

Trueblood, C.E. 2009. The development of an assessment protocol for potentially invasive plant species sold in the North Carolina horticultural trade. In *An Invasive Species Assessment System for the North Carolina Horticultural Industry*. MS Thesis. North Carolina State University, Raleigh, pp. 10-35.

**The development of an assessment protocol for potentially invasive plant species sold in the
North Carolina horticultural trade**

ABSTRACT

A systematic assessment protocol was developed to evaluate the potential invasiveness of plant species sold in the North Carolina nursery industry. Results from these assessments will provide objective criteria with which the North Carolina Nursery and Landscape Association (NCNLA) may advise their members regarding sale and marketing of plants that have been reported to be invasive. The North Carolina assessment is largely non-predictive and designed to assess both the environmental risks and overall benefits associated with potentially invasive ornamental plant species through a system of weighted criteria. The North Carolina assessment protocol was adapted from several existing invasive assessment models that have been developed by other states and environmental groups for the evaluation and categorization of potentially invasive plant species. The criteria of these state and national assessment systems were compared and integrated to develop an assessment tool specifically tailored for North Carolina. The North Carolina criteria are grouped into four sections: Ecological Impact, Distribution and Invasive Potential, Management Difficulty, and Benefits and Value. Eighteen ornamental plant species that have naturalized, at some level, in North Carolina were evaluated using the state-specific assessment and classified as invasive, moderately weedy, or noninvasive.

INTRODUCTION

The purpose of developing an invasive species assessment system for North Carolina is to provide the North Carolina Nursery and Landscape Association (NCNLA) with information to make better decisions regarding the sale and distribution of potentially invasive ornamental plant species sold in the North Carolina horticultural trade. The conclusions and recommendations of the assessment are intended to help prevent the spread of potentially invasive ornamental plant species and minimize environmental impacts within natural areas of North Carolina.

Documentation, preferably from published peer-reviewed literature, is required to answer criteria and complete the North Carolina assessment. A science-based assessment with objective criteria, developed specifically for North Carolina, may help the nursery industry to justify the categorization and potentially limit the sale of species that have been identified as invasive plants.

The North Carolina assessment has been designed to evaluate potentially invasive plant species that affect natural areas. *Invasive species* are defined as non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health that outweighs any benefits (NISC 2006). For the purpose of this assessment, *natural areas* have been defined as ecosystems that are primarily managed to be in a natural state. Areas immediately adjacent (<10 meters) to roads and trails are not considered natural areas in the North Carolina assessment. The North Carolina assessment is largely non-predictive and not intended to predict invasive attributes or prescreen species not currently utilized in the North Carolina horticultural trade; however, potential for further spread of existing species is considered.

The criteria for the North Carolina assessment protocol were adapted from several existing risk or invasive assessment models that have been developed by other states and environmental groups for the evaluation and categorization of potentially invasive plant species. The assessment tools that served as models in developing the North Carolina protocol have varying objectives and utilize a diversity of criteria, but each model is nonpredictive and largely science-based, meaning some kind of documentation is required to support each criterion that assesses species already present in the region. Researchers and plant pest advisory groups from several states, including Arizona, California, Florida, Indiana, and Michigan have developed assessment criteria and produced categorized lists of invasive non-native plants that have been identified as threats to natural areas within their states. Morse et al. (2004) developed an invasive assessment protocol for NatureServe, a non-profit environmental organization that may be modified for regional, state, or local areas.

Several states, including Arizona (Northam et al. 2005) and Indiana (IPSAWG 2005) have adapted existing assessment models to evaluate potentially invasive species. Northam et al. (2005) relied upon the criteria created in California by Warner et al. (2003) to develop an assessment tool for Arizona. The Indiana assessment tool (IPSAWG 2005) is largely derived from the Florida assessment written by Fox et al. (2005). In these cases, invasive plant working groups adapted assessment protocols from other states by looking to a single assessment as a model protocol. These groups have drawn upon existing criteria to evaluate potentially invasive species in their region for the purpose of providing management recommendations to agencies and organizations in their state. Rather than rely on one existing model for the state assessment criteria, the North Carolina assessment incorporates elements of a variety of existing state and national assessments.

