Chapter 9
Invasive Plant Species and the Ornamental Horticulture Industry

Alex X. Niemiera and Betsy Von Holle

Abstract The ornamental horticulture industry is responsible for the introduction, propagation, and transport of thousands of nonnative plant species, most of which stay in their intended locations or spread without significant environmental impacts. However, some nonindigenous plant species have proved to be particularly invasive and quite environmentally deleterious. The economically and politically powerful horticulture industry is faced with the dichotomous dilemma of the freedom to import and propagate plant species juxtaposed with the responsibility to be a diligent land steward. We discuss the various fundamental biological factors of plant invasion, as well as the environmental impacts, probability, prediction, and ranking of invasive species. We also review the role of the nursery industry in importing nonnative species, the perception of the problem by nursery personnel, and the impact of governmental and self-regulation. We conclude with recommendations for the ornamental plant industry to mitigate its role in dispersing invasive, nonnative plant species.

Keywords Ornamental horticulture industry • nonindigenous species • invasive plants • voluntary regulation

Abbreviations ANLA: American Nursery and Landscape Asssociation; ANLA – HRI: American Nursery and Landscape Association – Horticultural Research Institute; APHIS: Animal and Plant Health Inspection Service; AQIS: Australian Quarantine and Inspection Service; BANR: Board on Agriculture and Natural Resources; Cal-IPC: California Invasive Plant Council; EPPC: Exotic Pest Plant Council; EPPO: European and Mediterranean Plant Protection Organization; EMG: Extension Master Gardener; FL-EPPC: Florida Exotic Pest Plant Council; GISP:

A.X. Niemiera
Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
niemiera@vt.edu

B.Von Holle (✉)
Department of Biology, University of Central Florida, Orlando, FL 32816, USA
vonholle@mail.ucf.edu

Inderjit (ed.), *Management of Invasive Weeds,*

Global Invasive Species Programme; IRA: Import Risk Analysis; NGIA: Nursery and Garden Industry Australia; NIS: Nonindigenous species; SE-EPPC: Southeast Exotic Pest Plant Council; US: United States; USDA: United State Department of Agriculture; WRA: Weed Risk Assessment

9.1 Introduction

Nonindigenous species (NIS), also termed nonnative, exotic, and alien, are the subject of a considerable amount of interest, research, and debate. Many nonnative plant species are incontrovertibly a great benefit to society by serving as food, timber, and ornamental plants (Ewel et al. 1999). However, other nonnative plant species are particularly invasive, and therefore a bane to society when they negatively impact native biodiversity and cause huge economic expenditures (Parker et al. 1999; Pimentel et al. 2000).

The topic on invasive, nonindigenous plants encompasses a great breadth of issues and stakeholders. There is a vast literature dealing with the ecological, economic, regulatory, control, management, and social aspects of invasive, nonnative plants. Vested stakeholders include scientists, environmental groups, land managers, regulatory officials, businesses in ornamental horticulture, seed, forest products, and the gardening public. The scale of stakeholder interests ranges from international to local arenas. Stakeholders' interest greatly affects their perspective of the topic on nonnative plants; even the definitions of terms within the invasive NIS lexicon are greatly affected by a stakeholder's interest. Differences in stakeholders' perception can lead to adversarial interactions (Drake 2005). These interactions are precipitated by the intersection of science, conflicting value systems, environmental ethics, and public policy (Lodge and Shrader-Frechette 2003). A particularly visible and pertinent example of a vested interest that precipitates differences in opinion is the ornamental horticulture industry, whose businesses import, propagate, sell, and plant mostly nonnative flora. This industry is especially vested in this issue since it is responsible for the introduction and spread of thousands of nonnative plant species, most of which stay in their intended locations or spread without significant environmental negative impacts, while other nonindigenous plant species have proved to be particularly invasive and quite environmentally deleterious. Thus, the juxtaposition of the industry's powerful and fruitful economic impacts and the environmental and regulatory agencies' desire to protect natural areas from invasive NIS sets the stage for a conflict with no clear compromise or resolution. The ornamental horticulture industry is by no means the only stakeholder in the fray of the invasive plant debate. Other parties that are in the midst of the contentious invasive plant issue include botanical gardens, gardeners and garden clubs, public agencies that plant and manage landscapes, and horticultural educational programs.

There is a relatively weak link between the scientific realm of invasive plant biology and the ornamental horticulture industry. This is primarily because the science of plant invasion biology is not often effectively communicated to individuals

outside of the research realm (Allendorf and Lundquist 2003; Jordan et al. 2003). The intersection of science, conflicting value systems, environmental ethics, public policy, and articles in the popular press have given mixed messages, confusion, and tension in the NIS theater (Lodge and Shrader-Frechette 2003). Communication shortcomings are especially evident for audiences in the ornamental horticulture industry and the gardening public. Ornamental horticulture personnel are generally aware of the issue of invasive NIS; however, there is a need for the industry to grasp the fundamental concepts of plant invasion biology and to address and formulate strategies concerning the sale and planting of potentially invasive NIS. The nursery-mediated spread of invasive plants is a major challenge and concern for the future of the nursery industry (Green and Green 2003). The objective of our paper is to convey the salient aspects of plant invasion biology that are relevant to the ornamental horticultural audience. We will cover the fundamental aspects of invasive nonnative plants, the role of the nursery and landscape industry in invasive nonindigenous plant species, the reasons why the ornamental horticulture industry should care about NIS, and recommendations for the ornamental plant industry to mitigate its role in dispersing invasive, nonnative plant species.

9.2 Fundamental Aspects of Invasive NIS

9.2.1 What is Plant Invasion?

Biological invasion is a phenomenon that is old as life itself (Drake 2005). However, the rate of invasion has greatly accelerated in the past century due to anthropogenic factors such as removal of dispersal barriers, international travel, and enterprise (Drake 2005). The process of invasion (area occupied vs. time) exhibits the pattern of a sigmoidal curve in which the initial slow growth, exponential growth, and the flattening of the curve represent introduction, colonization, and naturalization, respectively (Radosevich et al. 2003). Radosevich et al. (2003) state that a species is naturalized "when it successfully establishes new self-perpetuating populations, is dispersed widely throughout a region, and is incorporated into the resident flora." The time from first arrival to the rapid occupation by the naturalizing species is termed *lag time* and may occur in years or decades (Kowarik 1995). Lag time duration can be influenced by environmental factors of the recipient habitat that improve conditions for the invading organism, detection, invasion pressure, dispersal pathways, introduction of new pollinators, or genetic changes that improve fitness of the organism (Bryson and Carter 2004; Crooks and Soule 1999; Mack et al. 2000). Lag times for woody plants can exceed 100 years (Kowarik 1995); however, lag times for herbaceous perennials are believed to be much shorter than for woody plants (Reichard and White 2001). Detection of invaders and quantification of their invasiveness is a function of human perception. Species may be cryptic and widespread and therefore go unnoticed for years until people start to look for them.

