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The Invasive Species Assessment Protocol: A Tool for Creating Regional and National Lists of Invasive Nonnative Plants that Negatively Impact Biodiversity

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We developed a protocol for categorizing nonnative plants according to their negative impacts on biodiversity in a large area such as a state, nation, or ecological region. Our objective was to provide a tool that makes the process of identifying, categorizing, and listing nonnative plants that cause negative impacts to biodiversity analytic, transparent, and equitable and that yields lists that are useful to researchers, land managers, regulators, consumers, and commercial interests such as the nursery industry. The protocol was designed to distinguish between species that cause high, medium, low, or insignificant negative impacts to native biodiversity within the state, region, or nation of interest. It consists of 20 multiple-choice questions grouped into four sections, which each address a major aspect of a species' total impact and when combined yield an overall "Invasive Species Impact Rank" or "I-Rank" (high, medium, low, or insignificant). The nonprofit organization NatureServe is now using this protocol to assess the estimated 3,500 nonnative vascular plant species that are established in the United States to create a national list prioritized by negative impact on biodiversity. The protocol and additional information are available on the Internet at http://www.natureserve.org/getData/plantData.jsp, and over 500 completed species assessments are available through NatureServe Explorer (http://www.natureserve.org/explorer/).

Key words: Invasive species, nonnative plants, biodiversity, impacts, ranking.

Hundreds to thousands of nonnative plant species are established and spreading outside cultivation in many states and countries (e.g., Hickman 1993; Kartesz 1999; Wagner et al. 1990; Webb et al. 1988; Wunderlin 1998). Some of these species are abundant and known or suspected to cause significant reductions in native species populations, severe alterations of native ecological communities, or significant changes in ecosystem processes and parameters (Bratton 1982; Hobbs and Mooney 1998; Gordon 1998; Randall 1993, 1996; Vitousek 1986; Wilcove et al. 2000). Within a particular nation, state, or region, however, only a relatively small proportion of the established nonnative plant species are recognized as causing, or having the potential to cause, significant damage to native biodiversity (e.g., Randall et al. 1998). In fact, many established nonnative species are uncommon, rarely colonize areas other than croplands and other heavily disturbed sites, or otherwise have little or no detectable impact on lands and waters set aside for conservation or in other habitats that support native species. Some nonnative species were reported as established in the wild only historically but have not been seen outside cultivation again for many decades or more ("casual alien plants" in the sense of Richardson et al. 2000). It is critical that we be able to determine which nonnative species are causing significant biodiversity impacts so we can prioritize the most harmful

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Interpretive Summary

The Invasive Species Assessment Protocol described in this paper can be used to categorize and list nonnative plants for a large area such as a nation, state, or region (e.g., the Great Plains) according to their overall impacts on biological diversity. It provides a transparent process for generating lists of invasive species, which should be more useful and widely accepted as objective and accurate than lists developed without any formal protocols. Lists created with this protocol will be more useful to researchers, land managers, and regulators eager for accurate information on the most troublesome invasive plants, as well as to consumers and commercial interests that use or sell plants but are willing to seek alternatives for species reliably identified as harmful. The protocol does not rank plants in numerical order but instead places them into one of four categories: species that cause high, medium, low, or insignificant negative impacts to native biodiversity within the area of interest. The protocol is freely available on the Internet at http://www.natureserve.org/getData/plantData.jsp. The nonprofit organization NatureServe is now using this protocol to assess the estimated 3,500 nonnative vascular plant species that are established in the United States to create a national list prioritized by negative impact on biological diversity. Over 500 completed species assessments are available through NatureServe Explorer (http://www.natureserve.org/explorer/).

species for prevention and management to protect native species and ecological communities (Hiebert and Klick 1988).