The ranking and scoring systems and qualitative and quantitative measurements of these existing assessment models were compared to develop the initial framework for an assessment tool unique to North Carolina. Support for the inclusion of criteria derived from available models was based upon the availability of documented support from peer-reviewed journal articles and current research regarding invasive biology and the link between horticulture and invasive plant introductions (Goodwin et al. 1999; Mack et al. 2000; Reichard and White 2001). Criteria selected for the North Carolina assessment are those that are likely to have information available for a variety of species.

The screening effectiveness of the draft invasive assessment model for North Carolina and the model's ability to discern damaging from innocuous non-native plants was tested by evaluating both known noxious weeds and nonindigenous species that are generally perceived to be noninvasive.

SELECTING SPECIES FOR THE ASSESSMENT

This model is non-predictive and designed to evaluate species that are already present in the horticultural trade in North Carolina. Fourteen ornamental plant species that have naturalized, at some level, in North Carolina were evaluated using the state-specific assessment. These potentially invasive species were identified by NCNLA members and North Carolina land managers in a prior survey. Plant species identified by other state assessments, such as the Florida protocol (Fox et al. 2005), as damaging invasive species and available in the horticultural industry in North Carolina were also examined using the North Carolina model. Species were evaluated independently. Cultivars of species may be considered separately if they have been rigorously tested and determined to have unique non-invasive traits (e.g., seedlessness).

APPLYING THE CRITERIA

Criteria are presented as straightforward questions with a limited number of clearly defined yes-no or multiple-choice responses. For each main assessment question, the evaluator selects a response that corresponds to a particular point value. Numerical values assigned to criteria are for ranking purposes and to separate invasive from innocuous non-native species.

All supporting information must be documented on the species' Dataform and Score Sheet. If information is unavailable to answer a particular question, the response is marked as unknown. After supporting information has been reviewed, scores for each Index Category are determined. An overall score is compiled from the section scores.

DESCRIPTION OF THE CRITERIA

The North Carolina assessment protocol includes five yes-no screening questions and 21 weighted multiple-choice assessment questions grouped into four index categories that collectively measure the environmental risk and overall benefit of potentially invasive ornamental plant species (Table 1):

1. Ecological Impact (4 questions; 40% of final score)
2. Current Distribution and Potential for Expansion (5 questions; 40% of final score)
3. Management Difficulty (7 questions; 20% of final score)
4. Benefit and Value (5 questions; 15% of final score)

Table 1.1 Summary of the North Carolina Assessment System for Potentially Invasive Ornamental Plant Species

Introductory Screening Questions	
i.	Is this species listed on a federal or North Carolina noxious or prohibited plant list?
ii.	Is this species sold in the horticultural trade in North Carolina?
iii.	Is this species native to North Carolina?
iv.	Is this species known or suspected to be present in natural areas within the four Physiographic Provinces (Blue Ridge Province, Piedmont Province, Inner Coastal Plain, Outer Coastal Plain) of North Carolina?
v.	Is this a specific cultivar that has been rigorously tested and determined to be seedless and does not produce viable seeds or vegetative propagules that disperse widely under natural conditions?
Section 1. Ecological Impact (4 questions, 40% of rating)	
1a. Impact on Ecosystem Processes and System-Wide Parameters (10 points)	
1b. Impact on Plant Community Structure and Composition (20 points)	
1c. Impact on Species of Special Concern or Threatened or Endangered Plants (5 points)	
1d. Impact on Higher Trophic Levels (5 points)	
Section 2. Current Distribution and Potential for Expansion (5 questions, 40% of rating)	
2a. Local Range Expansion or Change in Abundance (7 points)	
2b. Long-Distance Dispersal Potential (13 points)	
2c. Reproductive Characteristics/Biological Character (8 points)	
2d. Range of Communities in which Species is Invading (6 points)	
2e. Similar Habitats Invaded Elsewhere (6 points)	
Section 3. Management Difficulty (7 questions, 20% of rating)	
3a. Herbicidal Control (5 points)	
3b. Nonchemical Control (2 points)	
3c. Necessity of Individual Treatments (2 points)	
3d. Average Distribution Pattern (2 points)	
3e. Likelihood of Reestablishment (2 points)	
3f. Accessibility of Invaded Areas (2 points)	
3g. Impact of Management on Native Species and the Environment (5 points)	

