EUROPEAN CODE OF CONDUCT FOR BOTANIC GARDENS ON INVASIVE ALIEN SPECIES

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PRESENTATION

The Council of Europe has been particularly active in the last 20 years in the field of invasive alien species, one of the main world threats to native biological diversity. The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) created in 1993 a Group of Experts devoted to the analysis of the impacts of invasive alien species on European biodiversity. The Group was asked to propose measures that governments may take to avoid new introductions and control the spread of invasive alien species. These are complex tasks that cannot be just trusted to a few experts, but that need the collaboration of the many different actors dealing on a daily base with organisms or living material, be it in the horticultural industry, in the pet trade or in institutions, such as botanical gardens, zoos or aquaria which hold collections of non-native animals or plants. The Council of Europe is preparing, for their attention, a number of "codes of conduct" aimed at making those industries and institutions more aware of the risks for native biodiversity of the non-native species they handle. Even though botanic gardens are usually managed by scientists who understand well the risks to the environment from invasive alien species, not many of them have devised special policies to address this problem. The present code aims to offer some guidance to all botanic garden personnel in the hope that, knowing their commitment to biodiversity conservation, they will use it in their everyday work and thus contribute to the noble task of preserving our ecosystems free as far as possible from the impacts of invasive alien species.

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THE CODE OF CONDUCT – AN OVERVIEW

1. Awareness

- Ensure that all botanic garden personnel are made aware of the issues and problems posed by invasive alien organisms and are involved in formulating and implementing the policies adopted by the garden
- Be aware of which species are known to be invasive in Europe and especially in your country or region and of the risks that they pose
- Ensure that the Botanic Garden complies with existing legislation and regulations regarding invasive alien species at a national, European and international level and that all relevant staff are made aware of them.

2. Share information

- Share information with other botanic gardens and other organisations concerned with the impacts or control of invasive alien species.

3. Preventing new invasions

- Undertake an audit of the existing collections in the Botanic Garden for invasion risk
- Try to ensure that no invasive or potentially invasive plants are unintentionally introduced into the collections
- Take great care when disposing of plant waste material from any part of the garden and do so responsibly
- Take great care in disposing of unwanted stocks of plants
- Consider adopting the International Plant Exchange Network (IPEN) Code of Conduct
- If the Botanic Garden produces a Seed List (Index Seminum), ensure that it does not freely offer seed or propagules of invasive or potentially invasive plants
- Be vigilant and ensure that staff report any signs of invasiveness shown by plants in the public collections and in the nursery areas
- Do not offer for sale known or potentially invasive species in garden shops or nurseries.
- Adopt good labelling practices

4. Control measures

- Actual or suspected signs of invasive behaviour should be carefully monitored
- Invasive plants or other organisms should be controlled or removed as soon as detected and confirmed

5. Outreach

- Engage with the public on the dangers of alien invasive plants and their economic consequences
- Suggest alternative species to invasive plants
- Alert those involved in revegetation schemes, including local authorities and landscape architects of the risks of IAS being included in commercial seed mixtures and provide advice on what materials to use

6. Forward planning

- Consider developing research activities on invasive species and becoming involved in collaborative research projects at national and regional levels
- Prepare for the impacts on botanic gardens in a period of global change

1. Introduction

Throughout the ages, Europe has seen the introduction of many plant species for agriculture, horticulture, forestry, medicine, ornament, trade and scientific curiosity. These plants have provided us with countless economic and social benefits. During the past 500 years, botanic gardens have played a significant role in this process. An unexpected consequence of the introduction of many thousands of plant species into cultivation was the escape of considerable numbers of them from agricultural fields, private and botanic gardens into disturbed habitats and some of these in turn became naturalized and a threat to natural plant communities. This did not begin to be appreciated until well into the 20th century and today such alien and invasive plants are now seen as a major threat to biodiversity conservation as well as having serious social, health and economic consequences.

Cardamine corymbosa

The term Invasive Alien Species (IAS) is applied to these plants and also to introduced animals and microorganisms. They are non-native in that they occur outside of their historic range and invasive in that they cause environmental, social, or economic harm. The term 'potentially invasive' is applied to those species that are shown to have a high invasive potential when subjected to a risk assessment (see p.26). The terminology concerning invasive species issues is complex and can be confusing and is elaborated in Annex 1.

Invasive Alien Species have often evoked strong emotional responses (Larson 2005; Heywood 2006), sometimes reflected in the terms which are applied to them, such as 'Mongolian invaders', and approaches to limit or control introduced species have been criticized as being nativist, racist or xenophobic (Simberloff 2003). On the other hand, some non-native species can provide conservation benefits and it has been suggested that instead of just focusing on their negative effects, we should also consider any potential benefits in reaching a judgement and that a more meaningful definition of an invasive species would be one for which there is a net negative effect (Schlaepfer *et al.*, 2011). A review of the ecology, status and policy affecting invasive species in Europe is given by Keller *et al.* (2011).

1.1 Biological and economic impacts

Addressing the impacts of IAS on European ecosystems and native species is one of the most challenging issues in the field of biodiversity conservation and sustainable use (Fernández-Galiano, 2009) today.

Some species of invasive alien plants have the capacity to inflict huge economic damage. For example, it has been estimated that it would cost about £1.6 billion to eradicate Japanese Knotweed (*Fallopia japonica*) in the UK alone[i] and over £150 million are spent there annually on its control in development sites (Williams *et al*, 2010), with an estimated total cost to the

Diospyros lotus

British economy of c.£166 million. The eradication of *Carpobrotus edulis* and *C. acinaciformis*, in various parts of the Mediterranean, notably Mallorca and Menorca, Spain (Andreu *et al.*, 2009) where it poses a serious threat to the native endemic flora incurs annual costs of hundreds of thousands of euros and has been included in LIFE Nature projects. Some idea of the scale of the operations involved can be obtained from the campaign to eradicate *Carpobrotus* undertaken in Menorca from 2002 to 2005: 233,785 m^2 of *Carpobrotus* were eliminated, representing the removal of 832,148 kg of biomass and involving 9,041 hours of work. For other examples of the costs of terrestrial IAS see Vilà *et al.* (2010).

Various estimates have been published of the overall economic costs of IAS in Europe (Vilà and Basnou 2008): a study by Kettunen *et al.* (2008) on 25 species for which there was existing evidence of significant environmental, social and economic impacts in Europe were selected for analysis indicated that the economic costs of IAS in Europe amounted to some €12 billion. For terrestrial plants the sum of known costs in the EU was €3,740.8 million per annum. Many European countries have produced estimates of the economic impact of IAS, such as Belgium (Halford *et al.*, 2011) and Great Britain (Williams *et al.*, 2010).

The environmental consequences of IAS can be serious, with impacts both at the species and ecosystem level. Examples are the impacts of *Carpobrotus* on native coastal plants in parts of the Mediterranean and in Britain, Germany and Ireland; the large-scale changes to ecosystems caused by the colonisation of sand dunes by Australian *Acacia* spp. in Portugal; the invasion of riparian habitats in France, Germany and Switzerland by knotweeds (*Fallopia* spp.) reducing the number of species supported (Gerber *et al.*, 2008).

Some invasive species pose health hazards such as Common Ragweed (*Ambrosia artemisiifolia*) which is one of the major causes of pollen-induced allergy such as hayfever and allergic rhinitis and dermatitis as well as being a noxious agricultural weed (Buttenschøn *et al.*, 2009). It causes hundreds of millions of Euros to be spent in Europe each year on treatment and through absence from work.

1.2 European legislation and initiatives

Although good practice relating to IAS is adopted in some parts of Europe the overall picture is patchy. 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). No mechanisms currently exist to promote harmonisation or basic consistency of approach between neighbouring countries or countries in the same region. Unless steps are taken to introduce and implement policies at a pan-European level, the disparate measures now in place are unlikely to make a substantial contribution to lowering the risks posed by invasive alien plants to European ecosystems (Miko, 2009). Valuable sources of information on European legislation and instruments are provided by Genovesi and Shine (2004) and Stokes *et al.* (2004, 2011).

Likewise good practice (including Codes of Conduct) and regulations for botanic gardens vary considerably from country to country and region to region in Europe and it is likely that progress will be made in addressing these issues by the botanic garden community itself rather than by national or pan-European actions. This Code of Conduct should serve as a stimulus for European botanic gardens to adopt appropriate policies to combat the impacts of IAS.

Botanic garden managers should bear in mind the possibility that if the garden is shown to be the source and cause of a new plant invasion that has a significant adverse economic impact, it could become liable for damages.

1.2.1 The European Union

The new EU Biodiversity Strategy to 2020 (EC, 2011) recognizes that IAS "pose a significant threat to biodiversity in the EU, and this threat is likely to increase in the future unless robust action is taken at all levels to control the introduction and establishment of these species and address those already introduced". The Strategy includes as one of its targets (5: Combat Invasive Alien Species): "By 2020, Invasive Alien Species (IAS) and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS". It notes that the Commission will fill policy gaps in combating IAS by developing a dedicated legislative instrument by the end of 2012 (See EC. 2011). Further information on EU policy and activities on IAS can be obtained from its website: http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

1.2.1.1 DAISIE (http://www.europe-aliens.org/aboutDAISIE.do)

The Delivering Alien Invasive Species In Europe (DAISIE) project was funded by the sixth framework programme of the European Commission. Its general objectives are:

- To create an inventory of invasive species that threaten European terrestrial, fresh-water and marine environments;
- To structure the inventory to provide the basis for prevention and control of biological invasions through the understanding of the environmental, social, economic and other factors involved;

- To assess and summarise the ecological, economic and health risks and impacts of the most widespread and/or noxious invasive species;
- To use distribution data and the experiences of the individual Member States as a framework for considering indicators for early warning.

The DAISIE database is a key resource for information on invasive IAS in Europe (See p.20)

1.2.2 The Council of Europe

Within its nature conservation programmes, the Council of Europe promotes actions to avoid the intentional introduction and spread of alien species, to prevent accidental introductions and to build an information system on IAS. In 1984 the Committee of Ministers of the Council of Europe adopted a recommendation to that effect. Also, the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats), the main Council of Europe treaty in the field of biodiversity conservation, requires its 45 Contracting Parties "to strictly control the introduction of non-native species".

In 2003, the Bern Convention adopted the *European Strategy on Invasive Alien Species* (Genovesi and Shine, 2004), aimed at providing precise guidance to European governments on IAS issues. The Strategy identifies European priorities and key actions, promotes awareness and information on IAS, strengthening of national and regional capacities to deal with IAS issues, taking of prevention measures and supports remedial responses such as reducing adverse impacts of IAS, recovering species and natural habitats affected. National strategies have been drafted and implemented by many of the Parties following the priorities set in the European Strategy.

1.2.3 European and Mediterranean Plant Protection Organization (EPPO)

The European and Mediterranean Plant Protection Organization (EPPO) is an intergovernmental organization responsible for European cooperation in plant health. Nearly all countries of the European and Mediterranean region are members. EPPO's objectives are to protect plants, to develop international strategies against the introduction and spread of dangerous pests and to promote safe and effective control methods. It is developing a cooperative Europe-wide strategy to protect the EPPO region against invasive alien plants and created in 2002 an *ad hoc* Panel on Invasive Alien Species which was charged with identifying invasive plant species that may present a risk to the EPPO region and proposing measures to prevent their introduction and spread and recommendations on ways to eradicate, suppress and contain invasive species that have already been introduced. The Panel has established the EPPO List of Invasive Alien Plants which can be considered as a list of priorities. It publishes standards and guidelines and the EPPO Bulletin is a valuable source of information on IAS.

1.2.4. The European Strategy for Plant Conservation in 2008–2014
(Planta Europa, 2008)

The European Strategy for Plant Conservation in 2008–2014 includes a series of actions on IAS related to the Global Strategy for Plant Conservation Target 10 (*Effective management plans in place to prevent new biological invasions and to manage important areas for plant*

Carpobrotus

diversity that are invaded) as ESPC 10.1 *Action Frameworks developed and implemented for controlling and monitoring the 15 most problematic*[ii] *invasive alien species in each European region*. A recent review of progress in achieving this target states that there are many national/regional projects including proposed EU legislation but less information is available on the effectiveness and extent of management programmes. It notes that many programmes exist but it is still difficult to find information on cross-border projects or effectiveness. For details see Annex 2.

1.2.5. European Environment Agency (EEA) European information and early warning system

The publication *'Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe'* (Genovesi *et al.*, 2010) is the EEA's contribution to achieving the goal of improving our ability to react to invasions. The aim of this system is:

- to identify gaps in early warning and rapid response at the pan-European scale;
- to identify priorities for improving the ability of European Member States to respond rapidly to new incursions;
- to propose a set of options to bridge the existing constraints and gaps in the response to invasive alien species in Europe.

An early warning and rapid response system (EWRR) is defined as: a framework designed to respond to biological invasions through a coordinated system of surveillance and monitoring activities; diagnosis of invading species; assessment of risks; circulation of information, including reporting to competent authorities; and identification and enforcement of appropriate responses (NOBANIS, 2010).