9.2.2 Terminology

The interpretation of *invasive species* by horticulturalists, policy makers, and scientists often varies depending on stakeholder interests. The American Nursery and Landscape Association (ANLA, http://www.anla.org/industry/index.htm. Accessed 23 May 2008) and the Weed Science Society of America define invasive plants as "plants that have or are likely to (1) spread into native plant communities and cause environmental harm by developing self-sustaining populations and disrupting those systems; or, (2) spread into managed plant systems and cause economic harm" (Hall 2000). The legal definition of an invasive species, and the official position of the U.S. Government (Federal Register – Presidential Documents 1999), is "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." In a strict interpretation, any plant outside its native ecosystem is considered nonindigenous. For example, black locust (*Robinia pseudoacacia*) is a common tree native to the central US Appalachian and Ozark Mountains but is considered an invasive species in California. Thus, plants native to one state can be invasive in another state.

Richardson et al. (2000) define a minimum set of terms that describes the invasion/naturalization process of plant species: "*Introduction* means that the plant (or its propagule) has been transported by humans across a major geographical barrier. *Naturalization* starts when abiotic and biotic barriers to survival are surmounted and when various barriers to regular reproduction are overcome. *Invasion* further requires that introduced plants produce reproductive offspring in areas distant from sites of introduction (approximate scales: >100 m over <50 years for taxa spreading by seeds and other propagules; >6 m per 3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems)." Colautti and MacIsaac (2004) further refine the definition of "invasive species" with biogeographically based terminology, where an invasive species can be placed in three stages of invasion: widespread but rare (stage IVa), localized but dominant (stage IVb), or widespread and dominant (stage V). Thus, invasion biologists are moving toward more explicit terms to accurately define an invasive species. The dynamic nature of the lexicon is characterized by certain terms being abandoned due to their potential xenophobic link such as *alien* being replaced by the more objective *nonindigenous* (Simberloff 2003).

9.2.3 How Do Invasive Species Harm the Environment?

The definition of the impact of an invasive species has evolved quickly within the last few years yet policy makers and the gardening public have not been apprised of these scientific advances in terminology. Parker et al. (1999) characterize impact on the basis of range, abundance, and the per-capita or per-biomass effect of the invader. Daehler (2001) contends that the notion of impact depends on the variable being studied and the scale of study. He concludes that, "All species that meet the spread

criterion probably have ecological and environmental impacts, although for most non-indigenous species, these impacts have not been adequately quantified." Davis and Thompson (2001) counter Daehler's contentions by stating that, "outside of the discipline of ecology, 'invasive species' are usually explicitly defined on the basis of their impact." Davis and Thompson also contend that consolidating all NIS into the "invader" category contributes "to a belief that invasions are a unique ecological phenomenon, which we believe has hindered ecologists' efforts to understand the invasion process." They see value in segregating invasive plants on the basis of impact which may then lead to discovering the traits that are unique to "high impact" invaders. Lodge et al. (2006) aptly note that a best attempt to quantify net "harm" by an invasion to the environment, industry, or to human health requires the collective input of economists, public health experts, and ecologists.

To lump all invasive NIS into one group is, from a practical perspective, too inclusive since the impact of invasive NIS can range from relatively innocuous to very environmentally disruptive (Fox et al. 2003). This is an especially relevant point considering that the ornamental horticulture industry sells many plants that spread outside of planted sites and that the level of environmental impact of these widespread species has rarely been determined. Coulatti (2005), discussing the inclusion of impact in the invasive definition, concludes "there is a large intellectual rift between ecologists on one side, and resource managers and politicians on the other. This creates confusion for newcomers to the discipline, and impedes the rapid and unambiguous dissemination of knowledge from ecological experiments to the formation of strategies designed to protect natural habitats from problematic invaders."

Although NIS are a major environmental concern, the proportion of NIS plants that become invasive is quite small. Rejmanek et al. (2005) make a pertinent case that "not all naturalized plant taxa, and not even all invaders, are harmful…" Williamson and Fitter (1996) developed the "tens rule," which states that one in ten imported plant or animal species (brought into the country) appear in the wild (introduced, feral), and one in ten of those become established (self-sustaining population), and one in ten of established plants become a pest (negative economic effect). Thus, if 1,000 species were imported, then 100 species would escape into the wild, 10 species would establish in the wild, and only one species would be become a pest. These authors acknowledge that this is a relatively gross prediction and qualified that 1 in 10 actually represents the range of 1 in 5 to 1 in 20. They noted that crop plants did not follow this rule and had a higher incidence of becoming a pest than predicted by the tens rule. Lockwood et al. (2001) determined the proportion of naturalized (self-sustaining populations) NIS that were classified as "the most harmful exotics" or "natural area invaders" in three US states. These authors found that 5.8, 9.7, and 13.4% of nonnative plants in California, Florida, and Tennessee, respectively, were natural area invaders. Thus, their findings are in general agreement with the tens rule of Williamson and Fitter (1996). Despite the relatively low percent of plants that ultimately become serious invaders, the large number of garden plants for sale makes the potential invasive, nonindigenous plant list quite sizable. *Dave's Garden – Plant Files* (*Dave's Garden – Guides and Information*, http://davesgarden.com/guides/. Accessed 23 May 2008), an Internet

(worldwide) database of garden plants, lists 38,779 species and 100,685 cultivars. Isaacson (1996), in an inventory of North American seed and nursery catalogs (1988–1989), records almost 60,000 plant taxa sold. Applying the tens rule to the 38,779 species number, approximately 3,800 plants would escape, 380 species would establish in the wild, and 38 would become pests. Thirty-eight species can be construed as a relatively small number; however, this apparently low count belies the negative ecological effects of even a single species. One only has to consider the serious environmental effects caused by nonindigenous US landscape species such as Japanese honeysuckle (*Lonicera japonica*), English ivy (*Hedera helix*), cape ivy (*Delaireia odorata*), and Chinese tallow (*Triadica sebifera*) to realize that a single species can cause ecological havoc. The tens rule also does not take into account the unique situation of garden plants in which plants are sold year after year and planted in all parts of the country. Such repeated introductions (invasion pressure) will be discussed in the next section. Thus, the many NIS that are queued in lists of nongovernmental organizations and states vary considerably in their reproduction, rate and ecological region of spread, and impact. Hence, management decisions and regulatory actions should be species and region specific.

There are numerous governmental and nongovernmental lists, which queue invasive plant species by locality (i.e., county, state, region). These lists vary considerably in the criteria used to list a species and to rank a species' invasiveness. Thus, the usefulness of some of these lists is questionable. In an attempt to assess the criteria for published invasive plant lists, Fox and Gordon (2004) conducted a meta-analysis of 113 invasive plant lists from states, regions, and countries. They found that there was a gross lack of consistency of invasive criteria used to classify species as invasive or to rank invasiveness. Only 10% of the lists used invasive scoring systems that provided consistent application of criteria whereas two-thirds of the lists incorporated vague terms to describe environmental impact. In essence, their analysis showed that most invasive plant lists lack verifiable criteria that offer consistent interpretation and application. These authors, as part of a workshop effort, endorsed a standard system for invasive plant lists that (1) has a robust, scientific basis, (2) only lists species already present in an area, and (3) is flexible enough to be useful relative to the purpose of the list (e.g., regulatory or advisory). Fox and Gordon (2004) acknowledged the formidable challenges (i.e., complexity, collaboration between agricultural and natural system experts, continued data acquisition) to develop a standardized system with flexible options. Other than plants banned by the federal or state governments, most invasive plants lists in the USA carry no regulatory weight and serve to advise against the use of listed species. In contrast, New Zealand has a three-part invasive plant list system, i.e., banned plants, plants that require monitoring, and species-specific and site-specific weed control, which are clearly delineated and defined (Timmins 2004). New Zealand has 2,350 indigenous land plant species and 2,020 nonindigenous naturalized plant species; over 70% of invasive weeds were imported as ornamental plants (Department of Conservation 2002). While the USA has not adopted such an approach, some state governments, such as Montana, have tried stricter regulations (Simberloff et al. 2005). Additionally, New Hampshire (as of January 2007; New