Table 1.1 Continued

Section 4. Benefits and Value (5 questions)
4a. Estimated Wholesale Value for North Carolina (-7 points)
4b. Percentage of Wholesale Sales (-5 points)
4c. Ecosystem Services (-1 points)
4d. Wildlife Habitat (-1 points)
4e. Cultural and Social Benefits (-1 points)

Prescreening questions are designed to identify species eligible for assessment. To be eligible for assessment, a species must be a) currently not listed as a federal or state noxious weed (since those are already regulated by federal and state agencies), b) non-native, and c) sold in the horticultural trade in North Carolina, d) present or suspected to be present in natural areas in North Carolina, and e) not determined to be a non-invasive cultivar.

The criteria are divided among four sections: Ecological Impact, Distribution and Invasive Potential, Management Difficulty, and Benefits and Value. Scores from the Ecological Impact and Distribution and Invasive Potential sections weigh more heavily on the final recommendation due to the serious environmental implications associated with invasive species. Ecological Impact and Distribution and Invasive Potential are evaluated within natural areas and may be assessed separately in different geographic regions of North Carolina. The North Carolina assessment recognizes and considers the commercial value of selling potentially invasive ornamental plant species and the ecosystem services, wildlife habitat, and cultural benefits provided by some potentially invasive species. Scores from the Benefits and Value section are negative and subtract from the overall invasiveness rating and possible do not sell recommendation.

DERIVATION OF THE NORTH CAROLINA CRITERIA AND EVALUATION SYSTEM

- Introductory Screening Questions -

The North Carolina assessment begins with introductory screening questions to identify species that are eligible for assessment. The North Carolina assessment is designed to evaluate species that are a) currently not listed as a federal or state noxious weed, b) non-native and c) sold in the horticultural trade in North Carolina, d) present or suspected to be present in natural areas in North Carolina, and e) not a cultivar that is considered to be non-invasive.

The Florida (Fox et al. 2005), Indiana (IPSAWG, 2005), and Michigan (Schutzki et al. 2004) assessments include a prescreening section that automatically exempts a species from the assessment if it is listed on any federal or state noxious or prohibited plant lists. In addition, the Florida (Fox et al. 2005), Indiana (IPSAWG, 2005), and NatureServe (Morse et al. 2004) pre-screening questions identify species that currently invade natural or conservation areas of the state or region. These two screening questions were accepted for use in the NC assessment protocol. In addition, an exemption for a plant cultivar that has previously been demonstrated to be non-invasive was included. An example of such an exemption would be documented male and female sterility for a seed-propagated invasive species.

- Index Categories -

The North Carolina assessment includes four primary index categories: Ecological Impact, Current Distribution and Potential for Expansion, Management Difficulty, and Benefits and Value.

- Section 1. Ecological Impact

The purpose of the Ecological Impact section is to identify those species that alter ecosystem processes and plant community composition and impact endangered species and

higher trophic levels in natural areas. This section is similar to that in existing models (Arizona: Northam et al. 2005; California: Warner et al. 2003; Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004).

- Question 1a. Impact on Ecosystem Processes and System-Wide Parameters

The first question of the North Carolina assessment identifies whether a species substantially alters abiotic ecosystem processes and system-wide parameters in ways that may diminish the survival of native species. This section classifies the extent, ranging from severe, moderate, and mild, to negligible, that an invasive species alters abiotic processes, including fire frequency, erosion, sedimentation rates, hydrological regimes, nutrient and mineral dynamics, and light availability.

All models adapted for the North Carolina assessment examine the impact on abiotic ecosystem processes (Arizona: Northam et al. 2005; California: Warner et al. 2003; Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004). The long-term alteration of ecosystem processes is a highly rated criterion among ecological impacts of invasion (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004).

- Question 1b. Impact on Plant Community Structure and Composition –

This criterion in the North Carolina assessment asks whether the species alters plant community, composition, or vegetation structure in natural areas. Evaluators identify whether a species causes major, significant, minor, or no alteration in community composition. The highest number of points in this section is assigned to those species that cause major alterations in community composition (e.g., > 50% cover throughout one vegetation layer over multiple

successional stages, results in the extirpation of one or more native species, reduces biodiversity).