The EEA has also been involved in the Pan European initiative, SEBI 2010 (Streamlining European 2010 Biodiversity Indicators) which includes trends in invasive alien species (numbers and costs) as a specific indicator[iii].

1.2.6 European Botanic Gardens Consortium

There are c. 800 botanic gardens in Europe and in most countries these are linked through national botanic garden networks. Representatives of the national networks come together in the European Botanic Gardens Consortium, of which Botanic Gardens Conservation International (BGCI) is the convenor. This Consortium consists of representatives of all EU member countries, with Bulgaria, Croatia, Iceland, Norway and Switzerland invited to attend meetings as observers. One of its initiatives is the **Alien plants project** on sharing information and policy on potentially invasive alien plants in botanic gardens.

The aim of this initiative is to:

- Compile lists of known or potential invasive plants from a Garden, Local or Regional level to highlight cultivated taxa of concern across Europe.
- Identify emerging problem taxa in the large, and diverse, botanic collections, especially in an era of climatic change, so as to alert collection holders to their potential risk in terms of invasiveness.
- Foster vigilance through sharing early recognition of these newly problematic, or potentially problematic, taxa.
- Ensure responsible, pro-active policies in Botanic Gardens and other plant collections, and apply these in a coherent manner across Europe.
- Encourage gardens to engage with the public by informing them of the risks of introducing certain species into the wild, and how to recognise these species.

1.2.7 European national codes of conduct for botanic gardens

Very few national codes of conduct for botanic gardens have been published or are in preparation in Europe. A German-Austrian Code of Conduct for the cultivation and management of invasive alien plants in botanic gardens has been prepared (Kiehn *et al.*, 2007). The National Botanic Gardens of Ireland has a draft Code of Conduct on the management of actual or potentially invasive species. It is too early to assess the effectiveness of these initiatives.

1.2.8 Other European Codes of Conduct

Council of Europe/EPPO Code of conduct on horticulture and invasive alien plants

As part of the work of the Council of Europe's activities on invasive organisms, it commissioned a Code of conduct on horticulture and invasive alien plants. This was as a joint collaboration of the Council of Europe and the European and Mediterranean Plant Protection Organization (Heywood and Brunel, 2009, 2011). 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]
Czech and Polish versions have also been prepared.

In Belgium a national Code of Conduct on IAS for the horticultural sector has been published (Halford *et al.*, 2011)[iv]. The Code was developed within the framework of the AlterIAS LIFE project coordinated by the Biodiversity & Landscape Unit (University of Liège Gembloux Agro-Bio Tech, Belgium) and in close collaboration with horticultural professionals from the green sector and horticultural federations in Belgium.

Regional legislation (Walloon Region) aiming at prohibiting the use of IAS in public procurement for the supply or use of plant species was published on 23 April 2009 (http://environnement.wallonie.be/legis/general/marchespub003.htm).

The Horticultural Code of practice for England and Wales[v], originally published in 2005, was updated and republished in April 2011 to take into account the European Code of conduct and to provide further guidance.

1.2.9 International Plant Exchange Network (IPEN)

Although it does not deal with IAS, mention should be made of the International Plant Exchange Network (IPEN), established by European botanic gardens in order to comply with the access and benefit-sharing provisions of the Convention on Biological Diversity (CBD) (see Davis, 2005, 2008; von der Driesch *et al.*, 2005, Feit *et al.*, 2005). It covers the non-commercial exchange of plant material between botanic gardens. Members of the Network must follow its Code of Conduct for botanic gardens governing the acquisition, maintenance and supply of living plant material.

1.3 International instruments and initiatives

A summary of the main international instruments and initiatives on invasive alien species is given in Annex 3.

This Code of Practice should be seen as part of a global strategy on IAS and as a contribution to the Global Strategy for Plant Conservation of the Convention on Biological Diversity.

Opuntia ficus-barbarica,

1.4 Related initiatives

- St Louis/Chicago codes.

The St Louis set of Codes developed out of a meeting of representatives from the nursery industry, botanic gardens, landscape architects, the gardening public and government in St. Louis, Missouri, USA, in 2001 to develop codes of conduct. The codes were intended as voluntary guidelines, or best management practices, for the prevention of the introduction and spread of invasive plants. The code for botanic gardens is reproduced in Annex 4.

2. The Special Role of Botanic Gardens

Over the centuries, European botanic gardens have introduced many thousand plant species from around the world into cultivation for medicinal, ornamental, scientific, commercial and other use (Heywood, 2011a). Although initially these were mainly temperate or Mediterranean–climate species, with the development of orangeries and heated glasshouses from the 14th century onwards it became possible to grow a wide range of tropical species. The total number of species in cultivation in European botanic gardens today is not known with complete accuracy but a reasonable estimate is c.80 000[vi]. They have contributed enormously to European culture and the economy.

Agave americana

In the last few years, some European botanic gardens are beginning to search for new species to introduce that will be suited to the new conditions that have been predicted as a consequence of accelerated climate change. For example, the Barcelona Botanic Garden (Jardì Botánic de Barcelona) has been trialling with plants new to the Mediterranean climate with a view to their later introduction into gardening. In 2000 an agreement was made between the city council and municipalities in the metropolitan area to maintain the Garden and enable the centre to experiment with new plants and methods to promote sustainable gardening.

The majority of plant introductions to botanic gardens have been beneficial but inadvertently some of them have proved to have characteristics that make them invasive in some regions. The number of IAS introduced through botanic gardens in Europe is generally small as a proportion of the number of species they cultivate. In Germany, for example, where c. 50 000 taxa are cultivated in 80–90 botanic gardens, 40 IAS have been recorded[vii] (A.D. Stevens, personal communication June 2010).

It is widely accepted that most invasive plant species have originally been introduced for use in horticulture through nurseries, botanic gardens or by individuals (Reichard and White, 2001; Dehnen-Schmutz *et al.*, 2007; Drew *et al.*, 2010). In Europe it is estimated that 80% of current invasive alien plants were introduced as ornamental or agricultural plants.

Seriously invasive plants introduced deliberately as ornamentals include Japanese knotweed (*Fallopia japonica*), summer lilac (*Buddleja davidii*), common rhododendron (*Rhododendron ponticum*[viii]) and giant hogweeds (*Heracleum mantegazzianum* and related species[ix]).

As noted above, the number of invasive species in Europe apparently introduced by botanic gardens has so far been small and the issue has not received much attention until recently, with little guidance available. It has recently been suggested that botanic gardens have not been sufficiently active in addressing these issues (Dawson *et al.*, 2008; Hulme, 2011; see also responses by Sharrock *et al.*, 2011 and Richardson and Rejmánek, 2011, p. 802) although many of them have adopted policies or are heavily involved in actions to prevent such invasions.

At the Fifth European Botanic Gardens Congress (Eurogard V), it was recommended that botanic gardens should

- assess the risk of plants in their collections becoming invasive;
- share information on their experience of invasive organisms;
- develop and implement guidelines, Codes of Conduct, and appropriate practices to prevent the spread of alien species; and
- undertake research on the spread, control, management and risks posed by invasive alien species.

At the Sixth European Botanic Gardens Congress (EuroGard VI) it was suggested that, *inter alia*,

- Botanic Gardens had a responsibility to conduct research on IAS, including improving the taxonomic understanding of invasive species;
- The Council of Europe/BGCI Code of Conduct should be enshrined into national or regional policies;
- An alert system like that of EPPO could be used to make collection managers aware of new or emerging IAS;
- There was a need for innovative electronic solutions to enable rapid informing and sharing of knowledge between gardens, countries and regions.

Botanic gardens provide a wide range of habitats for potentially invasive species, including not only diverse landscapes but greenhouses and other forms of protection. Examples are given in Box 1.

It may be noted that many of the reported introductions are historical and occurred at a time when there was little appreciation of the potential risks that they might pose unlike the situation today. Today with increased awareness many botanic gardens are taking steps to prevent and mitigate such invasions and those that do not already do so should consider urgently taking such action (Dawson *et al.*, 2008; 2011).

The risks of species escaping from botanic gardens in Europe and invading adjacent native ecosystems are likely to increase considerably as a result of climate change (see p.36).

Botanic gardens have not only introduced tens of thousands of species into cultivation but have acted as a network of dispersal centres of species (Galera & Sudnik-Wójcikowsja, 2010). The formal large scale exchange of plants apparently began with the agreement

Box 1. Examples of invasive species known to have been introduced through European botanic gardens

The disposal in 1859 of *Elodea canadensis* into a river by the Berlin Botanical Garden is considered to be the starting point for the rapid spread of the species in the rivers Oder and Havel and their canal systems although today this species is considered to be integrated in the aquatic plant ecosystems or communities in Germany and it is not viewed as representing an ecological or economical threat*; likewise, the spread of *Impatiens parviflora* as an invasive plant from the Botanical Gardens of Dresden and Geneva began in 1837 (Kiehn *et al.*, 2007).

The invasion by the Oxford Ragwort (*Senecio squalidus*) has been well studied. It is a hybrid of two Sicilian species, *S. aethnensis* and *S. chrysanthemifolius* and was first grown in Oxford University botanic garden in the early 18th century. After some years it escaped from the botanic garden and spread into the city and was common on many of its walls by the end of the 18th century; then with the advent of the railway it spread along the tracks in the late 19th century (Abbott *et al.*, 2000). It has subsequently hybridized with native British species, resulting in fertile derivatives some of which have been recognized as separate species such as *S. cambrensis* and *Senecio eboracensis* (James & Abbott, 2006).

Other invasive aliens that are thought to have originated from a botanic garden are *Heracleum mantegazzianum* which is recorded (under the name *H. giganteum*) in the 1817 seed list of the Royal Botanic Gardens Kew and *Heracleum persicum* which was likewise first listed by Kew in 1819 (Nielsen *et al.*, 2005; Jahodová *et al.*, 2007a,b). Seed from similar plants to *H. persicum* cultivated in London were taken to northern Norway in 1836 and the species is now naturalized in Scandinavia (and possibly in Hungary and the United Kingdom) and is spreading rapidly in the Trondheim area of Norway.

Around 1806 the curator of the Malta botanic garden introduced *Oxalis pes-caprae* from the Cape Region of South Africa to Malta. It escaped from the garden after a few years and subsequently spread to Italy and Greece and then through the whole Mediterranean region. It is now a noxious weed in many parts of the world.

Although it is not known how it got to Britain originally, *Cardamine corymbosa* (New Zealand Bitter-cress) was first recognised as a weed in the rock garden of the Royal Botanic Garden Edinburgh (United Kingdom) by at least 1975 and then as a garden weed in Berwickshire by c. 1988, subsequently spreading through much of the UK; by the beginning of the 21st century it reached the Netherlands and Belgium, (Hoste *et al.*, 2008) where it has been recorded in the rock garden at the University of Ghent and the botanic garden of Leuven (Groom *et al.*, 2011). It produces a large quantity of seed and has proved to be particularly troublesome in polytunnels and in container-raised plants from nurseries and garden centres.


Pistia stratiotes

between the Chelsea Physic Garden and Leiden University in 1683. In addition the principal way in which most botanic garden material such as seeds and propagules is exchanged, free of charge, is through the Seed List (*Index Seminum*), the first one being that issued by Oxford University Botanic Garden in the 18th century. This is in effect a mechanism for the widespread movement of species around the world and could thereby potentially facilitate the spread of invasive species to new territories as is discussed below (p.31). As an illustration of the scale of exchange of material between botanic gardens, in Germany, Switzerland, and Austria annual seed exchange between 95 botanic gardens was estimated to reach 326 000 lots (3,441 per Garden) in 2001/2002 (Krebs, 2003).

A distinction should be made between (a) the role of botanic gardens as the original and direct cause of plant invasions through introducing and cultivating invasive species for the first time and these then escaping from cultivation in the garden and becoming naturalized, as in the case of *Elodea canadensis* and *Senecio squalidus*; (b) botanic gardens as the source of the material, for example by growing it or listing it in their Seed Lists but only the indirect cause of the invasion which may in fact be caused by gardeners, horticulturalists or the horticultural trade obtaining seed or other propagules from botanic gardens; and (c) their role as dispersal centres of material obtained from other botanic gardens, some of which may become invasive[xi].

A classic example of indirect invasion is that of false acacia (*Robinia pseudoacacia*), native to the southern Appalachian and Ozark mountains of the United States, introduced to the Jardin Royale des Plantes Médicinales (later the *Jardin des Plantes*) in Paris in 1635 as an ornamental tree by Vespasian Robin (1579–1662). It was subsequently widely cultivated for agricultural and commercial uses and has now become a serious invasive in several areas of the world, including Europe and parts of the USA.

Botanic garden greenhouses are also a source of the spread of invasive species as in the case of the highly aggressive *Oxalis corniculata* which was probably introduced unintentionally with fruit trees from the Mediterranean (Sykora, 1990); propagules were introduced accidentally (Galera & Ratynska, 1999; Galera & Sudnik-Wójcikowsja, 2010) into botanic garden greenhouses in Poland. Plant pots and other containers in greenhouses are a frequent source of dissemination of invasive plants and pests. Some invasive species are adapted to greenhouse conditions such as *Cardamine corymbosa*, *Oxalis corniculata* and *O. pes-caprae* and are difficult to eliminate once established.