To some authors, only plant species that are nonnative, spread into natural or seminatural habitats, and cause significant negative impacts to biodiversity meet the definition of ‘‘invasive'' plants (Cronk and Fuller 1995; White et al. 1993). Others use the term ‘‘invasive'' plants more broadly to cover all nonnative species with adverse effects on the economy, human health, and/or the environment (e.g., usage in U.S. National Invasive Species Plan, National Invasive Species Council 2001), and still others use ‘‘invasive'' for all nonnative species that establish and spread beyond cultivation (Rejmánek et al. 2002; Ricciardi and Cohen 2007; Richardson et al. 2000). In order to avoid confusion between these different definitions, we generally use the more precise (if longer) phrase ‘‘nonnative plants that negatively impact biodiversity'' in this paper when referring to this subset of species. A full set of definitions used in this paper is contained in the Appendix.

Several years ago, The Nature Conservancy identified the need for an analytically developed, scientifically based United States national list of nonnative plants that negatively impact native biodiversity. Despite the increasing interest in invasive species and their environmental and economic impacts, no such list existed. The U.S. Department of Agriculture and many state and county agriculture agencies maintain official noxious weed lists but the majority include only species that negatively affect agricultural production or have other negative impacts on human health or the economy. For this reason, a variety of government agencies and private conservation organizations have created separate lists of the nonnative plant species regarded as significant threats to biodiversity conservation. For example, lists have been developed for several states and regions of the United States (Anonymous 1993; Bowen and Shea 1996; Cal-IPC 2006; Connecticut Invasive Plant Council 2004; Florida Exotic Pest Plant Council Plant List Committee 2005; Gould and Stuckey 1992; Heffernan et al. 2001; Mehrhoff et al. 2003; Reichard et al. 1997; Schwegman 1994; Virginia Department of Conservation and Recreation and Virginia Native Plant Society 2003), Australia (Australian National Parks and Wildlife Service 1991; Carr et al. 1992; Humphries et al. 1991; Western Australia Department of Agriculture 2005; J. Thorp, unpublished data) and southern Africa (Henderson 1995). There are also national lists for Australia (Australian National Parks and Wildlife Service 1991; Swarbrick and Skarratt 1992; J. Thorp, unpublished data), Canada (White et al. 1993), New Zealand (Owen 1996), and South Africa (Robertson et al. 2003).

Many of these lists divide the species into categories that distinguish those that are most harmful from those with more moderate and low impacts. Such categorized lists draw attention to particularly harmful species, help to determine priorities for research and regional control programs, and provide information for the development of appropriate regulations and voluntary restrictions on intentional plantings of listed species. They are also useful information sources for people in nearby states or in more distant areas with similar climates who want to identify species with a high likelihood of spreading into and becoming troublesome in their area.

Unfortunately, for many of the existing lists, there is no documentation of the factors used to determine which species were included and how they were placed into different categories. Some lists include explanatory notes stating that they were based on the opinion of recognized experts in botany, plant ecology, or land management, but they provide little or no detail on the factors deemed most important. A few lists also note which species were considered but not listed because they were deemed to have insignificant impacts. Careful examination of these different lists and consultation with the people who created them reveals that the factors used as the basis for making decisions are similar in most cases but that there are some significant differences. This makes comparisons between lists difficult. It also means that compilations of lists, including those that had constituted the only attempts to create a single national listing of plants known to cause problems within natural areas in the United States (Alien Plant Working Group 2005), will yield inconsistent and only partially satisfactory results. Furthermore, apparent inconsistencies and poor documentation of the criteria used have raised concerns that personal prejudices and other ad hoc considerations may have played a role in determining which species are included in some lists.