Hampshire Administrative Code, Chapter Agr 3802.1., http://www.gencourt.state.nh.us/Rules/agr3800.html. Accessed 9 June 2008) and Massachusetts (as of January 2009; Massachusetts Prohibited Plant List, http://www.mass.gov/agr/farmproducts/proposed_prohibited_plant_list_v12–12–05.htm. Accessed 9 June 2008) ban the propagation, sale, purchase, or distribution of three common invasive nonindigenous landscape species (*Acer platanoides*, *Berberis thunbergii*, and *Euonymus alatus*).

9.2.4 Predicting Invasive Potential

Predicting which species will be invasive in a particular area is a very difficult task due to the complexity of nature (Drake 2005). There has been an abundance of work to determine which plant characteristics and what ecological factors lead to plant invasion (Dekker 2005; Kolar and Lodge 2001; Rejmanek and Richardson 2005; Myers and Bazely 2003). The interest in this subfield of invasion biology is substantiated by the fact that the number of scientific papers addressing invasion prediction increased fivefold from 1986 to 1999 (Kolar and Lodge 2001). At present, the most reliable and powerful predictor of a species' invasiveness is its record of invasiveness in other nonnative sites (Wittenberg and Cock 2001). Many prediction schemes have been developed to assess the potential of plant taxa to be invasive. These approaches to understanding the invasive potential significantly increase our ability to predict which taxa will be invasive. Prediction models have correctly identified (postpriori) 80–90% of invasive NIS (Reichard and Hamilton 1997; Widrlechner et al. 2004; Pheloung et al. 1999; Daehler and Carino 2000). The shortcoming of these models is that they have a relatively high rate (≥10%) of false positives (identifying a noninvasive species as invasive). Perhaps this high rate of false positives is the price we should pay to exclude invaders from our natural areas. Another shortcoming of invasive potential prediction is the knowledge needed for most of these schemes (plant and region specific), and scheme methodology has not been integrated so it can easily be used by those who are not well versed in ecology (Rejmanek et al. 2005). Mack (2005) emphasizes the need for prediction schemes to include, among other variables, the role humans play in overcoming the effect of environmental stochasticity on immigrant plant populations.

Prediction based on biological characteristics can reliably foretell if a plant will be invasive (i.e., establishment and spread); however, prediction is less reliable in forecasting the impact a taxon will have on an environment (Rejmanek et al. 2005). Rejmanek et al. (2005) note that "it is important to realize that invasiveness and impact are not necessarily positively correlated." These authors are in favor of categorizing invasive NIS that have had a profound effect on biodiversity, about 10% of invasive plants, with the term "transformer species," a term first proposed by Wells et al. (1986). Transformer species, because of their impact, would receive the majority of resources for containment, eradication, and control.

Prediction success can be hindered by the phenomenon of "invasional meltdown," a term coined by Simberloff and Von Holle (1999). Invasional meltdown is "the process by which a group of NIS facilitate one another's invasion in various ways, increasing the likelihood of survival and/or of ecological impact, and possibly the magnitude of impact." This phenomenon is especially relevant to the ornamental horticulture industry, which introduces hundreds of NIS as well as pest and pathogen "hitchhikers" on these ornamental plants into our landscapes that may synergistically interact in the future. Once a NIS is introduced, the unforeseen suite of future complex interactions greatly increases the difficulty of predicting the consequences of invasion (Mooney 2005).

NatureServe, in cooperation with The Nature Conservancy and the US National Park Service, developed a systematic assessment protocol that uses a set of questions and scientific documentation to rank invasive nonnative plant species (Morse et al. 2004). The Invasive Species Assessment Protocol is a tool for assessing, categorizing, and listing nonindigenous plant species on the basis of their impact on biological diversity. Each species has an overall ranking, which is composed of subrankings from four areas: (1) ecological impact, (2) current distribution and abundance, (3) trend in distribution and abundance, and (4) management difficulty. To date, 452 nonnative plant species occurring outside cultivation in the USA are ranked; the goal of the program is to rank 3,500 of these nonindigenous plant species. This objective ranking system and the documented list of invasive nonnative plant species serve as an effective decision support system for the ornamental horticulture industry to adopt for deciding which nonindigenous plant species to stop selling. The Invasive Species Assessment Protocol determines the ranking on a national distribution, and therefore the rank must be interpreted in the context of a specific region since a plant may not be problematic in all or most areas. However, in many cases a text description of the invasive nature of each species mentions the regional nature of invasiveness. In an attempt to consistently describe and categorize invasive nonnative plant species, some states, e.g., Florida (Fox et al. 2005), and Virginia (Heffernan et al. 2001), have also developed relatively rigorous assessment systems. Additionally, the Exotic Pest Plant Councils (EPPCs) rank nonnative plant species by their impact within specific regions or states [e.g., SE-EPPC (http://www.se-eppc.org/), FLEPPC (http://www.fleppc.org/list/list.htm), Cal-IPC (http://www.cal-ipc.org/)].

The call for improved and widespread prediction tools has been mandated by the US government. In an attempt to gain control of the importation of potentially NIS, the Animal and Plant Health Inspection service (APHIS, a branch of the USDA), the entity responsible for preventing the introduction of plant and animal pests, commissioned the National Research Council's Board on Agriculture and Natural Resources (BANR) to comprehensively review scientific knowledge regarding invasive NIS. BANR was charged to develop "risk assessments, identify potential invaders, and guide the strategic allocation of its resources to safeguarding plant life in the United States." In response to this charge, BANR established the Committee on the Scientific Basis for Predicting the Invasive Potential of Nonindigenous Plants and Pests in the USA, which was composed of experts in disciplines related to the invasive

NIS problem. This committee put forth 12 recommendations that strengthen the scientific basis of predicting the invasive potential of plants. The Global Invasive Species Programme (GISP), an international consortium of scientific, government, and foundation groups, has also recommended NIS prediction and screening schemes (Wittenberg and Cock 2001). Following an evaluation of US national policies and practices on biological invasions, and in light of current scientific and technical advances, the Ecological Society of America put forth six recommendations that require government action to "help prevent invasions, respond rapidly to new invasions and control and limit damage from existing invasions" (Lodge et al. 2006).