3. The Code of Conduct – a Voluntary Instrument

3.1 A voluntary instrument

This Code of Conduct is not a legally binding document but is voluntary. It adopts the principle of self-regulation and to some extent formalizes existing practice by some botanic gardens. It is hoped that most European botanic gardens will sign up to the recommendations made. In the current climate such non-mandatory approaches are widely regarded by botanic gardens and other stakeholders as the preferred way to proceed although there is also support for regulatory approaches by some other stakeholders. Although not compulsory, there is some evidence to suggest that such high-level 'soft law' instruments can be effective (Shine *et al.*, 2010) as in the example of the Council of Europe/EPPO Code of Conduct on Horticulture and Invasive Alien Plants (Heywood & Brunel, 2009, 2011; see also EPPO, 2009) 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. The Code was published in English and French editions and subsequently several European countries such as Spain, Poland and Czechoslovakia have produced their own national versions. It is too early, however, to assess the effectiveness of this Code.

On the other hand, it has been pointed out that 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) (see Box 2). For example, in the case of the St Louis Voluntary Code of Conduct for nursery professionals, a survey of such professionals showed that while only 7 per cent of respondents reported having heard of the Code, most (78 per

Opuntia ficus-indica

Box 2. Advantages and drawbacks of voluntary codes

Advantages:

- They play a key role in building awareness, encouraging best practice, changing attitudes and encouraging voluntary compliance.
- Being voluntary, they are easier to develop, modify and disseminate than legally binding instruments and they can be more readily adjusted to meet changing circumstances.
- If successfully implemented on a widespread basis, they may moderate the need for regulatory alternatives.

Drawbacks

- Codes of conduct or guidelines have no specific targets or time-frame and their effectiveness depends largely on how well they are promoted.
- Experience of the effectiveness of voluntary codes is mixed.
- Ensuring compliance would need to be carefully monitored, thus requiring some supervisory arrangements.
- Difficulties of getting the message to some of the key stakeholders.

cent) reported their willingness to engage in the majority of the preventative measures outlined in the Code (Burt *et al.*, 2007) but as Reichard (2011) comments 'it is hard to argue that botanic gardens are sufficiently addressing their role in the introduction and spread of invasive plants'. The survey recommended a series of actions to increase participation such as increased outreach, provision of clear and accessible information and the use of additional pathways to disseminate information directly to those working in the trade.

A survey of how horticulture professionals and nature reserve managers in Belgium, view the issues associated with invasive plant species (Halford *et al.*, 2011; Vanderhoeven *et al.*, 2011) showed that only 42 per cent of respondent horticulture professionals and 82 percent of nature reserve managers had a general knowledge of IAS, although some did have a proper understanding, and the authors suggest that the perception of invasive alien species issues was largely a result of availability of information. They also suggest that the fact that many IAS continue to be available underscores the need for both mandatory and voluntary approaches.

In the case of botanic gardens, a voluntary code of conduct has a good chance of success because the constituency is small and closely knit with good communication networks. Moreover, most botanic gardens are aware of the threats that invasive alien species pose and some of them as already noted are already engaged in initiatives to counter them.

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 and the European Botanic Gardens Consortium in association with the Council oif Europe and BGCI may wish to develop such a strategy. Individual botanic gardens could consider incorporating the tenets of the Code into their policy documents.

3.2 Audience and aims

This Code of Conduct contains a series of recommendations of good practice and actions to address the problems that botanic gardens face in dealing with IAS. It is addressed to all European botanic gardens and arboreta and to the government, municipal or other agencies and organizations responsible for their management. It is aimed at the professional staff of these institutions and seeks their cooperation in taking actions that will (1) generate a high level of awareness of the dangers and issues concerning invasive alien species; (2) help prevent the introduction and spread of such species, both those already known to pose a threat in Europe and those new to Europe that could pose a threat in the future.

The Code will also be relevant to municipal public parks and gardens and those responsible for deciding on which species to use in planting schemes. It complements the Code of Conduct on Horticulture and Invasive Alien Plants published by the Council of Europe (Heywood & Brunel 2009, 2011) aimed at the horticultural industry and trade. Both Codes should also be taken into consideration by private or public gardens or arboreta in Europe with major collections of plants that are not considered botanic gardens or form part of the horticultural industry. Although most of these gardens do not belong to any association or consortium they are important in terms of the plant collections they house and therefore can pose the same risks as botanic gardens or commercial nurseries in terms of invasive alien species.

Hyparrhenia hirta

Although prepared specifically for botanic gardens and arboreta in Europe, many if not most of the recommendations for action contained in the Code will be of relevance to botanic gardens in other parts of the world.

Individual botanic gardens may wish to adapt the Code to meet their particular circumstances and requirements.

It should be stressed that this Code of Conduct is voluntary and does not replace any statutory requirements under international or national legislation but should be seen as complementary to them. Although voluntary, it is important that as many botanic gardens as possible should adopt the good practices outlined in this Code so as to reduce the likelihood of compulsory legislation having to be introduced should self-regulation fail. Gardens may wish to publicize their adherence to the Code through adopting a symbol or logo indicating this. Gardens may find it useful to cooperate with each other, especially at a local or national level, when planning to implement the Code. Small gardens with limited resources may need support from other gardens if they are to implement the Code.

It should be noted that the Code covers not only invasive plants but relates also to insects, pests and pathogens that may be associated with the introduction, cultivation or exchange of plant material. For example, the invasive garden ant, *Lasius neglectus*, which is spreading through urban areas in Europe most probably entered through botanic gardens, greenhouses and parks (see Schultz and Busch, 2009).

The Code of Conduct

1. AWARENESS

Awareness of the threat posed by invasive species is of paramount importance in reducing the impacts of invasive species.

1.1 Ensure that all botanic garden personnel are made aware of the issues and problems posed by invasive alien plants and are involved in formulating and implementing the policies adopted by the Garden

It should not be assumed that all of the staff working in a botanic garden are well informed about the issues and problems that invasive alien species can present. Garden managers need to take the necessary steps to inform all staff on these issues. Garden staff, especially those involved directly in handling plants and seeds and those responsible for obtaining accessions should be appropriately trained in preventing the spread of invasive alien species.

1.2 Be aware of which species are known to be invasive in Europe and especially in your country or region and of the risks that they pose

Knowledge of which species are invasive in Europe or at a regional or national level is vital if appropriate actions are to be taken to screen the collections for invasive species or prevent their introduction as new accessions. It can, however, be difficult for Garden managers and curators to obtain accurate, up to date and easily accessible lists that provide at a glance indications of problem taxa.

Lists of species known to be invasive in Europe or which should be avoided in trade, cultivation and introduction to nature can be obtained from the initiatives given below such as DAISIE and the North European and Baltic Network on Invasive Species (NOBANIS), which provide detailed databases, and from national Initiatives, such as Harmonia – Invasive

Rhododendron ponticum

species in Belgium, the Irish National Invasive Species Database, InvasIBER (IAV of the Iberian peninsula) and, in Great Britain, the Non-native Species Information Portal (GB-NNSIP) which will be its key source of information on IAS (see Annex 7 which gives links to national lists). An account of online information systems with alien species occurrence records in Europe is given by Vandekerkhove and Cardoso (2011) who note that the most comprehensive resource for country level alien species occurrences in Europe is DAISIE (see below) but this fails to report about one out of every four species known to be alien to one or more countries within the EU27 + Norway territory. Botanic gardens should be aware of such lists and make them available to appropriate staff. It should be noted, however, that the situation is dynamic and lists and databases, both national and international, are being constantly updated as further information becomes available.

The principal European sources of information are:

- **Sharing information and policy on potentially invasive plants in Botanic Gardens** www.botanicgardens.eu/aliens.htm

The aim of this initiative of the European Botanic Gardens Consortium is to aid managers of gardens in obtaining a simple checklist of problem taxa, with an indication of their extent in Europe. A compilation of over 600 taxa has been developed, and this can be downloaded from the internet as a spread sheet[xii] .

- **DAISIE List of Species Alien in Europe and to Europe (2009)**

The DAISIE (**Delivering Alien Invasive Species Inventories for Europe**) database[xiii] and Handbook[xiv] are key sources of information. DAISIE aims to provide a 'one-stop-shop' for information on biological invasions in Europe (Hulme *et al.*, 2009). It records a total 3,749 naturalised alien plant species recorded in Europe, of which 1,780 are of extra- European origin (Pyšek *et al.*, 2009) but is being continually updated.

- **EPPO database and lists**

The European and Mediterranean Plant Protection Organization (www.eppo.org), maintains a database containing information on the distribution of quarantine pests: the Plant Quarantine Data Retrieval System (PQR). This system provides detailed information on the geographical distribution and host plants of quarantine pests. An EPPO *ad hoc* Panel on Invasive Alien Species has established the EPPO List of Invasive Alien Plants which can be considered as a list of priorities[xv]. The number of plants that can be considered as potential pest species is very large and the Panel is elaborating a prioritization process for all known, or potential invasive alien plants in the EPPO region (Brunel *et al.*, 2010 a,b)[xvi].

- EPPO A1/A2 Lists of pests recommended for regulation as quarantine pests

This is a list of invasive plants that have been added to the EPPO A1/A2 Lists of pests recommended for regulation as quarantine pests (as approved by EPPO Council in September 2007). The purpose of the EPPO A1/A2 Lists is to recommend that organisms of serious phytosanitary concern should be regulated as quarantine pests by EPPO member countries (A1 pests are absent from the EPPO region and A2 pests are locally present in the EPPO region).

- EPPO List of invasive alien plants

This is a list of plants that have been identified by the EPPO Panel as posing an important threat to plant health, the environment and biodiversity in the EPPO region.

- EPPO Alert List

This is a list of plants included in the Alert List that have been selected by the EPPO Secretariat or proposed by EPPO member countries, because they may present a risk to the EPPO region. Most species are still of limited distribution, or absent from the EPPO region. The objective of this List is to provide early warning.

- Other documented plant species

This is a list of potentially invasive plants that were studied but not finally retained in the EPPO Lists. Some of these species were documented by the EPPO Secretariat and mini datasheets were prepared for the EPPO Reporting Service.

- **NOBANIS (North European and Baltic Network on Invasive Alien Species)**: www.nobanis.org

NOBANIS is a gateway to information on alien and invasive species in countries in North and Central Europe (Austria, Belgium, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, Germany, Greenland, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, European part of Russia, Slovakia, Svalbard and Jan Meyen and Sweden). It provides:

- a distributed but integrated database on introduced species in the region;
- fact sheets on many of the most invasive species (Secretariat of NOBANIS, 2012);
- a list of the regulations relevant to invasive species in the participating countries;
- a literature database;
- connections to regional and global networks and projects of invasive alien species.

- **NEMO: Baltic Sea Alien Species Database:** www.corpi.ku.lt/nemo/mainnemo.html

The Baltic Sea Alien Species Database is a reference system on alien species for the Baltic Sea area, available online for environmental managers, researchers, students and other interested parties. Its aim is to update information on the alien species of the area, their biology, vectors of introduction, spread, impacts on the environment and economy.

In addition to the above information systems and databases specifically developed for Europe, it may be useful to consult global level tools such as the **Global Invasive Species Database (GISD)** of the IUCN Invasive Species Specialist Group, and the **CABI Invasive Species Compendium (ISC)**. Details are given in Annex 3. A preliminary List of invasive Alien Species Online Information Systems prepared for GISIN, updated to October 2008, is given at: http://www.gisin.org/WebContent/WS/GISIN/Documents/draftiasdbs.htm

The *Global Compendium of Weeds* (Randall 2002) is a valuable source of information on the weedy or invasive behaviour of plants in other parts of the world which is a useful criterion for a rapid initial assessment, especially for those species with similar climatic features.

1.3 Ensure that the Botanic Garden complies with existing legislation and regulations regarding invasive alien species at a national, European and international level and that all relevant staff are made aware of them.

It is the responsibility of management to ensure that the Garden complies with national, regional and international laws, regulations and instruments on invasive alien species, including not only plants but other organisms such as insects, snails, fungi and other pathogens that may be spread with the plants, even in compost and waste. Cases have been recorded of insects used for pest control escaping from botanic gardens (A.D. Stevens in litt., 2011).

- **National**

Many individual European countries have legislation or regulations that are aimed at preventing the possession, trade, transport or release into the wild of specific alien invasive organisms although none of these are aimed specifically at botanic gardens and arboreta. They cover a wide diversity of approaches (see review by Shine *et al.*, 2010) Information on these instruments may be obtained from the relevant ministry (usually environment or agriculture) or plant protection or environment agency. In some countries regional legislation or regulations may also apply. It is strongly recommended that botanic gardens engage with such national policy frameworks and initiatives where they exist and establish partnerships.

- **European legal and policy framework**

As noted in Section 1.2 above, at a European level no coherent policy framework for dealing with the threats from IAS yet exists although various policy options are currently (2012) under consideration (Shine *et al.*, 2010; Keller *et al.*, 2011).