The cumulative ecological impact of a species that invades and changes plant communities is considered heavily in existing models (Arizona: Northam et al. 2005; California: Warner et al. 2003; Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004). Assessments evaluate the degree of alteration of plant community composition, structure, or interactions. Examples of severe impacts include formations of monocultural stands or patches, occlusion of a native canopy, significant reduction of native populations (Arizona: Northam et al. 2005; California: Warner et al. 2003; Michigan: Schutzki et al. 2004), coverage of at least 50% in the affected stratum (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005). Within this section, evaluators may be asked to consider interactions that involve rare species or community types (Arizona: Northam et al. 2005; California: Warner et al. 2003). In the North Carolina assessment, there is a separate question (1c) to address the impact on species of special concern or threatened or endangered plants.

- Question 1c. Impact on Species of Special Concern or Threatened or Endangered Plants -

In other assessments, as part of the criterion examining the impact on plant community composition, structure, and interactions, evaluators are asked to consider interactions that involve rare species or community types (Arizona: Northam et al. 2005; California: Warner et al. 2003; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004). In the Florida (Fox et al. 2005) and Indiana (IPSAWG 2005) assessments evaluators are asked to consider whether the species has negatively impacted Federal- or state-listed Species of Special Concern or Threatened or Endangered plants or animals. In the North Carolina assessment, similar to the Florida (Fox et al. 2005) and Indiana (IPSAWG, 2005) assessment, there is a separate question (1c) to address the

important impact on species of special concern or threatened or endangered plants. Although impacts on threatened or endangered plants is of high concern, these situations are often very localized, and best addressed through management plans for specific natural areas where these plants exist, rather than state-wide recommendations.

- Question 1d. Impact on Higher Trophic Levels –

In the North Carolina assessment, this question regarding higher trophic levels identifies species that have a cumulative effect on other animals (nesting or foraging sites, habitat connectivity, migration corridors), act as a host plant or provide overwintering for insect pests that damage crop plants in North Carolina, and/or act as a host plant for insect pests that present a threat to human health.

In addition to the impacts on plant communities, the Arizona (Northam et al. 2005) and California (Warner et al. 2003) models consider how plant species affect animals and other organisms. Severe impacts include endangerment of native animal communities or the significant reduction in nesting or foraging sites, cover, or other critical resources.

- Section 2. Current Distribution and Potential for Expansion (Invasive Potential) –

The second section, Current Distribution and Potential for Expansion, evaluates the species' range in North Carolina, long-distance dispersal potential, reproductive traits associated with invasiveness, invaded natural communities, and similar habitats invaded elsewhere. The Distribution and Invasive Potential category of the North Carolina protocol was synthesized from a variety of categories developed by other assessment models. Existing assessments include a variety of sections that examine Invasive Potential (Arizona: Northam et al. 2005; California: Warner et al. 2003), Potential for Expansion (Florida: Fox et al. 2005, Indiana: IPSAWG, 2005),

and Ecological Amplitude and Distribution (Arizona: Northam et al. 2005; California: Warner et al. 2003; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004). The North Carolina model combines likelihood for long-distance dispersal with the number of natural community types invaded to create one comprehensive section on current distribution and potential for expansion. Reproductive traits are considered in the Current Distribution and Potential for Expansion section, rather than throughout the assessment or with the Management Difficulty section (Florida: Fox et al. 2005), to improve clarity of invasive potential and avoid redundancy in the model.

- Question 2a. Local Range Expansion or Change in Abundance -

The North Carolina model examines whether the overall range or extent of the distribution of a species has increased within the state. The highest number of points is assigned in cases where the range of the species is increasing rapidly. Existing models estimate the rate of spread within the range of the state or region as well (Arizona: Northam et al. 2005; California: Warner et al. 2003; NatureServe: Morse et al. 2004). As in the North Carolina model, the selection choices are descriptive and qualitative estimates, ranging from widespread, increasing rapidly (doubling in total range statewide in <10 years), increasing, but less rapidly, to stable, and declining (Arizona: Northam et al. 2005; California: Warner et al. 2003; NatureServe: Morse et al. 2004). Selection choices may also be quantitative and require distributional evidence that the species has been reported in more than two new discrete populations (at least 1 mile) in any 12 month period within the last 10 years (Florida: Fox et al. 2005).