We believe that a clearly explained, consistent protocol would make the listing process more analytic, transparent, equitable, and authoritative. National, state, and regional lists produced with such a protocol would be more useful to researchers, regulators, consumers, and commercial interests such as the nursery industry as well as for agencies, organizations, and individuals engaged in protecting biodiversity. Accordingly, we first assembled existing protocols for listing invasive plants and then evaluated them for intended use, intended scale of application, and the specific factors they evaluated. Our objective was to find, or if necessary create, a protocol that would categorize nonnative plants within a large area (such as the 48 contiguous United States) based on their total negative impacts to biodiversity. Such negative impacts may include reducing native species populations, damaging ecological communities, and/or altering ecosystem processes or parameters. In addition, we sought a system that would use types of information that are available for most plant species and would distinguish between species that have high, medium, low or insignificant negative impacts on biodiversity. Our ultimate goal was to develop a national list for the United States. We identified and evaluated 18 existing systems but found none that met all of our specifications and therefore we developed a protocol that does. This paper describes the protocol, which is available online at http://www.natureserve.org/getData/plantData.jsp and in hard-copy form (Morse et al. 2004). NatureServe is now using the protocol to create a U.S. national list of nonnative vascular plant species that threaten biodiversity and has completed assessments of over 500 species (assessments for each of these species available through NatureServe Explorer http://www.natureserve.org/explorer/). We offer the protocol here in the belief that it could also be useful for creating other national, state, provincial, and regional lists. We also believe that subjecting this protocol to greater scrutiny may help lead to the development of an improved, more objective and accurate version, particularly as detailed information on the impacts, distribution, and rates of spread of many more invasive species based on experiments and field observations becomes available.

Materials and Methods

Review of Existing Systems for Categorizing Nonnative Plant Species. Table 1 compares the 18 systems we evaluated plus the protocol we created. Six of the existing systems were intended to predict whether nonnative plant species that had not yet been introduced were likely to become established and spread (see first six rows in Table 1). They rely primarily on characteristics deemed best for distinguishing which species are most likely to become established and spread if introduced, but have little or no capability for further distinguishing those species most likely to negatively impact native biodiversity. These systems were intended for use in evaluating species prior to their intentional introduction, in order to screen out those identified as most likely to establish and spread.

The other 12 systems we evaluated had been designed to prioritize nonnative species that are already established. Two were specifically intended to prioritize a series of invaded sites for management (Timmins and Owen 2001; Wainger and King 2001). Another was designed to prioritize species at the management-site scale, which typically ranges between tens and tens of thousands of hectares (Hiebert and Stubbendieck 1993, 2007; also see APRS 2000, 2001; Hiebert 1997). Prioritization at the management-site scale necessarily includes heavy emphasis on the relative conservation value of different portions of the site and on the likelihood of successfully controlling the species with available technology and funding. Some systems also assign particular importance to identifying and preventing the spread of species that are present nearby, but which have not yet invaded the site or have just begun to do so.

The other nine systems were designed to identify and categorize harmful invasive nonnative plants at the state or national scale. Eight of these include characteristics that either have no bearing on a species' impacts to native biodiversity, or fail to evaluate important characteristics that do. For example, the Australian system (Thorp and Lynch 2000) is designed to include both agricultural and environmental weeds. The University of Florida Institute of Food and Agricultural Sciences system explicitly considers the commercial value of a species (Fox et al. 2000, 2001), as does the South African system (Robertson et al. 2003). These considerations are entirely appropriate for lists developed by extension services or regulatory agencies to address the needs of multiple constituencies. Although these systems use many factors appropriate for our needs, they did not meet all of our demands for a protocol that evaluates species one at a time and yields lists of all species deemed to have significant harmful impacts on native biodiversity, regardless of whether they are detrimental or valuable to agricultural, horticultural, other economic values, or human health.

The one other system that comes closest to our requirements is the California Invasive Plant Council/Southwest Vegetation Management Association System (Cal-IPC-SWVMA System; Warner et al. 2003). This was crafted using an earlier version of our protocol (Randall et al. 2001) as a starting point, then modifying it in a variety of ways such as adopting a different scoring system and eliminating the section evaluating the difficulty of control. This system has been used by separate groups in Arizona and California to create state lists (AZ-WIPWG 2005; Cal-IPC 2006).

The recently released National Post-Border Weed Risk Management Protocol, published jointly by Standards Australia and Standards New Zealand (Virtue et al. 2006) is neither a predictive nor a prioritization system but instead provides an overall framework and guidelines for using prioritization systems and their outputs to develop and implement weed management priorities. It was specifically designed to accommodate the use of a variety of prioritization systems (weed risk assessments in their terminology) depending on the precise goals of the users. It could be used with our protocol or with any of the other 12 systems designed to prioritize established nonnative species which are listed in Table 1.