- **International**

At an international level, the threats from IAS are addressed by various instruments, notably the Convention on Biological Diversity (CBD), Article 8(h) of which states 'Each contracting party shall, as far as possible and as appropriate prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. Guiding Principles on the implementation of this article were issued in 2002, including Guiding Principle 10 on intentional introduction which is particularly relevant to botanic gardens. It states that the first or subsequent intentional introduction of an alien species known to be invasive or potentially invasive within a country should be subject to prior authorization from a competent authority of the recipient State(s). Other relevant international treaties include the International Plant Protection Convention (IPPC) and the World Organization for Animal Health (OIE) (see Annex 3).

2. SHARE INFORMATION

'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', Symes (2011).

2.1 Share information with other botanic gardens and other organizations concerned with the impacts or control of invasive alien species.

It is vitally important that botanic gardens share information with each other on plants that are known to be invasive in their region or which are showing signs of becoming invasive. The European Botanic Gardens Consortium 'Alien plants project on sharing information and policy on potentially invasive alien plants in Botanic Gardens' initiative is a good example of this. BGCI is developing its databases to help share information on invasive species management between Botanic Gardens and how collaboration can be further strengthened. It has been proposed that botanic gardens and arboreta from around the world work together to form an *International Sentinel Plant Network* through which information on living plant collections 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) (Kramer and Hird, 2011).

Gardens should also consider using national CBD Clearing House Mechanisms to share information. Information may also be shared through websites, conferences such as those of EuroGard, books, journals, newsletters, articles in the press, leaflets and posters. Alerts about newly recognized threats from IAS could easily be communicated across networks through email and mailing list servers. As well as sharing information between gardens, other stakeholders such as national and local environment agencies, botanical and natural history societies, university departments, horticultural trade associations etc. should be involved.

Rhododendron ponticum

3. PREVENTING NEW INVASIONS

'...assessing invasion risk should become an integral part of conservation goals for all botanical gardens...', Dawson *et al.* (2008)

Following the principle that prevention is better than cure, efforts should be focused on preventing new invasions taking place that have their origin in botanic gardens so as to avoid having to manage them once they begin to show adverse impacts.

3.1 Undertake an audit of the existing collections in the Botanic Garden for invasion risk

Because botanic gardens cultivate such a wide diversity of species, they are one of the major sources of potentially invasive species that could pose a risk to adjacent ecosystems were they to escape. All botanic gardens should, therefore, take active steps to screen their collections for actual or potential invaders. A growing number of European botanic gardens are already adopting appropriate policies for this purpose. Given that undertaking an audit of the collections can be a time-consuming process, consideration should be given to sharing responsibility for this work with other gardens and also sharing information on species that have been audited. Gardens should cooperate closely with other agencies that are involved in combatting biological invasions when undertaking the screening of collections.

Some species that are known to be invasive in different ecoclimatic conditions to those of the garden, either in Europe or other parts of the world, may be grown for educational or demonstration purposes, providing they do not pose a high invasion risk. The advantages of growing potentially invasive species must be balanced against the possibility of their escaping and the consequent economic damage that might be caused. For example, *Gunnera* species are widely grown in botanic gardens for their spectacular foliage and *G. manicata* seems to pose no risk so far but *G. tinctoria* is reported as invasive in parts of Europe so vigilance is needed. On the other hand, the cultivation of *Eichornia crassipes* in northern European botanic gardens under protection is unlikely to pose any invasion risk under current climatic conditions but in southern European gardens its cultivation is not to be recommended as it is a serious invasive pest in parts of Italy, Portugal and Spain. When known invasive species are cultivated for the reasons mentioned, the fact that they are invasive (even when locally not a risk) should be clearly indicated on the plant label as this will serve to inform and educate visitors to the garden. In addition, great vigilance should be exercised to ensure that any signs of invasiveness are detected.

- **Verification of the correct identification of accessions**

The audit of the collections comprises various tasks, a key one of which is to verify that the accessions are correctly named. This can be a challenging task because most botanic garden accessions are of introduced alien (non-native) species and may have been incorrectly identified at source. The literature of taxonomy is very extensive and can be confusing to non-professionals so that correct identification will often require expert help from professional taxonomists.

The development of DNA-based methods for species identification, known as DNA Barcoding[xvii] (Krishna Krishnamurthy and Francis, 2012) is being used increasingly in biodiversity conservation and is beginning to be employed in invasion biology not only for

identification but for helping determine the distribution of target invasive species and monitoring the effectiveness of control measures. Under the Consortium for the Barcodng of Life (CBOL) an informal International Network for Barcoding Invasive and Pest Species (INBIPS) has been established, one of whose aims to act as a clearinghouse of information concerning organizations, initiatives, and species lists concerned with invasive and pest species (http://barcoding.si.edu/INBIPS.htm),

Although DNA Barcoding is now a well-established approach, it is not without drawbacks and should be used in combination with other evidence for identification purposes. Most botanic gardens will require specialist assistance if they are planning to use this technique. It may prove particularly useful in helping resolve the taxonomy of 'difficult' IAS (see below). It has been used to distinguish *H. ranunculoides* from a series of closely related congeners by using a single plastid DNA sequence, trnH-psbA (Van de Wiel *et al*. 2009). Misidentifications of invasive alien species can have serious consequences – harmless species can be confused with harmful invasive species leading to a waste of resources and what is even more serious, harmful invaders can be mistaken for innocuous species, so called 'invaders in disguise' (Verloove, 2010), and no appropriate action taken to counter the threats they pose.

Many species in cultivation in botanic gardens occur under a range of different names due to the problems of synonymy. No comprehensive Floras, reference works or databases exist that accounts for all plant species and gives their full synonymy. The *European Garden Flora 1984–2000* (Cullen *et al.*, 2011) is a valuable resource for species cultivated in European gardens. The *International Plant Names Index* (IPNI) provides a list of names and place of publication for around 1.5 million scientific plant names while *The Plant List*,[xviii] is a first working list of all known plant species prepared as a collaboration between the Royal Botanic Gardens, Kew and Missouri Botanical Garden. It records 904,649 species names for the Angiosperms of which 273,174 (30.2%) are accepted names, 421,698 (46.6%) are synonyms, 15,282 (1.7%) are unplaced and 194,495 (21.5%) are unassessed.

Some invasive alien plants pose particularly difficult taxonomic problems such as the case of *Heracleum mantegazzianum* and the related species *H. sosnowskyi* and *H. persicum* that are invasive in various European countries (see Anon, 2009 for details)[xix]. The situation is further complicated by hybridization with other species of *Heracleum*, the products of which may become invasive. Other examples where hybridization that can make identification of invasive species difficult include the knotweeds, *Fallopia japonica* and *F. sachalinensis*, and their hybrid, *F.* × *bohemica* (Child and Wade, 2000) and the Oxford ragwort (*Senecio squalidus*), itself a hybrid of two Sicilian species (*S. aethnensis* and *S. chrysanthemifolius*), which has subsequently hybridised in the UK with native species, resulting in fertile derivatives, some of which have been recognised as separate species such as *S. cambrensis* and *S. eboracensis* (James and Abbott 2006); and the *Carpobrotus edulis* and *C. acinaciformis* group of species which readily hybridize (Suehs *et al.*, 2004).

Special care should be taken to check the identity of material obtained through Seed Lists (*Indices Seminum*) as these often contain misidentifications (Aplin and Heywood, 2008).

A global level assessment of the taxonomic support needed to manage invasive alien species was made for the GISP programme by Smith *et al.* (2008) who note that taxonomy is a critical tool for combating the threats from alien invasive species.

- **Risk analysis and assessment of the collections**

One of the problems in identifying problem taxa is that there may be a lengthy lag phase between the time when a species becomes naturalised and does not then present a threat, to the stage when it may become highly invasive. The lag phase has been estimated to last on average 147 years, 170 for trees and 131 for shrubs (Kowarik 1995). This means that many species are present that have the potential to become invasive in the future. Unfortunately there are no foolproof ways of predicting these events.

The likely dangers of introducing invasive plant species and their likelihood of escaping may be assessed using some form of risk analysis and assessment; various methodologically rigorous protocols and approaches exist (Pheloung *et al.*, 1999; Reichard 2000; Weber and Gut, 2004; Dawson *et al.*, 2008). If a species is shown by a risk assessment to have a high invasive potential, the most sensible course of action is not to allow its introduction. The use of risk assessment schemes not only helps reduce the risk of invasions but allows gardens to focus their efforts on the introduction pathways of those species that pose a high risk of becoming invasive. A review of existing approaches to regulating the movement of invasive plants and the role of risk assessment systems is given by Roberts *et al.* (2011) while a comparative analysis of European risk assessment procedures is given by Essl *et al.* (2011).

Risk analysis comprises three component parts (NNSS 2011):

- Risk assessment – determining the hazards posed by a species, the severity of those hazards and the likelihood that they will occur.
- Risk management – the practicalities of reducing the risk.
- Risk communication – interpreting the results of the analysis and explaining them in a meaningful way.

The most widely used protocol is the Australian Weed Risk Assessment system (Pheloung *et al.*, 1999) which was designed for use in Australia and New Zealand. It has been successfully adopted and adapted in many other countries, including Belgium (Branquart *et al.*, 2009), Italy (Crosti *et al.*, 2010), Spain (Gassó *et al.*, 2009; Andreu & Vilà, 2010) in Europe and in Japan (Nishida *et al.*, 2009), Canada (McClay *et al.*, 2010) and the United States[xx,xxi]. It has been reviewed by the University of Washington Botanic Garden and Montgomery Botanical Center in partnership with others to develop a Weed Risk Assessment for botanic garden decision making (Husby *et al.*, 2010). On the other hand, in the United States the Invasive Species Assessment Protocol has been developed as a tool for creating regional and national lists of invasive nonnative plants that negatively impact biodiversity (Randall *et al.*, 2008). This was prepared after identifying and evaluating 18 existing systems but finding none that met all of their specifications. The protocol 'consists of 20 multiple-choice questions grouped into four sections, which each address a major aspect of a species' total impact and when combined yield an overall 'Invasive Species Impact Rank' or 'I-Rank' (high, medium, low, or insignificant). The non-profit organization NatureServe is now using this protocol to assess the estimated 3,500 non-native vascular plant species that are established in the United States to create a national list prioritized by negative impact on biodiversity' (see Annex 5).

The Jardin botanique de la Villa Thuret (INRA d'Antibes) (France) has developed a protocol for monitoring the behaviour of alien introduced species in the Garden.

A risk assessment system for Central Europe was developed by Weber and Gut (2004) to assess the invasion potential of new environmental weeds in central Europe and an evaluation of the strengths and weaknesses of the main risk assessment protocols is given by Verbrugge *et al.* (2010). The German-Austrian Black List Information System (GABLIS) proposed by Essl *et al.* (2011) has been developed as a comprehensive trans-national and taxonomically universal risk assessment system for Central Europe dealing with IAS that pose a risk to biodiversity. It recognizes three categories of lists according to the severity of impacts: a White List of species with no negative impact and are non-invasive, a Grey List of species thtat probably or possibly threaten biodiversity and a Black List of those species that are invasive and whose negative impact is confirmed.

Botanic gardens should consider adopting the International Standard on Phytosanitary Measures No. 11 on Pest Risk Analysis (ISPM, 2006) as adapted by the European and Mediterranean Plant Protection Organization) which is in the form of a decision-support scheme[xxii]. This assesses information on: preferred habitats, climatic, soil and water requirements, life history of the plant, natural or human assisted spread, reproduction, intended use, ease of detection of the plant, persistence, competitiveness, possibility to be controlled, and economic, ecological and social impacts. The UK risk assessment scheme for all non-native species was adapted from the EPPO system and reflects standards used by other schemes such as the International Plant Protection Convention and the Australian Weed Risk Assessment system (Baker *et al.*, 2005, 2008).

A set of procedures for weed risk assessment has been prepared by FAO (2004). This includes an assessment system in the form of key 'for use by countries with limited access to information or resources to undertake weed risk assessments. It embodies the general principles of weed-risk assessment used internationally, while requiring the minimum of information for an unequivocal outcome of accept or reject'.

- **Rapid risk assessment**

If a species is suspected of being a potential invader, it can be subjected to a rapid preliminary risk assessment along the lines of the Protocol for Initial Weed Risk Assessment of Plant Species in New South Wales[xxiii] which poses a number of basic questions (Box 3.):

Solanum eleagnifolium

EPPO has proposed a prioritization process for invasive alien plants designed (i) to produce a list of invasive alien plants that are established or could potentially establish in the EPPO region and (ii) to determine which of these have the highest priority for an EPPO pest risk analysis (for details see Brunel *et al.*, 2010b).

3.2 Try to ensure that no invasive or potentially invasive plants are introduced into the collections

In addition to screening the existing collections for invasion risks, it is important to try and avoid introducing new material that may pose a risk of escaping and becoming invasive. A key prerequisite for such an approach is to ensure that the botanic garden has clear guidelines about what kinds of plants it should grow – an accessions policy – and that appropriate management practices are followed.

Box 3: Preliminary weed risk assessment (modified and adapted from Johnson *et al.* (n.d.))