- Question 2b. Long-Distance Dispersal Potential Within North Carolina –

The North Carolina model examines the likelihood for long-distance natural dispersal (> 1 km) and considers whether the species exhibits examples of long-distance dispersal mechanisms (e.g., seed disseminated by wind) or has been known to be distributed long distances via animals and abiotic mechanisms. Natural long-distance dispersal potential is evaluated by many existing models (Arizona: Northam et al. 2005; California: Warner et al. 2003; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004). Natural long-distance dispersal mechanisms include transport by animals or abiotic mechanisms that can move seed, roots, stems, or other propagules long distances (Arizona: Northam et al. 2005; California: Warner et al. 2003; Michigan: Schutzki et al. 2004). The likelihood of long-distance natural dispersal (> 1 km) is described in qualitative terms that include frequent, occasional, and rare (Arizona: Northam et al. 2005; California: Warner et al. 2003) or little to great potential for long-distance dispersal (Michigan: Schutzki et al. 2004).

- Question 2c. Reproductive Characteristics/Biological Character -

The North Carolina model summarizes reproductive attributes listed in other models to identify species that reproduce readily from seed in a variety of conditions, resprout after cutting, and fragment easily. Reproductive capacity is often used to identify a plant's invasive tendency, and species that have a high capacity to reproduce by seed and vegetative means are ranked highly in other models (Arizona: Northam et al. 2005; California: Warner et al. 2003; NatureServe: Morse et al. 2004; Michigan: Schutzki et al. 2004).

- Question 2d. Range of Communities in Which Species is Invading -

The North Carolina assessment identifies how many community groups or habitats are affected by a potentially invasive species. This question rates the number of primary natural

community systems a species has invaded as an indication of the diversity of ecological types affected. The natural communities of North Carolina are characterized by plant and animal composition, topography, substrate, hydrology, and soil characteristics (Shafale and Weakley 1990). A list of the natural communities associated with each system is included with the model. Species that invade a wide range of communities (≥ 3 primary systems) receive the maximum number of points, since these species are likely to have wide environmental tolerances and broader impacts than species that are limited to a narrow range of communities (Fox et al. 2005).

Other models examine the number and proportion of different ecological types invaded within a state or region (Arizona: Northam et al. 2005; California: Warner et al. 2003; NatureServe: Morse et al. 2004) or range of communities and habitats in which a species is invading (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005). Community groups are defined by state departments of natural resources or state natural area inventories.

- Question 2e. Similar Habitats Invaded Elsewhere -

The North Carolina assessment examines whether a species has invaded a number of ecological types, in similar climates, elsewhere in the United States that exist in North Carolina and are as yet not invaded by this species. Natural communities are defined by Shafale and Weakley (1990) as in question 2d regarding the range of communities in which the species is invading.

The Arizona (Northam et al. 2005), California (Warner et al. 2003), and NatureServe (Morse et al. 2004) models estimate the likelihood of further spread within a state or region by considering whether the species has invaded ecological types in other states or countries that are similar to the invaded ecological types within the state or region of the assessment. In areas of

the state where the plant has not invaded, the climate and availability of habitat types suitable for the growth of this species may also be considered (Florida: Fox et al. 2005).

- Section 3. Management Difficulty –

The third section, Management Difficulty, identifies species that are difficult to manage due to the time, money, and effort required to control infestations in natural areas. Other assessment models, including Florida (Fox et al. 2005), Indiana (IPSAWG 2005), Michigan (Schutzki et al. 2004), and NatureServe (Morse et al. 2004) include a section addressing Management Difficulty. These models include questions that specifically ask about the total costs of control per acre in the first year, the number of acres that would require management, and the number of discrete populations in managed areas. Since this information is often difficult to obtain in published state-specific resources or entirely unavailable, the North Carolina model attempts to reflect the cost of managing invaded sites by considering the availability of control methods, need for individual treatments, average distribution in invaded areas, likelihood for reestablishment, and colonization of inaccessible areas.

- *Management Difficulty* –

- Question 3a. Herbicidal Control -

The North Carolina model considers whether a species is well-controlled by herbicides labeled for use in the invaded sites and allows the evaluator to select the degree and ease of herbicidal control, rather than simply selecting true or false for this criterion. The availability of effective herbicide treatments is considered by the Michigan (Schutzki et al. 2004) and Florida models (Fox et al. 2005) as well. In the Florida model, the availability of effective herbicide treatments is one of the most highly rated factors affecting management difficulty.