In an attempt to reduce the risks of the introduction of noxious weeds and host pests associated with the importation of plants for planting, APHIS is undertaking a revision of the regulations (Code of Federal Regulations, 7 CFR Part 319.37) governing the import of plants for planting, commonly referred to as Q-37 (USDA, APSHIS Import and Export – Plant Import Information –Importation of Plants for Planting – Revision of the Nursery Stock Quarantine, http://www.aphis.usda.gov/import_export/plants/plant_imports/Q37_revision.shtml. Accessed 9 June 2008). Revision of Q-37 was necessary because trade in plants has now expanded to greater global coverage of imports, with increasing numbers and magnitude of plant taxa imported, making monitoring of plant material less likely. Following the basic tenet behind propagule pressure, the increasing magnitude of imported plant material increases the likelihood of new successful invasive species to the USA (Reaser et al. 2008).

9.3 The Role of the Ornamental Horticulture Industry in Invasive NIS

The USA is the world's foremost producer of and market for nursery and floriculture crops (ANLA). These industries provide entrepreneurial opportunities, supply jobs for tens of thousands of employees, and generate large tax revenues for the government. Because of their substantial economic effect, these industries are a politically potent force. The horticulture industries sell hundreds of NIS. Most of these taxa have graced our landscapes with untold aesthetic and environmental value. However, there is no ambiguity that these industries are responsible for introducing a relatively high percentage of the invasive NIS that have negative economic and environmental impacts ranging from minor to major. Reichard (1997) calculated that 85% of the 235 known invasive woody NIS in the USA were introduced by the nursery industry as landscape material. Randall and Marinelli (1996), using invasive NIS lists from the Nature Conservancy and the National Association of EPPCs, determined that half of the 300 invasive NIS in the USA (excluding Hawaii) were imported for horticultural purposes. Bell et al. (2003), using data of six nongovernmental organizations that listed invasive NIS, determined that 34–83% of the total number of invasive taxa in the USA had a horticultural origin. In Florida, at least 47% of plants that are negatively affecting the environment were introduced for ornamental purposes; an additional 27% are

suspected of such origins (Fox et al. 2003). This phenomenon is not unique to the USA. Mack and Enberg (2002) found that 65% of invasive plants introduced into Australia between 1971 and 1995 were introduced as ornamentals. Thus, the ornamental horticulture industry unwittingly introduced invasive NIS to market. This is not a recent phenomenon. While some plant species were imported into North America for ornamental purposes prior to the seventeenth century, aesthetic plant importation was most evident in and after the eighteenth century (Mack 2003): By 1860, imported ornamental plant species significantly outnumbered imported utilitarian species (Mack and Enberg 2002).

One of the most lucrative areas of ornamental plant sales is new plant introductions. This is evidenced by the emergence of many nursery businesses whose major marketing focus is novel plant introductions. Additionally, the American Nurseryman (1999), a leading trade journal for nursery and landscape professionals, devotes an entire bimonthly journal issue each year to new plant introductions. While no quantification of the nativity or residence time in the USA of these introductions has been made, the new-to-the-trade plant phenomenon stimulates efforts to seek out new introductions, many from outside the USA, and yield substantial profits. A quick glance at most garden plant catalogs and mail order web sites verifies this trend. Internet-based sales of ornamental plants are now a sizeable provider of garden plants, which facilitates the importation of NIS. Dave's Garden – Garden Watchdog (Dave's Garden – Garden Watchdog, http://davesgarden.com/products/gwd/. Accessed 23 May 2008), an internet site directory of gardening (plants and plant-related items) mail order vendors lists 6,257 businesses, most of which have a web site. Internet sales of NIS are sources of invasive, potentially invasive, and even some illegal plant taxa (Clayton 2004). To halt the sale of prohibited invasive NIS on the internet, researchers from North Carolina State University and the USDA have developed Web application software that searches the Internet for vendors who sell illegal invasive NIS (NC State University News Release 2003). One would assume that imposing strict limitations on new plant introductions, especially those that are likely to become invasive (determined via screening procedures) or carry nonnative pests and pathogens, would increase our success rate in preventing the release of invasive NIS. However, Simberloff et al. (2005) point out two limitations to this assumption. First, there is a great divergence in opinion on the impact of invasive NIS between stakeholders. Embedded in these differences of opinion are the conflicts of interest of the regulatory agency tasked to govern the flow of NIS (USDA), which ironically is funded, in part, by the tax money generated by the sale of NIS. Second, the central aspects of risk assessment, predicting specific negative consequences and estimating their probability, are greatly affected by the unpredictability of impacts of introduced species.

Members of the ornamental horticulture industry recognize the need for action regarding invasive NIS. Hall (2000) surveyed ANLA members and found the following results: (1) Sixty-eight percent of respondents were in favor of the government screening new NIS introductions. However, respondents wanted policies to be more regionally directed than political boundary directed, to have a more effective enforcement and implementation of policies, and have more scientific proof justifying decisions and species placed on invasive lists. (2) Over half of the respondents

were willing to participate in programs to educate themselves, and almost one-third of the respondents were willing to actively educate (e.g., hold workshops) their customers. (3) Sixty-four and 29% of the respondents said they would definitely or maybe, respectively, remove invasive NIS from their stock. (4) Over half of the respondents were willing to have new, noninvasive cultivars to replace invasive NIS. (5) About a third of the respondents said that they would stop selling invasive plants only if they knew that other businesses had stopped selling invasive NIS. This last finding is suggestive of limited nursery participation in the event of a voluntary system for banning the sale of invasive NIS.

The public is generally unaware of the negative ecological and economic impacts of invasive NIS (Colton and Alpert 1998). However, surveys have found mixed evidence for awareness of the gardening public about invasive garden NIS (Wolfe and Dozier 2000; Kelly et al. 2006). In an Internet survey of gardeners, Reichard and White (2001) came to the conclusion that, "Because the preference to buy noninvasive species is correlated with familiarity, as the general plant-buying public becomes more aware of invasions, nurseries and the seed trade industry will have to alter their practices to ensure that invasive species are not sold."

9.4 Why Should the Horticultural Industry Care about Nonnative Species?

The very nature of the ornamental horticulture industry (selling, transporting, and cultivating NIS) has the potential to foster the invasion process. One of the most important factors that contribute to an area being invaded is invasion pressure, i.e., the large numbers or frequency of introduction of NIS (Lockwood et al. 2005; Von Holle and Simberloff 2005). Supporting the invasion pressure contention and emphasizing the role of the ornamental horticulture industry in invasion pressure, Pemberton (2000) investigated the naturalization rate of NIS related to the number of years a NIS was sold in the nursery trade; he found that the rate of naturalization increased as the period of sale increased. For example, only 1.9% of plants naturalized that were sold for 1 year, whereas 30.9% of plants naturalized that were sold for 10 years or more. Once sold, garden plants are cultivated. This cultivation is an important process in overcoming the environmental resistance to invasion and favors the invasion process (Kowarik 2003; Mack 2000, 2005). Additionally, desirable garden plant characteristics, such as a fast growth rate, abundance of fruit, and tolerance of poor growing conditions (e.g., drought, poor soil), are also characteristics of successful invaders. Mack (2005) contends that the horticulture industry is in a favorable position to devise a flexible, rapid, science-based system to screen NIS for invasiveness, which could help mitigate its role in supporting the process of invasion.