Development of the Invasive Species Assessment Protocol. Because none of the systems we evaluated fully met our needs, we concluded that we should create a new system. We named this system the Invasive Species Assessment Protocol. We began with an acknowledgment that a nonnative species' total adverse effect on biodiversity depends on a variety of interacting factors. Primary among these are (1) the intensity of the species' ecological impacts per unit area, multiplied by (2) the extent of its range in the region of interest, as pointed out by Parker et al. (1999). Also important is (3) the species' rate of spread, as an indication of its potential range size 5 to 50 yr in the future (a period bracketing the planning horizons used by a variety of conservation and land management agencies and organizations) and (4) the ease or difficulty of managing established populations of the species.

With this framework as a basis, we developed a system for evaluating one species at a time using information that is available for many species. We created four sets of multiple-choice questions designed to evaluate the four factors that contribute to a species' overall total adverse effect on biodiversity: ecological impact, range, rate of spread, and difficulty of management. Every answer to each question was assigned a point value and a scoring system was created which tallies points for each of the four sections separately to yield four categorical subranks of high, medium, low, or insignificant. The scoring system then assigns points to each subrank and tallies these points to yield an overall "Invasive Species Impact Rank" or "I-Rank" for short.

An early version of our protocol was briefly described in a 1996 abstract (Randall et al. 1996) and an intermediate version was described and presented in full by Randall et al. (2001). The protocol has gone through several subsequent rounds of testing, review, and revision, resulting in the version presented here. The most extensive test was conducted by having over 100 people with expertise in the biology and management of one or more of 30 test species use the early version of the protocol to evaluate and categorize the species they knew best. We used the results of this test and comments of the volunteer evaluators to assign relative weights to each of the four sections and to each question within each section. The evaluations and comments submitted by these experts supported a scoring system that assigns 50% of the possible points to the species' ecological impacts, another 25% to its current distribution, 15% to its rate of spread, and 10% to difficulty of management. Comments made by these experts were also used to refine and clarify several of the protocol's questions. Further refinements in the relative values of the different questions in each section resulted from comments and criticisms offered and the general consensus reached at a 2-d workshop in March 2002 attended by a dozen individuals familiar with invasive plants from government agencies, universities, conservation organizations, and industry.

Below, we provide a more detailed description of the protocol including information on the questions and the scoring system. We also offer suggestions for implementing this methodology. Definitions of important terms used in the protocol are included in the Appendix. The protocol and instructions for using it are available on NatureServe's Internet site (http://www.natureserve.org/getData/plantData.jsp). We anticipate modifying and improving the protocol based on users' experience and as more information on the impacts, distribution, and rates of spread of invasive plant species based on experiments and quantitative field observations becomes available. Once the NatureServe Version 1.0 U.S. list is completed we also anticipate comparing and contrasting both the protocol and that list with the Cal-IPC-SWVMA System (Warner et al. 2003) and the state lists for California and Arizona created with it by the California Invasive Plant Council and Southwest Vegetation Management Association, respectively.

Results and Discussion

Detailed Description of the Invasive Species Assessment Protocol. The Invasive Species Assessment Protocol is designed for use within large, clearly specified areas such as nations, states, or ecoregions (Bailey 1995; Groves 2003, chapter 2; Olson et al. 2001) and to evaluate one species (or infraspecific taxon, as appropriate) at a time. It includes two preliminary screening questions and 20 questions that make up body of the protocol (Table 2). The protocol score-sheet provides instructions for assigning points to each answer and for tallying the points to determine a subrank for each of the four sections as well as an overall Invasive Species Impact Rank (informally called

Table 1. Predictive and prioritization systems for invasive nonnative plants. Citation in bold represents this paper.