- Question 3b. Nonchemical Control -

The North Carolina assessment examines whether the species is well-controlled using nonchemical control methods, such as hand pulling, mowing, disking, grazing, flame, or biological control. The Michigan model (Schutzki et al. 2004) considers the effectiveness of nonchemical control methods in the management difficulty section as well.

- Question 3c. Necessity of Individual Treatments –

The North Carolina assessment considers whether individual treatments, chemical or nonchemical, are necessary to treat individual plants and manage this species. Points are assigned when individual treatments (e.g., cut stem applications) are necessary, since this procedure increases time and labor costs, which are a measure of management difficulty.

- Question 3d. Average Distribution Pattern -

The North Carolina assessment examines the average distribution of the species and asks whether the distribution pattern is in a discrete patch formation or diffuse stands. Points are assigned for those species that are often distributed in diffuse stands, since this pattern may increase treatment time, labor costs, and management difficulty.

- Question 3e. Likelihood for Reestablishment -

This criterion estimates the likelihood for reestablishment of the species following management treatments. Other models (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004) consider the need for re-treatment or re-survey of an area due to recruitment from persistent seeds or vegetative structures, or by dispersal from outside the site, since this increases the level of management difficulty.

- Question 3f. Treatment in Inaccessible Areas -

The North Carolina assessment asks whether the species is found in inaccessible areas that cannot be reached or treated easily. The Florida (Fox et al. 2005) and NatureServe (Morse et

al. 2004) models consider colonization of the species in inaccessible areas. Species that colonize areas that cannot be reached easily by surface vehicles or cannot easily be treated by an individual carrying a backpack sprayer or hand-held tool increase management difficulty.

- *Non-Target Impacts* –

- Question 3g. Nontarget Impacts –

The North Carolina assessment examines whether the management of the species negatively impacts native species and the environment. Species that are difficult to control without significant damage to native species may be widely dispersed, attached to native species, or easily mistaken for a native plant. Non-target management impacts are highly rated, and the Florida (Fox et al. 2005), Indiana (IPSAWG, 2005), Michigan (Schutzki et al. 2004), and NatureServe (Morse et al. 2004) models estimate damage to native species.

- Section 4. Benefit and Value –

The final section of the North Carolina protocol evaluates the benefits and value of potentially invasive ornamental plants and the benefits provided by potentially invasive species, including ecosystem services, wildlife habitat, and intrinsic cultural or social value. This Value and Benefits section allows the assessment to weigh the commercial value and benefits of a species against the ecological risk of potential invasiveness. Other state assessments, including Florida (Fox et al. 2005), Indiana (IPSAWG 2005), and Michigan (Schutzki et al. 2004) identify species with some significant economic value. Since species-level production and sales information is largely unavailable, the Florida (Fox et al. 2005) and Indiana (IPSAWG 2005) models estimate economic value based on sales from chain retail stores. The sale of high income species at retail stores is suspected to translate to grower sales within the state. The Economic Value sections of the Florida (Fox et al. 2005) and Indiana (IPSAWG 2005) models identifies

whether a species has Low or High Economic Value, and numerical scores are not assigned to Economic Value criteria. In addition to economic value, the Michigan model (Schutzki et al. 2004) considers the aesthetic, erosion control, and wildlife habitat value.

In the Benefits and Value section of the North Carolina assessment, species with high benefits and value are assigned negative point values that subtract from the overall invasiveness rating and may reduce the likelihood that the NCNLA recommend the limited use or sale of a species. Since state-level and species-specific data were unavailable for North Carolina, a short online grower survey was developed for NCNLA members to provide information on plant production and general sales. By addressing the value added to the state of North Carolina and the economic impact to the nursery industry, the North Carolina assessment uniquely addresses both the benefits and environmental risks associated with the sale of potentially invasive ornamental plant species.

- Question 4a. Estimated Wholesale Value for North Carolina -

The North Carolina assessment considers the estimated wholesale value of selling potentially invasive ornamental plants as a measure of economic and commercial value in the state. Point values assigned to criteria in this section are negative and subtract from the overall invasiveness scale and likelihood of not recommending a plant for sale.