Step 1 Determine the correct identity of the species.
Step 2 Is the species weedy in the world?
Step 3 Has the species become naturalised in Europe?
Step 4 Has the species become naturalised in your country?
Step 5 Is the species a known weed in at least one ecosystem in your country or similar ecosystems elsewhere in Europe?
Step 6 Does the species have known impacts in your country or similar ecosystems in Europe?
Step 7 If the species satisfies most or all of the conditionss identified at Steps 1–6 it will be given priority for assessment by a full scale Weed Risk Assessment/Management System.

- **Importance of an accessions policy**

Many botanic gardens have formulated and adopted an accessions or collections policy. Those that do not have one should consider introducing one. Until recently, most accessions policies did not take into account the invasiveness or invasive potential of the plants. Guidance on preparing an accessions policy may be obtained from Rae (2011). An example of a collections policy is that of the Royal Botanic Garden, Edinburgh, UK (Rae, 2006) Even though this policy is quite detailed in places, the management recognises that it cannot be applied all of the time in each of its four gardens and it is made clear to staff that it is for guidance in developing the Collection and not to be followed slavishly. The Curator of each Garden has to interpret and apply it for his area/garden (D. Rae, personal communication 6 July 2011). An adapted version of the guidance for Cataloguing and Record Keeping for Plant Collections for the National Botanic Garden of Ireland is available[xxiv].

- **Review of management practices**

Good management practices should be followed in order to avoid the unintentional introduction and spread of invasive alien plants in newly acquired plant material. Good hygiene should be maintained at all times. Particular care should be taken to check the soil and growing media in which the new plants are received. It is good practice to keep newly imported plants isolated from locally produced plants and from those growing in the wild. Likewise, in making plants available for exchange, attention should be paid to the cleanliness of the soil and growing media used and care should be taken to avoid accidental disposal of waste material that could contain viable propagules. Pots and other containers (especially the base) can harbour material of invasive organisms as well as the gravel, polythene sheeting, capillary matting and other materials on which they may be stood. The reuse of plastic pots or containers during propagation can pose a risk unless carefully cleaned as residue from the medium used for the previously grown plants may cling to the sides of the containers and could contain seeds from them.

Particular care should be taken with accessions of aquatic plants which may also be contaminated by vegetative fragments of other aquatic invasive alien plants. Also, during the propagation of aquatic plants precautions should be taken as discarded material can spread rapidly if it is allowed to get into waterways. Even when aquatic plants are on display in the Garden there is a risk of their escaping and Gardens should make the public aware of the danger they pose. To reduce the risks of introduction or spread of invasive organisms, the following are recommended (based partly on the Wisconsin Manual of Best Management Practices – Wisconsin Urban Forestry, 2009).

- Avoid planting material about which you have doubts;
- Use healthy plants;
- Avoid unnecessary soil disturbance;
- Stabilise disturbed soils as soon as possible;
- Avoid moving soil that is known to contain noxious weeds;
- Use materials (top soil, soil modifiers, potting and other compost, gravel, stone and mulch) that are free from invasive seed or propagules;
- Avoid contamination by treating organic growing media to kill the contaminants (e.g. by chemical disinfestation or steam sterilization);
- Know the source of top soil, compost, wood chips and other planting materials and avoid the use of those that may contain invasive propagules (see EPPO PM3/54 1993[xxv]). If appropriate a sample should be requested for inspection and the supplies should be checked on delivery;
- Remove soil, seeds, plant material and other debris from shoes, clothing, equipment, barrows, trolleys, vehicles and trailers before leaving an area by scraping, brushing, washing and other means so as to avoid the risk of transporting seed or other propagules of invasive plants, insect eggs, larvae, pupae and spores of pathogens.

- **Protocols for evaluating new introductions**

All new introductions should be carefully assessed for their invasion risk. Consideration should be given to adopting guidelines or protocols for this purpose (see above: Risk analysis and assessment). For example, the National Botanic Gardens of Ireland's Draft Code of Conduct on the management of actually or potentially invasive species proposes that as well as following all legislation on the importation and quarantine of materials across boundaries, the Garden will perform risk assessment for all plants introduced to the Garden through its accessions policy. Species new to the country will be evaluated for at least four years after reaching reproductive maturity and the evaluation must be completed before the species is included in the permanent collections. The Austrian Botanic Gardens working group has started a series of publications aimed at informing other gardens (and scientists) about species in their collections that are showing tendencies to become invasive, such as *Pinellia ternata* (Araceae), *Nonea lutea* (Boraginaceae) and *Geranium sibiricum* (Geraniaceae)[xxvi], as part of an early warning system (Lechner and Kiehn, 2010; Eberwein *et al.*, 2010).

3.3 Take great care when disposing of plant waste material from any part of the garden and do so responsibly

All plant material should be disposed of in such a way as to avoid the risk of spreading invasive organisms. The following methods may be used: burial, composting, incineration, anaerobic digestion or chipping or used for fuel, canes or other purposes. The *EPPO*

Guidelines for the management of plant health risks of biowaste of plant origin (EPPO, 2008) which advise on how such biowaste should be treated in order to destroy plant pests should be consulted and adopted as appropriate.

Plant waste should never be dumped in the countryside, in natural ecosystems or in waterways. The following good practices should be considered:

- Ensure that local regulations regarding the disposal of plant material are adhered to. For example, some countries prohibit the composting of certain species such as Japanese Knotweed (*Fallopia japonica*);
- Plant waste materials may be bagged and clearly labelled if known to contain material of invasive species;
- If to be buried, the depth of burial must take into account the specific nature of the material, for example in the case of Japanese Knotweed for which special regulations for its disposal exist in some countries;
- For composting, consideration should be given to using centralised municipal facilities (as in the case of Uppsala University Botanic Garden) which provide much higher temperatures than are normally possible in botanic gardens and are more effective in killing weeds and weed seeds. The EPPO guidelines caution that although in principle, the temperatures reached in composting should destroy plant pests including weeds, there is clear published evidence certain pests survive some treatment processes.

- **Disposal of aquatic plants**

Particular care should be exercised in disposing of aquatic plants and avoiding the risk of their getting into rivers, waterways or seas. The methods that can be used for their disposal are: composting and burying, drying or freeze drying and subsequent safe disposal. Care should also be taken in disposing of the packaging used for aquatic plants as this may house 'hitchhikers' including spores, parasites or other species which may be hidden in the tissues of the specimens, in or on the surfaces of their packaging or in the holding water or sediments. Proper handling is needed to avoid the risk of any hitchhikers escaping.

- In the UK Defra and the Scottish Government have launched **Be Plant Wise** campaign to raise awareness among gardeners, pond owners and retailers of the damage caused by invasive aquatic plants and to encourage the public to dispose of these plants correctly. It has developed resources including advice on compositing aquatic plants (https://secure.fera.defra.gov.uk/nonnativespecies/beplantwise/).

- **Disposal of packaging and containers**

The packaging material in which plants are received (or sent) is also a recognized pathway for import and export of invasive plants. It is good practice to:

- check packaging material carefully for material of invasive species, including seeds, eggs, etc;
- destroy imported packaging material or clean it for reuse;
- ensure that packaging material to be used to send plants is kept clean and isolated from other plant material that might contaminate it.

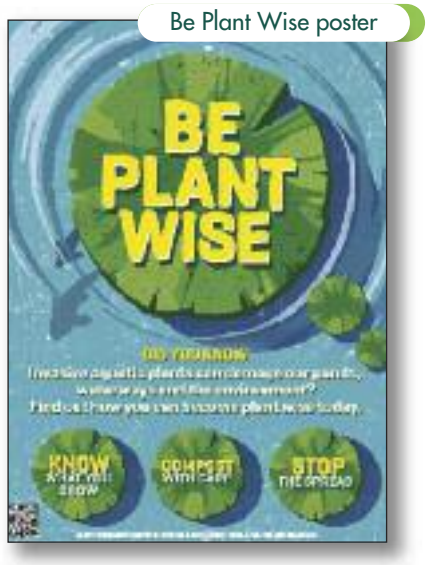
3.4 Take great care in disposing of unwanted stocks of plants

Botanic gardens should adopt strict procedures when disposing of surplus material, whether by sale, exchange, gift, composting or other means of disposal. The norms suggested above should be followed.

A related issue that has seldom been addressed adequately is how to manage or dispose of the collections when a botanic garden is forced to close. Every effort should be made to ensure that both the arrangements for closure of the garden or its conversion for other use, and the disposal of the collections, are undertaken in such a way as to minimize any risk of invasion. Any material of high invasion risk should be clearly flagged.

3.5 Consider adopting the International Plant Exchange Network (IPEN) Code of Conduct

Be Plant Wise poster



Many European botanic gardens already belong to the International Plant Exchange Network (IPEN)[xxvii], an exchange system for botanic gardens for non-commercial exchange of plant material, based on the CBD. It was originally developed by the Verband Botanischer Gärten (an association of gardens in German speaking countries) and was adopted by the European Consortium of Botanic Gardens.

Gardens joining the network must sign and abide by a Code of Conduct[xxviii] that sets out gardens' responsibilities for acquisition, maintenance and supply of living plant material and associated benefit-sharing. Although the IPEN Code of Conduct does not specifically refer to IAS, its general adoption by European botanic gardens is to be recommended and would contribute to an effective policy for the handling of actual or potential IAS. The IPEN covers:

- transfer of living plant material from countries of origin to botanic gardens;
- plant exchange between registered botanic gardens;
- supply of plant material to not registered gardens and other institutions;
- sharing of benefits arising from non-commercial use (e.g. basic research).

3.6 If the Botanic Garden produces a Seed List (*Index Seminum*), ensure that it does not freely offer seed or propagules of invasive or potentially invasive plants

The Seed List or *Index Seminum* is one of the defining characteristics of a botanic garden. Given that the purpose of a Seed List is to make seed and other propagules of plants grown in the botanic garden or collected in the wild available to other botanic gardens by exchange, this has effectively created a network of botanic gardens and other scientific institutions in many parts of the world. It also provides, unintentionally, a mechanism for the spread of alien invasive plants and some European botanic garden seed lists actually offer freely seed of

species known to be invasive in Europe without giving any indication of the potential dangers they pose to native plant life should they escape, such as *Fallopia japonica, Heracleum 'mantegazzianum'* and *Rhododendron ponticum* (Aplin *et al.*, 2007; Aplin and Heywood, 2008). Similar considerations apply to commercial seed catalogues (Mack, 2003).

In compiling the *Index Seminum*, botanic gardens should take care not to include species known to be invasive in Europe in the list of seed that is freely available and should only provide such seed on a special request basis. Consideration should be given to flagging species known to be invasive even if they are not a threat in the Garden's own country, as in 2010 Seed List of the University of Zagreb Botanic Garden, Croatia which notes such species as IAS. Some *Indices Seminum* (e.g. the 2010 list from the Botanic Garden, University of Szeged. Hungary) include a disclaimer for any damage caused by plants raised from seeds they offer should they become invasive but do not flag such species, nor does the *Index Seminum* of the Hortus Botanicus Tergestinus, Trieste, which contains the warning: **'Invasive species.** Some of the offered species may be invasive. It is the responsibility of the importer to take the necessary measures to ensure that these species do not escape from cultivation'.

Likewise, botanic garden management should alert all those who have authority to select seed or other propagules from the *Indices Seminum* received of the need to avoid requesting seed of species that are known invasives. Given the frequent misidentifications found in Seed Lists, care should be taken to check the identity and nomenclature of the material listed (Aplin and Heywood 2008).

3.7 Be vigilant and ensure that staff report any signs of invasiveness shown by plants in the public collections and in the nursery areas

Botanic garden staff, especially those involved directly in the daily handling of plants and those responsible for obtaining accessions, should be on the lookout for any signs of invasiveness and report them to management (see Control measures).

3.8 Do not offer for sale known or potentially invasive species in garden shops or nurseries

Some European botanic gardens have been observed to have material (seed, living plants) of IAS on sale. A check should be made to ensure that this is not happening and any inappropriate material should be removed and where appropriate disposed of in a safe and effective manner. Those involved in running botanic garden shops or nurseries offering plants for sale to the public need to be included in education and awareness programmes.

3.9 Adopt good labelling practices

Botanic gardens by their nature normally provide labels on the plants grown both in the public and in the nursery areas and in research or other special collections. The labels of plants in the public parts of the garden provide an opportunity of indicating to visitors the potential risks that invasive species pose and this should be clearly indicated for any such species that are grown, even though they are not currently known to be a threat nationally.

In the nursery areas and in special collections, consistent and accurate labelling of all material is not only good general horticultural practice but essential to avoid material of potentially invasive plants being inadvertently planted or made available for exchange.

4. CONTROL MEASURES

4.1 Actual or suspected signs of invasive behaviour should be carefully monitored

Following the precept that prevention is better than cure, any signs of invasiveness reported in the Garden should be carefully monitored so as to avoid serious problems developing. As the German and Austrian Guidelines note, 'In the garden first signs of spreading and invasive behaviour are most likely to be noticed by informed garden staff' (Kiehn *et al.*, 2007).

4.2 Invasive plants or other organisms should be controlled or removed as soon as detected and confirmed

Plants already present in the collections that are known to be invasive or that are showing signs of becoming invasive should be contained or controlled or preferably removed from the Garden.