Another reason why the NIS issue requires attention by the ornamental horticulture industry is the previously mentioned phenomenon of "lag time," the initial period of a slow spread rate prior to exponential rate of spread. Thus, without a predictive analysis performed for invasive potential of each species prior to

introduction, widely propagated and distributed taxa will have an unknown potential for harming the environment.

The probability of invasion increases with time (i.e., residence time of NIS) because more propagules are spread and the probability of founding new populations increases (Rejmanek et al. 2005). Thus, the mass propagation, distribution, and planting of a species serve to greatly increase invasion pressure and is most apt to shorten the lag time for a potentially invasive NIS to become invasive. Additionally, "invasional meltdown" may decrease this lag time for invasion and is another reason why the ornamental horticulture industry should take a more active role in invasive NIS issues. For example, figs cannot reproduce without the presence of a coevolved pollinator. Of the 60 species of fig (*Ficus*) occurring in south Florida, 20 of them are widely planted, and the specific pollinating wasps for three of these widely planted species were recently introduced into the area. The introduction of these three nonnative species of pollinating wasps has resulted in the reproduction of all three associated, introduced fig species and the rapid spread of one of these species (*Ficus microcarpa*) (Kaufman et al. 1991).

9.5 What Should the Ornamental Horticulture Industry Do?

9.5.1 Voluntary Regulation

The ornamental horticulture industry has taken steps to address and mitigate its role in being purveyors of invasive NIS. In 2001, a coalition of horticulture entities met at the Missouri Botanical Garden for a meeting entitled "Linking Ecology and Horticulture to Prevent Plant Invasions" and formulated the Saint Louis declaration, which consisted of a two-part treaty, Findings and Proceedings and Voluntary Codes of Conduct (Baskin 2002). The latter was a list of measures for various sectors of the ornamental horticulture industry (government, nursery professionals, gardening public, landscape architects, and botanic gardens and arboreta) "to curb the use and distribution of invasive plant species through self-governance and self regulation." A follow-up meeting "Linking Ecology and Horticulture to Plant Invasions II" was held in Chicago in 2002 (Fay 2003). Many of the major ornamental horticulture organizations endorsed the Voluntary Codes of Conduct. These codes have helped to develop measures to reduce the sale of invasive NIS and form partnerships such as the California Horticultural Invasives Prevention (Cal-HIP, http://www.cal-ipc.org/landscaping/calhip.php. Accessed 23 May 2008) (California Invasive Plant Council) and Washington State Nursery and Landscape Association Task Force (Washington Invasive Species Coalition, http://www.invasivespeciescoalition.org/GardenPlants/TaskForce. Accessed 9 June 2008). In 2005, the Horticultural Research Institute, the research arm of the ANLA, granted 15% of their $220,000 research budget to invasive plant research (ANLA – HRI, http://www.anla.org/pdffiles/Projlistingwcharts.pdf. Accessed 23 May 2008). An example of proactive behavior regarding invasive NIS occurred in Florida in which

growers agreed to voluntarily stop growing 45 potentially invasive NIS (Wirth et al. 2004). However, growers continue to grow and sell 14 invasive NIS, which are considered highly ornamental, widely used in landscapes, and of significant value to Florida growers. The economic impact of discontinuing the sale of these 14 species was an estimated $59 million and 800 jobs (Wirth et al. 2004). However, a full economic and public policy analysis should include a cost–benefit analysis of control costs of the 14 species in natural environments and private properties as well as costs of implementation and enforcement of any regulatory actions (Wirth et al. 2004). The Florida situation poses a typical balance between economic benefits and costs, as well as environmental costs, and regulatory action.

The ornamental horticultural industry can greatly enhance its image by taking a noticeable and active role in addressing and providing solutions to the problems posed by the invasive NIS it currently sells. Bell et al. (2003) proposed that the nursery industry address four issues to effectively respond to the problem of invasive plants. These were (1) recognize the importance of the problem to natural landscapes, (2) recognize that ornamental plant nurseries are involved, (3) establish a dialog with public agencies and private groups concerned about invasive plants, and (4) be willing to participate in programs to eliminate or reduce sales of problem species. One potential complication to the wholesale adoption of the nursery industry to stop selling NIS is that the industry is relatively fragmented, as it comprises many small businesses. Many of these do not belong to national, state, or regional trade associations (based on personal observations and communications with industry personnel). The main obstacles of these businesses to participating in preventative measures proposed by the St. Louis Voluntary Codes of Conduct were listed as “the lack of information,” “limited personnel,” and “too time consuming” (Burt et al. 2007). We (authors) feel that a proactive stance on the invasive NIS topic would be an act of responsible land stewardship and will not result in a loss of profit if alternative noninvasive taxa are properly marketed. Clearly, there is a need for effectively communicating the fundamentals of invasive plants to industry personnel.

9.5.2 Nonvoluntary Regulation

Australia regulates exotic species import via an Import Risk Analysis (IRA) system (*AQIS Import Risk Analysis Handbook*, http://www.daff.gov.au/__data/assets/pdf_file/0011/399341/IRA_handbook_2007_WEB.pdf. Accessed 23 May 2008). The IRA system operates on a politically independent and scientifically based process. The Australian Weed Risk Assessment system (WRA), a portion of the IRA, (Biosecurity Austrailia – The Weed Risk Assessment System, http://www.daff.gov.au/ba/reviews/weeds/system. Accessed 23 May 2008) is a methodology to determine whether a NIS should be imported into Australia. Answers to questions on various plant aspects are given numerical scores, which are used to determine an outcome: to *accept*, *reject*, or *further evaluate* the species.

The Nursery and Garden Industry Australia (NGIA) as well as many state nursery and garden assocations (in Australia) have proactively formed working alliances with state governments on restricting the distribution and sale of invasive species (EPPO Reporting Service – Invasive Plants 2007/061). The main foci of the NGIA's "Invasive Policy Position" (Nursery and Garden Industry – Invasive Plants Policy Position, http://www.ngia.com.au/docs/pdf/your_associations/NGIA_invasiveweedspolicy.pdf. Accessed 9 June 2008) are (1) that government takes a fair approach to ascribing blame for invasive plants to nursery and garden groups, (2) the development of mutually agreed upon national and state prohibited plant species lists, (3) reliable and independent methods for assessing invasiveness, (4) government recognition of the industry's invasive plant regulation efforts, (5) government approval and support of industry-based communciation and awareness programs that target industry and consumer groups, and (6) government support for a secure and sustainable nursery and garden industries.

An example of nursery industry and government collaboration is the Australian "Grow Me Instead" Program (Nursery & Garden Industry – Grow Me Instead! http://www.ngia.com.au/home_gardeners/growme_instead.asp. Accessed 9 June 2008). The purposes of this program are to (1) identify garden species that are invasive, (2) identify suitable native and nonnative alternative species, and (3) educate the public via nursery industry programs with the ultimate goal of ceasing the sale of invasive plant species. This best management practices approach to the invasive plant problem exemplifies an advocative relationship between government and industry. Such a progressive relationship is apt to reduce the sale of invasive species and avoids the more typical adversarial relationship between the nursery and governments because the nursery industry is taking an *active* role in educating the public and managing the sale of invasive species.