The Florida (Fox et al. 2005) and Indiana (IPSAWG 2005) models incorporate a section on economic value, and these state assessments ask whether there are more than 10-20 commercial growers of this species state-wide. Rather than assigning point values for these criteria, the Florida (Fox et al. 2005) and Indiana (IPSAWG 2005) models designate a species as High or Low Value, according to the combined responses from this section.

- Question 4b. Percentage of Wholesale Sales –

Among producers that sell the plant, the North Carolina assessment examines the percentage of total sales attributed to the species. The Indiana model (IPSAWG 2005) asks whether more than five growers in the state rely on this species as more than 10% of their production. The Michigan model (Schutzki et al. 2004) considers whether the species constitutes more than 10% of the crop produced or sold by commercial growers that produce the plant in the state.

- Question 4c. Ecosystem Services -

The North Carolina assessment subtracts points from the overall rating if the species is currently used for erosion control, storm water management, phyto-remediation, bank stabilization, windbreaks, and/or modifying microclimates. The Florida (Fox et al. 2005) and Michigan (Schutzki et al. 2004) models also consider whether a species has economic value for forage, biomass, erosion control, or remediation purposes.

- Question 4e. Wildlife Habitat -

The North Carolina assessment considers whether the plant is currently used for wildlife management (food, cover, etc.). The Michigan model (Schutzki et al. 2004) considers whether the plant benefits wildlife conservation and habitat as well.

- Question 4f. Cultural and Social Benefits -

The North Carolina model considers whether this species provides unique cultural and social benefits that provide intrinsic value in the state. The Michigan model (Schutzki et al. 2004) includes contributions to recreation and leisure activities as part of the species' economic value.

- Overall Taxon Evaluation Scores and Recommendations –

The North Carolina model uses a straightforward scoring system, based on a total of 100 points. Numerical values assigned to criteria are for ranking purposes and to separate invasive from innocuous non-native species. According to the overall score combined from the four index categories, species may be classified as invasive, moderately weedy, or minimal concern.

Species that score highly, with an overall score between 67 to 100 points, are considered invasive and may be recommended by the NCNLA for limited horticultural use in North Carolina. These species identified as invasive have relatively high ecological impact, distribution and invasive potential, and management difficulty in relation to economic value. Discontinued production and sale of these species in North Carolina should be recommended.

Moderately weedy species receive an overall score between 34 to 66 points and may be recommended for use in North Carolina with specific guidance to minimize escape or spread from cultivation. These moderately weedy species may naturalize in some areas, but have less than high ecological impact, distribution and invasive potential, and management difficulty in relation to economic value. These plants should not be grown in close proximity to natural areas that have communities similar to those where this plant has been found to naturalize or near natural areas that have sensitive or threatened plants and/or natural communities. No recommendation for discontinued production or sale is warranted at this time for moderately weedy species, but less weedy alternatives are encouraged, particularly in locations near natural areas.

Species that score between 0 to 33 points are considered to be of minimal concern and may be recommended for use in North Carolina. These noninvasive exotic species have limited ecological impact, distribution and invasive potential, and management difficulty. Low-rated

species may be locally problematic but biological/ecological traits limit their rate of invasion in natural areas.

When documented information is unavailable for a complete assessment, a species may be designated as 'Evaluated but not listed.' These species may be potentially invasive in North Carolina, but additional information is necessary for further evaluation and conclusions.

All models (Arizona: Northam et al. 2005; California: Warner et al. 2003; Florida: Fox et al. 2005; Indiana: IPSAWG, 2005; Michigan: Schutzki et al. 2004; NatureServe: Morse et al. 2004) used to develop the North Carolina assessment separate overall taxa ranking scores into primary categories that may include rankings of Very High, High, Medium, and Low, based on the combined scores from a variety of index categories. Highly rated species have severe ecological impacts and high rates of dispersal, and when management difficulty is considered, are difficult to control. Taxa with an overall ranking of Medium have substantial ecological impacts, moderate to high rates of dispersal, establishment enhanced by disturbance, and limited distribution within a community range. Low rated species have minor ecological impacts, low rates of invasion, limited distribution, and when considered, low management difficulty. Additional categories may include Alert or Red Flag, which highlight species that may be classified in High or Medium categories if additional documentation regarding the environmental consequences are suspected but not available (Arizona: Northam et al. 2005; California: Warner et al. 2003). When adequate information is missing in a species' evaluation, those taxa may be 'Evaluated but not listed' (Arizona: Northam et al. 2005; California: Warner et al. 2003).