The main control options are prevention of introduction, containment, control of spread and eradication. The measures used include manual/physical (e.g. cutting, pulling, digging, smothering, and girdling), chemical and biological means but it is beyond the scope of this Code to go into details of this very complex area. For guidance see: North Carolina Botanical Garden (2007), Cronk and Fuller (1995), Stokes *et al.* (2004). A tool kit of best prevention and management practices has been prepared by GISP (Wittenberg and Cock, 2001)

If a botanic garden includes an area of native vegetation or is responsible for such an area, any invasive species detected in it should be contained, controlled or eradicated.

Gunnera tinctoria

5. OUTREACH

Botanic gardens in Europe receive many million visits by the public every year and have a unique opportunity to showcase biodiversity and conservation issues. Invasive alien species is one of the issues that should be highlighted.

5.1 Engage with the public on the dangers of alien invasive plants and their economic consequences

Botanic gardens play a major role today in educating the public about the importance of biodiversity and the risks to which it is exposed. The risks posed by invasive species is one of the messages that can be conveyed by gardens to visitors and the general public. This may be done through labelling in the garden, public lectures, special displays or features, pages on the garden's website, articles in newspapers and magazines, publications (such as that on 20 invasive alien plants in NW France produced by the Conservatoire Botanique National de Bailleul (Levy *et al.*, 2011) and the illustrated identification guide to the main aquatic and riverbank invasive species found in Provence and Languedoc (ARPE PACA, 2009) produced in collaboration with the Conservatoire botanique national méditerranéen de Porquerolles[xxix], brochures and leaflets (for example that produced by Jeanmonod and Lambelet (2004) for the *Conservatoire et jardin botaniques*, Ville de Genève).

Robinia pseudoacacia

Botanic gardens should work with other relevant organizations in their countries (e.g. Zoological Gardens) to develop common messages for the public.

5.2 Suggest alternative species to invasive plants

In addition to helping to educate visitors and the general public about the dangers of growing invasive plants, botanic gardens should consider giving advice on which alternative species, whether native or exotic, might be planted instead. This can be in the form of posters, leaflets, information on the garden website or books. A good example from North America is the finely illustrated volume published by Brooklyn Botanic Garden on native alternatives to invasive plants (Burrell, 2007) which profiles between one and four native species for each invasive species listed. A booklet aimed at promoting commercially available alternatives to potentially invasive ornamental plant species in New England, has been published by the Connecticut Agricultural Experiment Station (Abbey, 2004). In Europe, the AlterIAS project has produced a guide to alternative species (Mathys *et al.*, 2012) in Belgium and a folder on aquatic invasive plants and alternatives (Branquart, 2011); the UK wild plant conservation charity Plantlife and the Royal Horticultural Society have published a guide to plants that can be used in place of invasive non-native species (Plantlife/RHS, 2010).

Ipomoea acuminata

Such lists or compilations of alternative species are intended only for the country or region concerned and it should be remembered that a species proposed as an alternative in one area may prove to be invasive in another.

5.3 Alert those involved in revegetation schemes, including local authorities and landscape architects of the risks of IAS being included in commercial seed mixtures and provide advice on what materials to use

One of the consequences of the continuing loss of biodiversity and degradation of habitats is the growing demand for habitat restoration, revegetation and reafforestation. Commercial seed suppliers cannot provide the quantity and range of plants that are needed for restoration and the availability of native seed is extremely limited (Jorba and Vallejo, 2008) and what is available may not be correctly identified. More seriously, some of the seed included in commercially available mixtures are of IAS. Botanic Gardens on the other hand do have the knowledge and skills and should collaborate actively with local authorities and agencies engaged in such restoration projects through the provision of advice on which species to employ that do not pose an invasion risk and where possible act as suppliers of seeds and other material for planting. A relevant model is the Seeds of Success (SOS) programme (http://www.nps.gov/plants/sos/index.htm) that was established in 2001 by the United States Bureau of Land Management (BLM) in partnership with the Royal Botanic Gardens, Kew Millennium Seed Bank (MSB) to collect, conserve, and develop native plant materials for stabilizing, rehabilitating and restoring lands in the United States., SOS now has over 13,000 native seed collections in its National Collection.

6. FORWARD PLANNING

6.1 Consider developing research activities on invasive species and becoming involved in collaborative research projects at national and regional levels

Invasion biology is a complex multidisciplinary field and Gardens are well placed to undertake research on topics such as the spread, control, management and risks posed by invasive alien species in collaboration with national or local environment agencies and appropriate regional or European bodies.

6.2 Prepare for the impacts on botanic gardens in a period of global change

It is widely accepted that global change over the coming 50–100 years will have a wide range of impacts on the environment and on the distribution of species. In particular, the effects of climate change such as increasing levels of CO_2 and rising temperatures, coupled with land use change and population growth and movements are expected to have both positive and negative effects on plant growth and on the risks of invasion (Bradley et al., 2010). Although the relationship of climate change to biodiversity is still in its infancy and accurate predictions at an appropriate scale, especially of specific responses of wild species, have proved difficult to establish (Parmesan *et al.*, 2011), there is already good evidence of the impacts of recent shifts in the distribution of species and ecosystems that can be attributed to the effects of climate change. Species commonly respond to climate change through shifts in phenological features such as changes in time of budburst, flowering, fruiting, leaf coloration and leaf-fall (Cleland *et al.*, 2007). For assessments of the impacts of climate change on biodiversity see Council of Europe (2010), on European and Mediterranean plant species see Heywood (2009, 2011b, 2012) and for a global review of plants and climate change by BGCI see Hawkins *et al.* (2008).

Botanic gardens should take into account the likely consequences of global change on the plants they currently grow and factor in the likelihood that some of them will not be able to adapt to the novel ecoclimatic conditions that may ensue. They should take care not to introduce species that have aggressive tendencies and be vigilant for any signs of invasive behaviour by any newly introduced species. Already some botanic gardens and commercial nurseries are beginning to experiment with the introduction to cultivation of new species that are adapted to warmer and more xeric conditions and some of these may pose an invasion risk (Heywood, 2011a; Bradley *et al.*, 2012). Ironically, the very characteristics that make some species attractive for introduction (ease of propagation, fast-growing, adaptable, high reproductive output, resistance to pests and diseases, tolerant of disturbance and a range of environmental conditions) are the same properties that increase the likelihood of the species becoming invasive. Risk assessment strategies may need to be adapted to address this new type of threat.

Pennisetum villosum and *Oxalis pes-caprae*

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ANNEXES

Annex 1. Definitions

The terminology used in the literature when discussing alien invasive species is complex and confusing as many of the terms have been used in different ways by different authors. For a discussion of terminology and a set of recommended definitions, see Richardson *et al.* (2000); and for a glossary of the concepts and terminology of invasion ecology, see Richardson *et al.* (2011). Colautti & MacIsaac (2004) list in their Table 1 some 32 common terms in the English literature on invasion ecology. They also propose a neutral invasion terminology based on current models that break the invasion process into a series of consecutive, obligatory stages.

The definitions employed in the *Code of Conduct on Horticulture and Invasive Alien Plants* (Heywood and Brunel, 2009) are followed in this document for consistency:

The term **native** (indigenous) refers to those species that occur naturally in an area and thus have not been introduced deliberately or accidentally by humans. The term is usually applied to plants which evolved *in situ* or which arrived in the area before the beginning of the Neolithic period (see discussions in Heywood 1989; Webb 1985).

The term **alien** is used to refer to plants that are not native to the country, territory, area or ecosystem under consideration. Such plants are also referred to in the literature as exotic, non-native, non-indigenous, anthropophytes, metaphytes, neophytes or neobiota

The Convention on Biological Diversity (CBD) Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species define an alien species as one that has been introduced outside its natural past or present distribution, with an introduction being defined as the movement by a human agency, either directly or indirectly, of an alien species outside its natural range.

Casual alien plants according to Pyšek *et al.* (2004) are aliens that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence. Most of them do not persist and they are widely referred to in the literature as 'casuals', 'adventives', 'waifs', 'transients', 'occasional escapes' and 'persisting after cultivation'.

Transience, according to the International Plant Protection Convention (IPPC), refers to the presence of a pest that is not expected to lead to establishment [ISPM No. 8, 1998]. A 'transient species' is considered to be 'a casual species'.

Establishment is the stage in the invasion process at which the plant becomes successfully self-reproducing. According to the CBD 2002, establishment is the process whereby a species in a new area is able to reproduce successfully at a level sufficient to ensure its continued survival without infusion of new genetic material from outside the area. The invasive plant is then said to be established and in this sense is equivalent to 'naturalized' (see below).

The term **naturalized** is applied to alien plants that reproduce successfully without human intervention and form self-reproducing populations over several generations. The term invasive is applied to alien plants that have become naturalized and are, or have the potential to become, a threat to biodiversity through their ability to reproduce successfully at a considerable distance from the parent plants and have an ability to spread over large areas and displace elements of the native biota. When they cause significant habitat transformation, leading to biodiversity loss and reduction in ecosystem service, they are often known as **transformers** or **transformer species** (Richardson *et al.* 2000).

According to the Convention on Biological Diversity (CBD), an **invasive alien species** is 'an alien species whose introduction and/or spread threaten biological diversity' (annex footnote 57, CBD, 2002). This definition can be interpreted as covering both natural and agricultural systems, unlike the definition in the IUCN Guidelines (IUCN 2000) which defines an invasive alien species as an alien species which 'becomes established in natural or semi-natural ecosystems, is an agent of change, and threatens native biological diversity'. It should be noted that the CBD defines 'invasive' in terms of (negative) impact, while other definitions use ecological and biogeographical criteria and explicitly exclude considerations of impact, so that invasive species are then defined as alien species that maintain self-replacing populations at considerable distances from the site of introduction (see discussion and references in Richardson *et al.*, 2011; Blackburn *et al.* 2011).

Although originally aimed at protecting human health and trade in agricultural commodities, one of the most effective means of containing the spread of IAS is the use of quarantine measures, especially in the case of invasive plants. This introduces the notion of **pests** which describe species that threaten or harm agricultural activity (Riley, 2005).The term 'pest' is not normally employed or defined outside this context. According to the International Plant Protection Convention (IPPC) a **pest** is 'any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products", while a quarantine pest is 'a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled'. As a consequence, considering that potential economic importance can account for environmental concern (according to the supplement the International Standard on Phytosanitary Measures n°5 Glossary of phytosanitary terms), the IPPC definition of a quarantine pest covers much of what is considered an invasive alien species under the CBD. Differences arise from the fact that a quarantine pest does not necessarily threaten biodiversity and may only affect agriculture (Lopian, 2005), and that an invasive alien plant may not be considered a quarantine pest if it is widely distributed.

The term **weed** is applied to plants, whether native or alien, which infest agricultural or horticultural crops or domestic gardens and adversely affect the plants being cultivated, often reducing yield. Their control costs the industry hundreds of millions of euros annually. They also occur in waste ground or disturbed habitats to which they are often adapted and tend to be vigorous and fast –growing and often have a high reproductive capacity which allows them to spread rapidly. Unlike invasive species, they do not invade natural ecosystems or displace native wild species.

Annex 2. European Strategy for Plant Conservation

The European Strategy for Plant Conservation was developed by the Planta Europa Network and the Council of Europe in discussion with relevant conservation organisations in Europe. The actions relevant to IAS proposed in the Strategy are as follows:

ESPC 10.1 Action Frameworks developed and implemented for controlling and monitoring the 15 most problematic invasive alien species in each European region (Mediterranean, Baltic, Alps, South East Europe, East Europe, Atlantic etc).

Action 1 Publicise the available lists of European alien invasive species (the EPPO list, the DAISIE list, the SEBI2010 list)

Action 2 Promote the national implementation of the European Strategy of Alien Invasive Species (Bern Convention 2003) and the EU communication on Invasive Alien Species (2008)

Action 3 Promotion of trans-boundary examples of control (e.g. Croatia)

Action 4 Exchange of experiences/toolkit/best practice case studies for dealing with invasive species, via the PE website

Action 5 Promote the aims & results of the European (and global) organisations working on invasive alien species (the Council of Europe, the Bern Convention, NEOBIOTA, EPPO, DAISIE, NOBANIS, GISP)

Action 6 Encourage Planta Europa members to provide information on current programmes & projects for the interactive map of the Global Invasive Species Programme (GISP) and other relevant organisations

ESPC 10.2 Action frameworks developed and implemented for controlling and monitoring 10 problematic invasive alien species in each country, with reference to information from other countries and regional initiatives

ESPC 10.3 The existing EU web based information system (DAISIE) to include at least 80% of European countries

ESPC 10.4 The Code of Conduct on Horticulture and Invasive Alien Plants adopted and implemented in at least 10 European states.

Action 1 Publicise the Code of Conduct on Horticulture and Invasive Alien Species
Progress to date has been limited, largely through lack of capacity.

