCN-World Conservation Union. The GISD was developed as part of the global initiative on invasive species led by the Global Invasive Species Programme (GISP) and is supported through partnerships with the National Biological Information Infrastructure, Manaaki Whenua-Landcare Research, the Critical Ecosystem Partnership Fund, the University of Auckland and private donations.

The Global Invasive Species Database focuses on invasive alien species that threaten native biodiversity and covers all taxonomic groups from micro-organisms to animals and plants in all ecosystems. Species information is either supplied by or reviewed by expert contributors from around the world.

www.issg.org/database

The Global Invasive Species Information Network

The GISIN is a Web-based network of data providers including government, non-government, non-profit, educational, and other organizations that agree to work together to provide increased access to

data and information on IAS around the world. Computer-based information systems like those in the GISIN present specific information to help detect, rapidly respond to, and control IAS. GISIN data providers such as the Invasive Species Specialist Group's Global Invasive Species Database (www.issg.org/database), the U.S. National Institute of Invasive Species Science (www.niiss.org), and the Delivering Alien Invasive Species Inventories for Europe (DAISIE) project (www.europe-aliens.org), create common gateways to search, share, and compare IAS information from around the globe. While varying in scope and administrative origin, these initiatives are united by a common set of principles. They seek to make IAS data freely and quickly available to a broad population of consumers around the world. To achieve this, they participate in the development and promotion of IAS information management standards and technological translations to ensure that retrieval and exchange of information can take place across political, linguistic, technological, and institutional boundaries.

www.gisin.org

The Programme of Work on Invasive Alien Species of the Convention on Biological Diversity

The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) has recognized that there is an urgent need to address the impact of invasive alien species (IAS), and has established IAS as a cross-cutting issue. A portal on the CBD website has been designed as a gateway to information relating to invasive alien species.

www.cbd.int/invasive/

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