The Index Scores and Low, Medium, High ratings produced in other assessment models may then be converted to Conclusions and Recommendations for the use of a particular species (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005). Species that score highly may be eligible

for a proposal for specified and limited use or may not be recommended for use in the state at all (Florida: Fox et al. 2005; Indiana: IPSAWG, 2005).

INTENDED OUTCOME OF THE NORTH CAROLINA ASSESSMENT PROTOCOL

The North Carolina assessment tool provides a uniform assessment to evaluate the invasiveness of ornamental plants and develop a categorized listing of invasive ornamental plant species. The classification process compiles information on impacts and benefits of each species and provides specific rankings along with citations. The assessment results are intended to allow the North Carolina Nursery and Landscape Association (NCNLA) to advise their members regarding plants that are found to be invasive. While the recommendations are advisory and non-regulatory, the assessment results may allow the NCNLA to: 1) educate their members regarding particular plants that present severe ecological impacts, 2) identify species that are potentially too invasive for sale in North Carolina, and 3) prioritize funding for the development of sterile noninvasive cultivars. The process of assessing invasiveness of ornamental plants within North Carolina may be strengthened with additional research in invasive biology as it relates to the horticultural industry. In particular, more information is needed regarding environmental impacts, including the impact on abiotic ecosystem processes and plant community structure, and distribution within natural areas.

LITERATURE CITED

- Fox, A.M., D.R. Gordon, J.A. Dusky, L. Tyson, and R.K. Stocker. 2005. IFAS Assessment of the Status of Non-Native Plants in Florida's Natural Areas. (<http://plants.ifas.ufl.edu/assessment.html>) Accessed October 1, 2007.
- Goodwin, B.J., McAllister, A.J., and L. Fahrig. 1999. Predicting invasiveness of plant species based on biological information. *Conservation Biology*. 13:422-426.
- Invasive Plant Species Assessment Working Group (IPSAWG). 2005. Indiana. (http://www.in.gov/dnr_old/invasivespecies/8_03_05_assessment.pdf) Accessed October 1, 2007.
- Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M., and F.A. Bazzaz. Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological Applications*. 10: 689-710.
- Morse, L.E., J.M. Randall, N. Benton, R. Hiebert, and S. Lu. 2004. *An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1*. NatureServe, Arlington, Virginia.
- The National Invasive Species Council (NISC). 2006. Invasive Species Definition and Clarification and Guidance White Paper. (<http://www.invasivespeciesinfo.gov/docs/council/isacdef.pdf>) Accessed October 1, 2007.
- Northam, F.E., Backer D.M., and J.A. Hall. 2005. Development of a categorized list of invasive non-native plants that threaten wildlands in Arizona. Arizona Wildlands Invasive Plant Working Group.

(<http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/DevelopmentOfACategorizedList.pdf>) Accessed: October 1, 2007.

Reichard, S.H. and P.White. 2001. Horticulture as a pathway of invasive plant introductions in the United States. *BioScience*: 51:103-113.

Schutzki, R.E., Pearsall, D., Cleveland, A., Schultz, J., Herman, K., MacKenzie, D., MacDonald, S., Wood, T., and T. Myers. 2004. Michigan Invasive Plant Assessment System. Michigan Invasive Plant Council, Newago, MI.

Shafale, Michael P., and Alan S. Weakley. Classification of the Natural Communities of North Carolina. Raleigh, NC: North Carolina Natural Heritage Program Division of Parks and Recreation NC Department of Environment, Health, and Natural Resources, 1990.

Warner, P. J., Bossard, C.C., Brooks, M.L., DiTomaso, J.M., Hall, J.A., Howald, A.M., Johnson, D.W., Randall, J.M., Roye, C.L., Ryan, M.M., and A. E. Stanton. 2003. *Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands*. California Exotic Pest Plant Council and Southwest Vegetation Management Association. (www.caleppc.org) Accessed: October 1, 2007.