Annex 3. International instruments and initiatives on IAS

- **Convention on Biological Diversity (CBD) and its Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species.**

Article 8(h) of the CBD calls for measures 'to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. The Aichi Biodiversity Targets agreed in 2010 include: Target 9: By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

In 2002, the CBD approved a Global Strategy for Plant Conservation (GSPC) which included a series of time-bound targets, one of which was: Target 10: Management plans in place for at least 100 major alien species that threaten plants, plant communities and associated habitats and ecosystems. The Strategy was revised in 2010 and the target for 2011–20 was revised to read: Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded.

- **The Washington Convention (CITES)**

The Convention on International Trade in Endangered Species of Wild Fauna and Flora, commonly known as CITES, is an international agreement between governments aimed at ensuring that international trade in specimens of wild animals and plants does not threaten their survival. Because this trade crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. Today, it accords varying degrees of protection to more than 30,000 species of animals and plants, whether they are traded as live specimens, fur coats or dried herbs.

- **The International Plant Protection Convention (IPPC) (www.ippc.int)**

The International Plant Protection Convention (IPPC) is a plant health treaty which came into force in 1952 under the Food and Agriculture Organization. The mission of the IPPC is to secure cooperation among nations in protecting global plant resources from the spread and introduction of pests of plants, in order to preserve food security, biodiversity and to facilitate trade. While the CBD aims to conserve biological diversity and, in the specific case of invasive alien species, to protect ecosystems, habitats or species, the IPPC seeks to protect plants and plant products. The scope of the IPPC is not limited to the protection of agricultural plants, but covers all plants (IPPC Secretariat, 2005).

- **Invasive Species Compendium (ISC) – CABI**

The Invasive Species Compendium (ISC) is an online, global, comprehensive, encyclopaedic reference work covering recognition, biology, distribution, impact and management of the world's invasive species. It is being developed by a consortium of partners, led by the international organisation CABI with the US Department of Agriculture as a lead partner. The site may be accessed at: www.cabi.org/isc

The Compendium contains the following data.

- Datasheets on invasive species with referenced text sections, links to related content, images and distribution maps;
- Datasheets on natural enemies, hosts, vectors, ecosystems / habitats and countries;
- Downloadable distribution data in KML format (for use in Google Earth) and CSV format (for modelling packages);
- Case studies to illustrate location-specific management practices and impacts;
- Bibliographic database of over 60,000 records;
- Glossary, taxonomic framework and statistics;
- Library of full text documents and links to further resources.

- **Global Invasive Species Database (GISD)**

The Global Invasive Species Database is managed by the Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission. It 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 and the University of Auckland.

- **Global Invasive Species Information Network (GISIN)**

The Global Invasive Species Information Network (GISIN) provides a platform for sharing invasive species information at a global level, via the Internet and other digital means. A group of collaborators lead by the United States Geological Survey, are developing the GISIN as a Web-based network of databases that are connected by a common set of data types. The resulting network, or GISIN, provides increased access to data and information that will in turn help detect, rapidly respond to, and control invasive species.

- **IUCN Species Survival Commission Invasive Species Specialist Group (ISSG)**

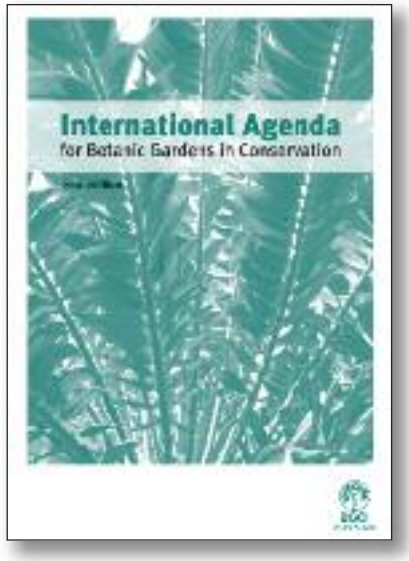
The Invasive Species Specialist Group (ISSG) is a global network of scientific and policy experts on invasive species, organized under the auspices of the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN). The ISSG aims to reduce threats to natural ecosystems and the native species they contain by increasing awareness of invasive alien species, and of ways to prevent, control or eradicate them. The ISSG was established in 1994. It currently has 196 core members from over 40 countries and a wide informal global network of over 2000 conservation practitioners and experts who contribute to its work. The ISSG promotes and facilitates the exchange of invasive species information and knowledge across the globe and ensures the linkage between knowledge, practice and policy so that decision making is informed. The two core activity areas of the specialist group are policy and technical advice, and, information exchange through our online resources and tools and through networking. In regard to these activities, the ISSG cooperates with the Convention on Biological Diversity, participates to the CBD Liaison Group on Invasive Alien Species, and is a partner of the Global Invasive Alien Species Information Partnership.

- **Botanic Gardens Conservation International**

Botanic Gardens Conservation International (BGCI) is an international networking organisation linking botanic gardens around the world. With a focus on plant conservation, environmental education and sustainable development, BGCI provides guidelines, tools and resources to support and enhance the work of botanic gardens. BGCI maintains two global, publicly accessible databases – GardenSearch, which is a directory of skills and expertise available in botanic gardens around the world; and PlantSearch, which provides a comprehensive listing of plants in cultivation in botanic gardens.

- **International Agenda for Botanic Gardens in Conservation**

BGCI's International Agenda for Botanic Gardens in Conservation provides an overall framework for the work of botanic gardens. The Agenda links the work of botanic gardens directly to international governmental policy and at the same time provides the botanic garden community with a unique common framework specific to their needs and skills. The Agenda recognises that botanic gardens hold large and diverse collections of plants, the majority of which are exotic, and many of which may be new to cultivation. It acknowledges that, for gardens that are developing or maintaining collections from geographically diverse regions, the potential of introducing an invasive species is a major concern, and that this is exacerbated by changing global climatic conditions. The Agenda makes a series of recommendations for actions botanic gardens should take with respect to invasive alien species, including the development and implementation of relevant codes of conduct.



- **An International Sentinel Plant Network**

An International Sentinel Plant Network (ISPN) has been proposed as a formal structure under which botanic 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, an ISPN would allow information on living plant collections from botanic gardens around the world to be dynamically connected and used to provide an early warning system to predict, detect and prevent the incursion of new invasive pests (insects, plant pathogens or invasive plants). BGCI's PlantSearch database would provide the foundation for an ISPN and a recent survey of botanic gardens revealed a solid foundation of expertise, resources, partnerships and practices already in place to understand and address invasive species problems at individual institutions. However there is a need for enhanced communication and coordination amongst institutions in order to increase the power and impact of the network. Further information is available from Kramer and Hird (2011).

Annex 4. St. Louis Voluntary Code of Conduct for Botanic Gardens and Arboreta (2002)

1. Conduct an institution-wide review examining all departments and activities that provide opportunities to stem the proliferation of invasive species and inform visitors. For example, review or write a collections policy that addresses this issue; examine such activities as seed sales, plant sales, book store offerings, wreath-making workshops, etc.

2. Avoid introducing invasive plants by establishing an invasive plant assessment procedure. Predictive risk assessments are desirable, and should also include responsible monitoring on the garden site or through partnerships with other institutions. Institutions should be aware of both direct and indirect effects of plant introduction, such as biological interference in gene flow, disruption of pollinator relationships, etc.

3. Consider removing invasive species from plant collections. If a decision is made to retain an invasive plant, ensure its control and provide strong interpretation to the public explaining the risk and its function in the garden.

4. Seek to control harmful invasive species in natural areas managed by the garden and assist others in controlling them on their property, when possible.

5. Promote non-invasive alternative plants or, when possible, help develop non-invasive alternatives through plant selection or breeding.

6. If your institution participates in seed or plant distribution, including through Index Seminum, do not distribute known invasive plants except for bona-fide research purposes, and consider the consequences of distribution outside your biogeographic region. Consider a statement of caution attached to species that appear to be potentially invasive but have not been fully evaluated.

7. Increase public awareness about invasive plants. Inform why they are a problem, including the origin, mechanisms of harm, and need for prevention and control. Work with the local nursery and seed industries to assist the public in environmentally safe gardening and sales. Horticulture education programs, such as those at universities, should also be included in education and outreach efforts. Encourage the public to evaluate what they do in their own practices and gardens.

8. Participate in developing, implementing, or supporting national, regional, or local early warning systems for immediate reporting and control. Participate also in the creation of regional lists of concern.

9. Botanical gardens should try to become informed about invasiveness of their species in other biogeographic regions, and this information should be compiled and shared in a manner accessible to all.

11 Become partners with other organizations in the management of harmful invasive species.

12 Follow all laws on importation, exportation, quarantine, and distribution of plant materials across political boundaries, including foreign countries. Be sensitive to conventions and treaties that deal with this issue, and encourage affiliated organizations (plant societies, garden clubs, etc.) to do the same.

Annex 5. Outline of The Invasive Species Assessment Protocol (Source: Randall *et al.*, 2008)

Summary of Invasive Species Assessment Protocol questions.*

Section I. Ecological impact (five questions, 50% of I-Rank score)
1. Impact on ecosystem processes and system-wide parameters (33 points maximum)
2. mpact on ecological community structure (18 points maximum)
3. Impact on ecological community composition (18 points maximum)
4. Impact on individual native plant or animal species (9 points maximum)
5. Conservation significance of communities and native species threatened (24 points max)

Section II. Current distribution and abundance (four questions; 25% of I-Rank score)
6. Current range size in region (15 points maximum)
7. Proportion of current range where it negatively impacts biodiversity (15 points max)
8. Proportion of region's biogeographic units invaded (3 points maximum)
9. Diversity of habitats or ecological systems invaded in region (3 points maximum)

Section III. Trends in distribution and abundance (seven questions; 15% of I-Rank score)
10. Current trend in total range within the region (18 points maximum)
11. Proportion of potential range currently occupied (3 points maximum)
12. Long-distance dispersal potential within region (9 points maximum)
13. Local range expansion or change in abundance (18 points maximum)
14. Inherent ability to invade conservation areas and other native spp. habitats (6 points)
15. Similar habitats invaded elsewhere (9 points maximum)
16. Reproductive characteristics (9 points maximum)

Section IV. Management difficulty (four questions 10% of I-Rank score)
17. General management difficulty (18 points maximum)
18. Minimum time commitment (15 points maximum)
19. Impacts of management on native species (15 points maximum)
20. Accessibility of invaded areas (3 points maximum)

* There are five possible answers for each question: A–D and unknown. Answer A carries the maximum number of points and the ratio of values for A, B, C and D is always 3 : 2 : 1 : 0.


Carpobrotus spp.

Annex 6. National or local lists of known and potential invasive plant species in European countries

Austria
The Austrian action plan on IAS contains the national list of invasive and economically harmful species, which can be downloaded from: http://www.umweltbundesamt.at/fileadmin/site/umweltthemen/naturschutz/Neobiota_Engl.pdf
General information: http://www.umweltbundesamt.at/umweltschutz/naturschutz/artenschutz/aliens/
Species list: http://www.umweltbundesamt.at/fileadmin/site/publikationen/DP089.pdf
Austrian Web page: http://www.ages.at/ages/landwirtschaftliche-sachgebiete/pflanzengesundheit/invasive-pflanzen/
Styria web page: http://www.verwaltung.steiermark.at/cms/ziel/22727563/DE/
Botanical Gardens Austria Web page http://www.botanik.univie.ac.at/hbv/index.php?nav=83b&lang=en

Austria and Germany
http://www.biologischevielfalt.at/de/hot-topics/nicht-heimische-arten/
http://www.floraweb.de/neoflora/

Belgium
National or local lists or assessments of IAS

- Black lists, watch lists or alert lists: The Belgian Forum on Invasive Species (http://ias.biodiversity.be/species/all) gathers scientific information on presence, distribution, auto-ecology, adverse impacts and management of invasive alien species. It regularly updates a reference list of exotic species in Belgium and is responsible for the elaboration of a black list gathering species with a strong detrimental impact on biodiversity.
- AlterIAS (http://www.alterias.be/en) is an ongoing EU-funded communication project which aims at educating the horticultural sector on the invasive plants issue, by implementing raising awareness actions and preventive measures in order to reduce introductions of those plants in garden, parks, green areas and along roadways, railways and waterways network. The Manual of the alien plants of Belgium (http://alienplantsbelgium.be/). This detailed flora of alien plants that grow in the wild in Belgium. The website includes keys, pictures and descriptions of alien plants. These species include invasive species, persistent escapes and casual species. The Catalogue of neophytes in Belgium list all alien plant species recorded in Belgium together with their current naturalization status (http://alienplantsbelgium.be/sites/alienplantsbelgium.be/files/tabel_2.pdf).

Croatia
http://hirc.botanic.hr/fcd/InvazivneVrste/ShowResults.aspx?hash=636268493
Borši , I., Milovi , M., Dujmovi , I., Bogdanovi , S., Cigi }, P., Rešetnik, I., Nikoli , T. & Miti , B. Preliminary check-list of invasive alien plant species (IAS) in Croatia. Nat. Croat., 17(2): 55–71, 2008, Zagreb.

Czech Republic
Pyšek P., Sádlo J. and Mandák B. 2002: Catalogue of alien plants of the Czech Republic. Preslia 74: 97–186.