Despite the proactive and proenvironment measures taken by the NGIA described earlier, there are some areas of cooperation that are not evident. A recent report, "Poisonous and Invasive Plants in Australia: Enabling Consumers to Buy Safe Plants" (Thomson 2007), calls for the NGIA to, in part, develop a plant labeling code of practice, which will give consumers concise information on a species' poisionous and invasive properties. The NGIA issued labeling guidelines in 2007 (Nursery & Garden Industry Australia – National Plant Labelling Guidelines 2007) but did not issue a code of practice. The lack of such a code makes implementation of labeling recommendations unlikely.

9.5.3 Biological Measures to Control Invasive NIS

There are some strategies and efforts to induce sterility into popular ornamental invasive NIS (Egolf 1981, 1986, 1988; Li et al. 2004; Olsen and Ranney 2005). As an example, the triploid *Hibiscus syriacus* L. "Diana" sets very little fruit (Dirr 1998), which is in contrast to the diploid species that sets a large amount of fruit and

prolifically reproduces itself (AXN, personal observation). Inducing sterility, either by breeding or molecular tools, could diminish invasion risk of a seed-dispersed species that, due to its popularity and economic impact, would not be removed from the ornamental horticulture trade. However, extensive research on the efficacy and stability of sterility systems as well as the realized prevention of invasiveness should be conducted before sterile, noninvasive cultivars are released (Anderson et al. 2006).

9.5.4 Volunteers to Assist in Controlling Invasive NIS

Volunteers are a valuable resource for early detection of invasive NIS (Simberloff 2003; Wittenberg and Cock 2001). Personnel associated with the horticulture and landscaping industries are well qualified to detect emergent invasive species. In addition to those employed to survey and scout for spreading NIS, Wittenberg and Cock (2001) suggest that gardeners, landscape managers, fisherman, land surveyors, hikers, and others who venture into natural habitats be trained to identify or seek identification for known or new invasive NIS. The Federal Interagency Committee for the Management of Noxious and Exotic Weeds in conjunction with other governmental, state, and local partners has proposed a National Early Detection and Rapid Response System of invasive plants in the USA (Westbrooks 2004). Early detection and reporting of suspected new invasive species by volunteers is the foundation of the system. Hegamyer et al. (2003) present several successful case studies on the use of volunteers for early detection of invasive species, some of which were performed by Extension Master Gardeners (EMGs). In the USA, there are approximately 90,000 active EMGs trained in aspects of plant science and land stewardship. Thus, EMGs potentially represent a sizable, effective volunteer force, especially in view of their knowledge of plant science and garden species.

9.5.5 Controlling Invasive NIS – Prevention and Eradication

The horticulture industry is uniquely situated to work with the scientific community to more accurately predict which NIS will be invasive. Mack (2005) recommends that we must go beyond the traditional use of invasive plant traits and the invasive history of species (criteria promoted in the *Voluntary Code of Conduct for Nursery Professionals*) and undertake field trials that (1) identify those species that easily self-propagate (sexually or asexually) with minimal or no cultivation, and (2) identify and report species that routinely escape cultivation. These measures will yield valuable data on those species that are apt to establish populations outside their planted range. Mack (2005) encourages nurseries to serve as test sites, a capacity that nurseries already serve in evaluating plant traits, to determine those species that require minimal or no cultivation and have the capacity to emigrate from their planted sites and generate new populations. Simberloff et al. (2005) proposed that the decision of whether a species should be introduced should be based on “a solid understanding of what regulates populations in their native range.” Both of these authors readily admit

that these approaches are unfeasible unless society is willing to cease introductions while species-specific information is collected. The horticulture and landscape industry would certainly view the call to cease plant introductions as radical. However, a first step toward accurate prevention of the introduction of invasive nonnative species would be an "International Invasive Plant Data Center" that would create and update a global database of invasive nonnative plant species (Rejmanek et al. 2005). Because the history of invasiveness in one region is the best predictor of invasive potential in another region, a comprehensive and up-to-date invasive plant database will be useful in determining which taxa might be safely introduced into new areas.

While accurate prediction of invasive potential and prohibiting the importation of invasive species is the best case scenario, early detection and eradication of escaped species is the next best strategy. Eradication is possible if the invasive species is detected early enough and enough resources are dedicated to its removal (Simberloff 1997). In terms of early eradication of invasive NIS, success is optimized by meeting the following criteria: (1) limited distribution of the target species or organism, (2) adequate eradication resources, (3) clear legal grounds for action and unambiguous lines of authority, (4) the biology of the organism must be understood to develop an effective extirpative strategy, and (5) eradication should not do more harm than good (Simberloff 2003).

9.5.6 Information Sources

Where do horticulture industry personnel and the gardening public get science-based information regarding a NIS? The USDA's *National Invasive Species Information Center: Gateway to invasive species information, covering Federal, State, local, and international sources* web site is a comprehensive site covering most aspects of invasive plants and animals (USDA National Invasive Species Information Center, http://www.invasivespeciesinfo.gov/. Accessed 9 June 2008). However, there is no single information source in which nursery/landscape industry personnel and the gardening public can obtain information that focuses on the issues of landscape plants and nursery industry-related invasive issues. A search of the Internet (Google™) for "invasive landscape plants" or "invasive garden plants" yields a listing of 1.1 million and 152,000 web sites, respectively. This enormous amount of information to consider will likely overwhelm those seeking specific information. Thus, a well-advertised web site targeted at nursery/landscape industry personnel and the gardening public is vital to public education regarding NIS. These groups need to know (1) the fundamentals of invasive NIS biology, (2) landscape species that have been documented to be invasive and their relative impact, (3) the region(s) in which these invasive NIS are a problem, (4) alternative, noninvasive species for each region to be used in place of invasive NIS, and (5) because NIS establishment and impacts will vary significantly in response to climate and physiographic region, regional and state resources are especially important (Fox et al. 2003).

Another effective strategy for the education of industry regarding nonnative species would be for the US Cooperative Extension Service to develop and conduct an education program for nursery businesses. The program would be targeted at industry members regarded as innovators. This innovative group would serve as the first adopters of the educational objectives, and then serve as a model for other businesses, thereby encouraging widespread adoption. Harrington et al. (2003) concluded that educating ornamental horticulture personnel and the public should be a major focus in mitigating the invasive plant problem. McKinney (2004) found a high correlation ($r^2 = 0.69$) between the number of introduced species (plants and animals) of an area and the human population in that area. He contends that educating the general public about the dangers of exotic species importation "may be the only way to reduce rates of introduction." The ornamental horticulture industry should move to make their efforts in addressing invasive NIS more visible and public than in the past. Educating personnel on the fundamental aspects of invasive NIS and referencing NatureServe's list of documented invasive taxa (NatureServe 2005) as plants not to be sold (based on regional observations) would be a significant first step in developing a best management practices strategy. Other helpful resources are California's "Don't Plant a Pest" (California Invasive Plant Council – Don't Plant a Pest, http://www.cal-ipc.org/landscaping/dpp/. Accessed 23 May 2008) and Washington's "Garden Wise" (Washington Invasive Species Coalition – Garden Wise, http://www.invasivespeciescoalition.org/GardenPlants/index_html/view?searchterm = water%20wise. Accessed 9 June 2008) educational programs that target nursery professionals and gardeners who wish to plant noninvasive species in their landscapes. Both programs offer noninvasive alternatives to popular invasive garden species. Adopting these types of educational resources by the ornamental horticulture industry would help conserve native biodiversity and be evidence of responsible land stewardship. Thus, the ornamental horticultural industry is uniquely situated to work with the scientists and policy makers to increase public understanding of invasive species as well as decrease the introduction and spread of high-impact invasive plant species.