Name of system	Purpose of system	Intended scale of application	Ability to invade/persist in natural systems	Impact on ecosystem processes and functions	Impact on community structure/ composition	Reproductive capability and competitive ability
Predictive systems						
USDA APHIS 2004	Listing as noxious weed	National	No	Yes	Yes	Yes
Australian weed risk assessment (Pheloung et al. 1999)	Accept or reject for importation/ introduction	National	Yes	Yes	Yes	Yes
USDA NRCS, 2000	Accept or reject for use in plantings	National, regional	Yes	Yes	Yes	Yes
Reichard and Hamilton 1997	Accept or reject for importation/ introduction	National	Yes	No	No	Yes
Rejmánek and Richardson 1996	Predict risk of woody plant invasions	National, landscape	No	No	No	Yes
Williams et al. 2001 (New Zealand)	Accept or reject for importation/ introduction	National	Yes	Yes	Yes	Yes
Prioritization systems						
Champion and Clayton 2001 (aquatic weeds in New Zealand)	Rank current and potential weeds by category (aquatic)	National	Yes	Yes	Yes	Yes
Fox et al. 2001 (Florida)	Categorize nonnative plants	State, zones	Yes	Yes	Yes	Yes
Heffernan et al. 2001 (Virginia)	Prioritize state list of invasives	State	Yes	Yes	Yes	Yes
Hiebert and Stubbendieck 1993, 2007 (NPS)	Rank by threat to site	Local, site	Yes	Yes	Yes	Yes
Randall et al. 2008 (Invasive Species Assessment Protocol)	**Rank nonnative plants by impacts to biodiversity; US list**	**National state, regional**	**Yes**	**Yes**	**Yes**	**Yes**
Orr et al. 1993 Also see: Orr (2003)	Rank by need for mitigation efforts	National, regional	Yes	Yes	Yes	Yes
Robertson et al. 2003 (South Africa)	Determine priorities for national management and research	National	Not explicit, Assumed?	Not explicit	Yes	No
Thorp and Lynch 2000	Determine priorities for national management	National	Yes	Yes	Yes	Yes
Timmins and Owen 2001 (New Zealand)	Weed-led and/or site-led control (identify high priority weeds and sites)	National, regional, landscape site	Yes	No	Yes	Yes
Virtue et al. 2001 (Australia)	Rank all weeds (agro, forestry, environment) for national significance	National	Yes	Yes	Yes	Yes
Wainger and King 2001	Value-based rank of sites, cost/ benefit of various responses	Local, site	Yes	Yes	Yes	No
Warner et al. 2003 (CalEPPC/SWVMA)	Categorize invasive nonnative plants that threaten wildlands	State	Yes	Yes	Yes	Yes
Weiss 1999 (Australia)	Categorize existing and emerging weeds by biological characteristics	State	Yes	No	No	Yes

Table 1. Extended.

Name of system	Dispersal ability (natural, human)	Current distribution/ range: site, county, state, nation, global (saturation)	Potential distribution: site, county, state, nation, global	Abundance (density)	History (date of introduction, native range, impacts in other areas, irreversibility)	Rate of spread and current trend	Feasibility or cost of control	Impacts on croplands, other domesticated vegetation	Economic value (e.g., as forage crop, horticulture)
Predictive systems									
USDA APHIS 2004	Yes	Yes	Yes	No	Yes	No	No	Yes	No
Australian weed risk assessment (Pheloung et al. 1999)	Yes	Yes	Yes	No	No	No	No	Yes	No
USDA NRCS, 2000	Yes	No	No	No	No	No	Yes	Yes	No
Reichard and Hamilton 1997	No	No	No	No	Yes	No	No	No	No
Rejmánek and Richardson 1996	Yes	No	No	No	No	No	No	No	No
Williams et al. 2001 (New Zealand)	Yes	No	No	No	Yes	No	No	No	Yes
Prioritization systems									
Champion and Clayton 2001 (aquatic weeds in New Zealand)	Yes	No	Yes	No	Yes	No	Yes	No	No
Fox et al. 2001 (Florida)	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Heffernan et al. 2001 (Virginia)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
Hiebert and Stubbendieck 1993, 2007 (NPS)	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No
Randall et al. 2008 (Invasive Species Assessment Protocol)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**
Orr et al. 1993 Also see: Orr (2003)	Yes	Yes	No	No	Yes	No	No	Yes	No
Robertson et al 2003 (South Africa)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
Thorp and Lynch 2000	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Timmins and Owen 2001 (New Zealand)	Yes	No	No	No	No	Yes	Yes	No	No
Virtue et al. 2001 (Australia)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Wainger and King 2001	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Warner et al. 2003 (CalEPPC/ SWVMA)	Yes	Yes	Yes	No	Yes	Yes	No	No	No
Weiss 1999 (Australia)	Yes	No	No	No	No	No	No	No	No