Denmark
http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/
There are three different lists:
- Invasive plantearter = invasive plant species
- Sortliste = The black list (the most invasive species)
- Observationslisten = those plants we monitor

Estonia
The List of Invasive Alien Species. RTL (Riigi Teataja Lisa) 2007, 40, 686
http://www.riigiteataja.ee/ert/act.jsp?id=12828512

Finland
List of harmful (presumably also invasive) alien species:
http://www.mmm.fi/attachments/mmm/julkaisut/tyoryhmamuistiot/5xY2BOIuB/trm2011_2.pdf_luettelo_haitallisista_vieraslajeista.pdf

France
http://inpn.mnhn.fr/isb/espece/indicateur/listeEspeces/FR/ES/7/KD/PH/Plantae/J

Germany
http://www.floraweb.de/neoflora/handbuch.html

Great Britain
https://secure.fera.defra.gov.uk/nonnativespecies/factsheet/index.cfm
The GB Non-native Species Information Portal (GB-NNSIP) 'provides access to distribution data for over 3000 non-native species in GB as well as additional information such as place of origin, date of introduction and methods of introduction. For 300 species much more detailed information is provided, including information on identification, impacts and control methods'.

Hungary
http://www.termeszetvedelem.hu/index.php?pg=menu_1731
Ágnes Csiszár (ed) (2012): Inváziós növények Magyarországon (Invasive alien plant species in Hungary) - Nyugat-magyarországi Egyetem Kiadó, Sopron (HUNGARY), 364 pp.
ISBN 978-963-334-050-9

Ireland
National Invasive Species Database. http://invasives.biodiversityireland.ie/
http://www.botanicgardens.ie/glasra/aliens.htm

Italy
Celesti-Grapow, L., Pretto, F., Carli, E., Blas, C. (eds) 2010. Flora vascolare alloctona e invasiva delle regioni d'Italia. Editrice Università La Sapienza, Roma.

Celesti-Grapow, L., Alessandrini, A., Arrigoni, P.V., Banfi, E., Bernardo, L., Bovio, M., Brundu, G., Cagiotti, M.R., Camarda, I., Carli, E., Conti, F., Fascetti, S., Galasso, G., Gubellini, L., La Valva, V., Lucchese, F., Marchiori, S., Mazzola, P., Peccenini, S., Pretto, F., Poldini, L., Prosser, F., Siniscalco, C., Villani, M.C., Viegi, L., Wilhalm, T. & Blasi, C., 2009. Inventory of the non-native flora of Italy. Plant Biosystems 143 (2): 386-430.
Celesti-Grapow, L., Alessandrini, A., Arrigoni, P.V., Assini, S., Banfi, E., Barni, E., M. Bovio, M., Brundu, G., Cagiotti, M.R., Camarda, I., Carli, E., Conti, F., Del Guacchio, E., Domina, G., Fascetti, S., Galasso, G., Gubellini, L., Lucchese, F., Medagli, P., Passalacqua, N.G., Peccenini, S., Poldini, L., Pretto, F., Prosser, F., Vidali, M., Viegi, L., Villani, M.C., Wilhalm, T. & Blasi, C. 2010. Non-native flora of Italy: Species distribution and threats, Plant Biosystems, Vol 144 (1): Pages 12 – 28.
Brundu, G., Camarda, I. & Satta, V. 2003. A methodological approach for mapping alien plants in Sardinia (Italy). In: Child, L.E., Brock, J.H., Brundu, G., Prach, K., Pyšek, P., Wade, M. & Williamson, M. (eds.), Plant Invasions: Ecological Threats and Management Solutions, pp. 41-62. Backhuys Publishers, Leiden, The Netherlands.

Latvia
Officially the List of invasive alien species of Latvia includes only one species: *Heracleum sosnovskyi* (Rules of the CM No.468 of 30.07.2008). But there is also an 'unofficial' list on the site of the Latvian Environment Agency http://www.lva.gov.lv/daba/lat/biodiv/invazivas_sugas.htm#sar (in Latvian) containing 15 species.

Lithuania
http://www.ku.lt/lisd/
The Lithuania invasive species database containing an inventory of invasive species, listed alphabetically by scientific name, and including taxon, date first recorded, country of origin, and associated references

Luxembourg
Black List: http://mnhnl.lu/cgi-bin/baseportal.pl?htx=/projects/neophytes/neophytes

Malta
The Malta Environment and Planning Authority(MEPA) 'has commissioned two studies to list alien plant and animal species found in the Maltese Islands and to identify the 'invasive' types which require further action such as eradicating or controlling their spread in protected areas'. See Invasive Alien Species: http://www.mepa.org.mt/outlook7-article8 (accessed 28 February 2012).

Netherlands
Q-bank Invasive Plants database: http://www.q-bank.eu/Plants/
This database 'focuses on vascular plants (excluding algae and mosses), with special attention to aquatic (non-marine) plants, because these plants cause acute and imminent problems in the ecozone comprising the Netherlands'. It lists 188 species (as at 28 February 2012).

Norway
A new report on alien species in Norway, including a Norwegian black list of alien invasive species, was released June 2012. Risk assessments of all species can be found in a database, managed by the Norwegian Biodiversity Information Centre.

Alien species database: http://databank.artsdatabanken.no/FremmedArt2012Report: Gederaas, L., Moen, T.L., Skjelseth, S. & Larsen, L.-K. (red.) 2012. Fremmede arter i Norge – med svarteliste 2012. Artsdatabanken, Norge.
The horticultural sector in Norway has also developed a standard for how the sector should treat invasive alien species. This includes guidelines for how plants should be treated for sale, production and use, see http://fagus.no/system/files/publikasjoner/2011-bransjestandard-om-invaderende-fremmede-planter_0.pdf

Poland
Alien species in Poland. Includes The list of alien plants and animals that may pose a threat for native species and habitats. http://www.iop.krakow.pl/ias/

Portugal
Portuguese legislation, which is currently (2010) being revised, lists around 400 exotic plant species as having been introduced into Portugal and 30 of these are classified as invasive species. A national list of invasive plant species is continuously being updated, together with a list of other species which have a high ecological risk associated with their invasive potential.
Almeida, J.D. and Freitas, H. (2006) Exotic naturalised flora of continental Portugal – a reassessment. Botanica Complutensis 30: 117-130.
Marchante, H., Marchante, E. & Freitas, H. (2005). Invasive plant species in Portugal: an overview. In: Brunel, S. (ed.), International Workshop on Invasive Plants in Mediterranean Type Regions of the World,Montpellier, France. Council of Europe Publishing, pp. 99-103.

Spain
Catálogo Español de Especies Exóticas Invasoras.
http://www.boe.es/boe/dias/2011/12/12/pdfs/BOE-A-2011-19398.pdf

This catalogue of alien invasive species, published 12 December 2011, contains a list of 62 plant species (including 9 species of Algae).

Slovenia
List available from N. Jogan: Jernej.Jogan@bf.uni-lj.si

Sweden
See NOBANIS

Switzerland
FOEN An inventory of alien species and their threat to biodiversity and economy in Switzerland Federal Office for the Evnironment 2006

NOTES

[i] DEFRA (2003).

[ii] as defined by the latest scientific information and with reference to the EPPO, the DAISIE information service, NEOBIOTA & other relevant organisations.

[iii] Streamlining European 2010 Biodiversity Indicators. http://www.bipnational.net/IndicatorInitiatives/SEBI2010

[iv] http://www.alterias.be/images/stories/downloads/code_conduct_en.pdf

[iv] Helping to prevent the spread of invasive non-native species. Horticultural Code of Practice: DEFRA (2011): https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?pageid=299

[vi] 50 000 species are recorded for German botanic gardens alone by Brandes (2008). Data on the numbers of species and other taxa cultivated in botanic gardens are notoriously unreliable. The number of taxa recorded in European gardens in the BGCI PlantSearch is 117,000: most of these are recorded at species level but some subspecies and cultivars are also included. Also, the synonymy has not been checked so the number of actual species will be less for this reason too (Suzanne Sharrock, personal communication, 7 September 2011).

[vii] BfN NeoFlora Die wichtigsten invasiven Pflanzenarten http://www.floraweb.de/neoflora/handbuch.html (accessed 11 July 2011)

[viii] In Britain, the invasive stands of *Rhododendron ponticum* have been shown to consist largely of deliberate and accidental hybridization with other species, in particular the North American *R. catawbiense* and *R. maximum* (Milne & Abbott, 2000; Cullen, 2011). The hybrid swarm has recently been named *R. × superponticum* (Cullen, 2011).

[ix] The identity of *Heracleum mantegazzianum* and related species is discussed in the relevant EPPO Data sheet (Anon, 2009) and by Nielsen *et al.* (2005) and Jahadová (2007a,b).

[xi] Galera & Sudnik-Wójcikowsja (2010) describe five patterns for the early stages of introduction and migration of species introduced through the network of central European botanic gardens.

[xii] See http://plantnetwork.org/wordpress/wp-content/uploads/4685/ebgc_invasives_a4.pdf

[xiii] DAISIE European Invasive Alien Species Gateway (http://www.europe-aliens.org)

[xiv] DAISIE, Handbook of alien species in Europe. Springer, Dordrecht.

[xv] Invasive alien plants - EPPO Lists and documentation. http://www.eppo.org/INVASIVE_PLANTS/ias_plants.htm

[xvi] Now published as: EPPO prioritization process for invasive alien plants. *Bulletin OEPP/Bulletin* 42(3): 463–474 (2012). ISSN 0250-8052. DOI: 10.1

[xvii] The standardized barcode marker for plants is a fragment of the ribulose 1,5-bisphosphate carboxylase gene (rbcL), combined with a fragment of the maturase gene (matK) (CBOL Plant Working Group 2009). A more recent development is DNA metabarcoding, which couples the principles of DNA barcoding with next generation sequencing technology (Coissac *et al.*, 2012; Shokralla *et al.*, 2012; Taylor and Harris, 2012).

[xviii] http://www.theplantlist.org/

[xix] The name *Heracleum trachyloma* has recently been used for the most widespread *Heracleum* sp. naturalized in the UK (Sell & Murrell, 2009) but this has not been independently confirmed.

[xx] The WRA model developed in the USA by the USDA 'accurately identified 95 per cent of the non- and major-invaders and in future work, we intend to incorporate a simulation into the WRA process so that consequences of assessor uncertainty on the final score can be evaluated' (Koop *et al.*, 2011).

[xxi] It should be noted that the Australian WRA was shown by Gordon & Gantz (2011) to weight aquatic plants heavily towards the presumption of invasiveness.

[xxii] EPPO decision-support scheme for Pest Risk Analysis for quarantine pests (PM 5/3(5)). This scheme has been fundamentally revised by the PRATIQUE EU project (Steffen *et al.*, 2012).

[xxiii] Johnson *et al.* (n.d.) http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/335788/protocol-initial-weed-risk-assessment.pdf (accessed 15 August 2010)

[xxiv] http://plantnetwork.org/wordpress/wp-content/uploads/5072/records.pdf

[xxv] http://archives .eppo.org/EPPOSt andards/PM3_PROCEDURES/pm3-54-e.doc

[xxvi] Eberwein R.K., Berg C., 2010: Pflanzen mit invasivem Potenzial in Botanischen Gärten I: *Pinellia ternata* (Araceae). *Carinthia* II 200/120: 81-86. Eberwein R.K., 2011: Pflanzen mit invasivem Potenzial in Botanischen Gärten II: *Nonea lutea* (Boraginaceae). *Carinthia* II 201/121: 243–248. Drescher A., Lechner M., Berg C., 2012. Pflanzen mit invasivem Potenzial in Botanischen Gärten III: *Geranium sibiricum* (Geraniaceae). *Carinthia* II 202/122: 33-46.

[xxvii] http://www.bgci.org/resources/ipen/

[xxviii] http://www.botgart.uni-bonn.de/ipen/conduct.pdf

[xxix] The Conservatoire Botanique National Méditerranéen de Porquerolles also has a list of invasive alien plant species in Languedoc-Roussillon and Provence-Alpes-Côte d'Azur on its website: http://www.invmed.fr/accueil

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Page 05 *Cardamine corymbosa*, New Zealand Bitter-cress, commonly invasive in in container-raised plants in nurseries (I Hoste)
Page 06 *Diospyros lotus*, European Date plum, an emerging invader in the Mediterranean (P Borremans)
Page 09 *Carpobrotus*, Hottentot-fig, Iceplant, invasive at Cap de Favoritx, Menorca, Spain (V H Heywood)
Page 11 *Opuntia ficus-barbarica*, invasive near Erzurum, Turkey (V H Heywood)
Page 12 *Agave americana*, Giardino Botanico Hanbury, La Mortola, Italy (V H Heywood)
Page 15 *Pistia stratiotes*, a South American freshwater species, often escaped from aquaria, growing near Valencia, Spain (V H Heywood)
Page 16 *Opuntia ficus-indica*, near Agrigento, Italy (V H Heywood)
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Page 33 *Gunnera tinctoria*, Chilean rhubarb, in Chiloé National Park [© Stevage]
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Page 55 *Carpobrotus* invasive at Boca de Inferno, Cascais, Portugal (V H Heywood)

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