References

Allendorf FW, Lundquist LL (2003) Introduction: population biology, evolution, and control of invasive species. Conserv Biol 17:24–30

American Nurseryman (1999) Invasives roundtable. Am Nurseryman 190:54–77

Anderson NO, Gomez N et al. (2006) A non-invasive crop ideotype to reduce invasive potential. Euphytica 148:185–202

Baskin Y (2002) The greening of horticulture: new codes of conduct aim to curb plant invasions. BioScience 52:464–471

Bell CE, Wilen CA et al. (2003) Invasive plants of horticultural origin. HortScience 38:14–16

Bryson CT, Carter R (2004) Biology of pathways for invasive weeds. Weed Technol 18:1216–1220

Burt JW, Muir AA et al. (2007) Preventing horticultural introductions of invasive plants: potential efficacy of voluntary initiatives. Biol Invasions 9:909–923

Canton BP (2005) Availability in Florida nurseries of invasive plants on a voluntary "do not sell" list. United States Department of Agriculture, Animal and Plant Health Inspection Service, Raleigh, NC

Clayton M (2004) Now, invasive species stream in online. Christian Science Monitor Oct. 28 (Features: Planet). The Christian Science Monitor, p. 13

Colautti RI (2005) In search of an operational lexicon for biological invasions. In: Inderjit (ed) Invasive plants: ecological and agricultural aspects. Birkhäuser, Germany

Colautti RI, MacIsaac HJ (2004) A neutral terminology to define 'invasive' species. Divers Distrib 10:135–141

Colton TF, Alpert P (1998) Lack of public awareness of biological invasions by plants. Nat Area J 18:262–266

Crooks JA, Soulé ME (1999) Lag times in population explosions of exotic species: causes and implications. In: Sandlund OT, Schei PJ et al. (eds) Invasive species and biodiversity management. Kluwer, Dordrecht, Netherlands, pp. 103–125

Daehler CC (2001) Two ways to be an invader, but one is more suitable for ecology. Bull Ecol Soc Am 82:101–102

Daehler CC, Carino DA (2000) Predicting invasive plants: prospects for a general screening system based on current regional models. Biol Invasions 2:93–102

Davis MA, Thompson K (2001) Invasion terminology: should ecologists define their terms differently than other? No, not if we want to be of any help! Bull Ecol Soc Am 82:206

Dekker J (2005) Biology and anthropology of plant invasions. In: Inderjit (ed) Invasive plants: ecological and agricultural aspects. Birkhäuser, Germany, pp. 235–250

Department of Conservation (2002) Space invaders – a summary of the Department of Conservation's strategic plan for managing invasive weeds. http://www.doc.govt.nz/upload/documents/conservation/threats-and-impacts/weeds/space-invaders.pdf. Accessed 23 May 2008

Dirr MA (1998) Manual of woody landscape plants – their identification ornamental characteristics, culture, propagation, and uses. Stipes, Champaign, IL

Drake JA (2005) Plant invasions: ecological and agricultural aspects. In: Inderjit (ed) Invasive plants: ecological and agricultural aspects. Birkhäuser, Germany, pp. XIII–XIV

Egolf DR (1981) 'Helene' Rose of Sharon (Althea). HortScience 16:226–227

Egolf DR (1986) 'Minerva' Rose of Sharon (Althea). HortScience 21:1463–1464

Egolf DR (1988) 'Aphrodite' Rose of Sharon (Althea). HortScience 23:223

EPPO Reporting Service – Invasive Plants (2007). http://archives.eppo.org/EPPOReporting/2007/Rse-0703.pdf. Accessed 23 May 2008

Ewel JJ, O'Dowd DJ et al. (1999) Deliberate introductions of species: research needs. BioScience 49:619–630

Fay K (2003) Linking ecology and horticulture to prevent plant invasions. II. Workshop at the Chicago Botanic Garden. http://www.centerforplantconservation.org/invasives/Download%20PDF/CBG_Proceedings.pdf. Accessed 23 May 2008

Federal Register – Presidential Documents (1999) Vol. 64, no. 25. http://www.invasivespecies.gov/laws/eo13112.pdf. Accessed 23 May 2008

Fox AM, Gordon DR (2004) Criteria for listing invasive plants. Weed Technol 18:1309–1313

Fox AM, Gordon DR et al. (2003) Challenges of reaching consensus on assessing which non-native plants are invasive in natural areas. HortScience 38:11–13

Fox AM, Gordon DR et al. (2005) IFAS assessment of the status of non-native plants in Florida's natural areas. http://aquat1.ifas.ufl.edu/finalassessjun05.pdf. Accessed 9 June 2008

Green JL, Green AK (2003) The nursery industry in the United States – always new frontiers. HortScience 38:994–998

Hall M (2000) IP plants: invasive plants and the nursery industry. Undergraduate senior thesis in environmental studies. http://www.brown.edu/Research/EnvStudies_Theses/full9900/mhall/IPlants/IPlants_Frames.html. Accessed 9 June 2008

Harrington RA, Kujawski R et al. (2003) Invasive plants and the green industry. J Arboric 29:42–48

Heffernan KE, Coulling PP et al. (2001) Ranking invasive exotic plant species in Virginia. Natural Heritage Technical Rep. 01-13. Virginia Dept of Conservation and Recreation, Division of Natural Heritage, Richmond. http://www.dcr.virginia.gov/dnh/rankinv.pdf. Accessed 9 June 2008

Hegamyer K, Nash SP et al. (eds) (2003) The early detectives: how to use volunteers against invasive species, case studies of volunteer early detection programs in the U.S. http://www.invasivespeciesinfo.gov/toolkit/detect.shtml. Accessed 9 June 2008

Isaacson RT (ed) (1996) Andersen horticultural library's source list of plants and seeds: a completely revised listing of 1988–89 catalog compiled by Richard T. Isaacson and the staff of the Andersen Horticultural Library, 4th edn. Andersen Horticultural Library, University of Minneapolis, Minneapolis, MN

Jordan N, Becker R et al. (2003) Knowledge networks: an avenue to ecological management of invasive weeds. Weed Sci 51:271–277

Kauffman S, McKey DB et al. (1991) Adaptations for a two-phase seed dispersal system involving vertebrates and ants in a hemiepiphytic fig (*Ficus microcarpa*: Moraceae). Am J Bot 78:971–977

Kelly KM, Conklin JR et al. (2006) Invasive plant species: results of a consumer awareness, knowledge, and expectations survey conducted in Pennsylvania. J Environ Hort 24:53–58

Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. Trends Ecol Evol 16:199–204

Kowarik I (1995) Time lags in biological invasions with regard to the success and failure of alien species. In: Pysek P, Prach K et al. (eds) Plant invasions: general aspects and special problems. SPB Academic, Amsterdam

Kowarik I (2003) Human agency in biological invasions: secondary releases foster naturalisation and population expansion of alien plant species. Biol Invasions 5:293–312

Li Y, Cheng Z, et al. (2004) Invasive ornamental plants: problems, challenges, and molecular tools to neutralize their invasiveness. Crit Rev Plant Sci 23:381–389

Lockwood JL, Simberloff D (2001) How many, and which, plants will invade natural areas. Biol Invasions 3:1–8

Lockwood JL, Cassey P et al. (2005) The role of propagule pressure in explaining species invasions. Trends Ecol Evol 20:223–228

Lodge DM, Shrader-Frechette K (2003) Nonindigenous species: ecological explanation, environmental ethics, and public policy. Conserv Biol 17:31–37

Lodge DM, Williams S et al. (2006) Biological invasions: recommendations for U.S. policy and management. Ecol Appl 16:2035–2054

Macdonald IA, Loope LL et al. (1989) Wildlife conservation and invasion of nature reserves by introduced species: a global perspective. In: Drake JA, Mooney HA et al. (eds) Biological invasions. A global perspective. SCOPE 37. Wiley, Chichester, UK

Mack RN (2000) Cultivation fosters plant naturalization by reducing environmental stochasticity. Biol Invasions 2:111–122

Mack RN (2003) Plant naturalizations and invasions in the eastern United States: 1634–1860. Ann Missouri Bot Gard 90:77–90

Mack RN (2005) Predicting the identity of plant invaders: future contributions from horticulture. HortScience 40:1168–1174

Mack RN, Erneberg M (2002) The United States naturalized flora: largely the product of deliberate introductions. Ann Missouri Bot Gard 89:176–189

Mack RN, Simberloff D, et al. (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecol Appl 10:689–710

McKinney ML (2004) Citizens as propagules for exotic plants: measurement and management implications. Weed Technol 18:1480–1483

Mooney HA (2005) Invasive alien species: the nature of the problem. In: Mooney HA, Mack RN et al. (eds) Invasive alien species: a new synthesis. Island Press, Washington

Morse LE, Randall JM et al. (2004) An invasive species assessment protocol: evaluating nonnative plants for their impact on biodiversity, Version 1. NatureServe, Arlington, VA. http://www.natureserve.org/library/invasive_species_assessments.pdf. Accessed on June 9 2008

Myers JH, Bazely D (2003) Ecology and control of introduced plants. Cambridge University Press, Cambridge
NC State University News Release (2003) http://www.ncsu.edu/news/press_releases/03_07/196.htm Accessed 9 June 2008
Nursery & Garden Industry Australia – National Plant Labelling Guidelines (2007) http://www.ngia.com.au/docs/pdf/your_associations/NGIA_Labelling_Guidelines_AUG07v1.1.pdf. Accessed June 9 2008
Olsen RT, Ranney TG (2005) Breeding for non-invasive landscape plants. http://www.ces.ncsu.edu/depts/hort/nursery/short/2005_short_cs/breeding_noninvasive.htm. Accessed 9 June 2008
Parker IM, Simberloff D et al. (1999) Impact: toward a framework for understanding the ecological effects of invaders. Biol Invasions 1:3–19
Pemberton RW (2000) Naturalization patterns of horticultural plants in Florida. In: Spencer NR (ed) Proceedings of the X International Symposium on Biological Control of Weeds. Montana State University Bozeman, Montana
Pheloung PC, Williams PA (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. J Environ Manage 57:239–251
Pimental D, Lach L et al. (2000) Environmental and economic costs of nonindigenous species in the United States. BioScience 50:53–64
Radosevich SR, Stubbs MM et al. (2003) Plant invasions – process and patterns. Weed Sci 51:254–259
Randall JM, Marinelli J (eds) (1996) Invasive plants: weeds of the global garden. Brooklyn Botanic Garden, New York. http://www.bbg.org/gar2/topics/sustainable/handbooks/invasive-plants/. Accessed 9 June 2008
Reaser J, Meyerson L et al. (2008) Saving camels from straws: how propagule pressure-based prevention policies can reduce the risk of unintentional introductions. Biol Invasions 10:1085–1098
Reichard SH (1997) Prevention of invader plant introductions on national and local levels. In: Luken JO, Thiere JW et al. (eds) Assessment and management of plant invasions. Springer, New York
Reichard SH, Hamilton CW (1997) Predicting invasions of woody plants introduced into North America. Conserv Biol 11:193–203
Reichard SH, White P (2001) Horticulture as a pathway of invasive plant introductions in the United States. BioScience 51:103–113
Rejmanek M, Richardson DM (2005). Plant invasions and invisibility of plant communities. In: van der Maarel E (ed) Vegetation ecology. Blackwell Science, Oxford, UK
Rejmanek M, Richardson DM et al. (2005) Ecology of invasive plants: state of the art. In: Mooney HA, Mack RN et al. (eds) Invasive alien species: a new synthesis. Island Press, Washington
Richardson DM, Allsopp N et al. (2000) Plant invasions – the role of mutualisms. Biol Rev 75:65–93
Simberloff D (1997) Eradication. In: Simberloff D, Schmitz DC (eds) Strangers in paradise: impact and management of nonindigenous species in Florida. Island Press, Washington, DC
Simberloff D (2003) Confronting introduced species: a form of xenophobia. Biol Invasions 5:179–192
Simberloff D, Von Holle B (1999) Positive interactions of nonindigenous species: invasional meltdown? Biol Invasions 1:21–32
Simberloff D, Parker IM et al. (2005) Introduced species policy, management, and future research needs. Front Ecol Environ 3:12–20
Thomson N (2007) Poisonous and invasive plants in Australia: enabling consumers to buy safe plants. WWF-Australia Issues Paper. WWF-Australia, Sydney
Timmins SM (2004) How weed lists help protect native biodiversity in New Zealand. Weed Technol 18:1292–1295
Von Holle B, Simberloff D (2005) Ecological resistance to biological invasion overwhelmed by propagule pressure. Ecology 86:3212–3218

Wells MJ, Poynton RJ, et al. (1986) The history of introduction of invasive alien plants to southern Africa. In: Macdonald IAW, Kruger FJ et al. (eds) The ecology and management of biological invasions in southern Africa. Oxford University Press, Cape Town, South Africa
Westbrooks RG (2004) New approaches for early detection and rapid response to invasive plants in the United States. Weed Technol 18:1468–1471
Widrlechner MP, Thompson JR et al. (2004) Models for predicting the risk of naturalization of non-native woody plants in Iowa. J Environ Hort 22:23–31
Wilson EO (1992) The diversity of life. Harvard University Press, Cambridge, Massachusetts
Williamson M, Fitter A (1996) The varying success of invaders. Ecology 77:1661–1666
Wirth FF, Davis KJ et al. (2004) Florida nursery sales and economic impacts of 14 potentially invasive landscape plant species. J Environ Hort 22:12–16
Wittenberg R, Cock MJW (eds) (2001) A toolkit of best prevention and management practices. CAB International, Wallingford, Oxon, UK
Wolfe EW, Dozier H (2000) Development of a scale for monitoring invasive plant environmentalism. J Appl Measure 1:219–237