Table 2. Summary of Invasive Species Assessment Protocol questions.[a]

Section I.	Ecological impact (five questions, 50% of I-Rank score)
1.	Impact on ecosystem processes and system-wide parameters *(33 points maximum)*
2.	Impact on ecological community structure *(18 points maximum)*
3.	Impact on ecological community composition *(18 points maximum)*
4.	Impact on individual native plant or animal species *(9 points maximum)*
5.	Conservation significance of communities and native species threatened *(24 points max)*
Section II.	Current distribution and abundance (four questions; 25% of I-Rank score)
6.	Current range size in region *(15 points maximum)*
7.	Proportion of current range where it negatively impacts biodiversity *(15 points max)*
8.	Proportion of region's biogeographic units invaded *(3 points maximum)*
9.	Diversity of habitats or ecological systems invaded in region *(3 points maximum)*
Section III.	Trends in distribution and abundance (seven questions; 15% of I-Rank score)
10.	Current trend in total range within the region *(18 points maximum)*
11.	Proportion of potential range currently occupied *(3 points maximum)*
12.	Long-distance dispersal potential within region *(9 points maximum)*
13.	Local range expansion or change in abundance *(18 points maximum)*
14.	Inherent ability to invade conservation areas and other native spp. habitats *(6 points)*
15.	Similar habitats invaded elsewhere *(9 points maximum)*
16.	Reproductive characteristics *(9 points maximum)*
Section IV.	Management difficulty (four questions 10% of I-Rank score)
17.	General management difficulty *(18 points maximum)*
18.	Minimum time commitment *(15 points maximum)*
19.	Impacts of management on native species *(15 points maximum)*
20.	Accessibility of invaded areas *(3 points maximum)*

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

an "I-Rank") for each species. We expect that some users will find certain subranks to be at least as informative and useful as the I-Rank. I-Ranks range from High to Insignificant as follows:

High: Species is a severe threat to native species and ecological communities.

Medium: Species is moderate threat to native species and ecological communities.

Low: Species is a significant but relatively low threat to native species and ecological communities.

Insignificant: Species is an insignificant threat to native species and ecological communities.

Two screening questions are used to first determine whether the species under consideration (1) is a non-native established outside cultivation somewhere in the area under consideration and (2) spreads into conservation areas or other native species habitats. The protocol is not applicable to species that are not established outside cultivation. Species that are established outside cultivation, but which do not spread into conservation areas or other sites that support native species, are assigned an I-Rank of Insignificant and need not be evaluated further.

The 20 multiple-choice questions in the body of the protocol are designed to distinguish between species that cause high, medium, low, or insignificant negative impacts to native species and other components of native biodiversity within the area under consideration (Table 2). There are five possible answers for each of the 20 questions (A, B, C, D, or unknown) which are entered into the data form and score sheet (see http://www.natureserve.org/library/dataformScoresheet.xls). Letter ranges (such as AB or BD) may be entered if evaluators do not have enough information to give a more precise response.

The 20 questions are grouped into four sections representing four major factors that contribute to a species' total impact: ecological impact (five questions), current distribution and abundance (four questions), trends in distribution and abundance (seven questions), and management difficulty (four questions). Parker et al. (1999) state that the impact of a nonnative species is the product of its per capita impact, its mean abundance in the area it occupies, and its range. Our first two sections equate roughly with this formulation. Section I equates to the per capita impact of the nonnative species on native biodiversity and Section II equates to the species range times its mean abundance in areas where it is established. Sections III and IV cover factors not explicitly addressed by the Parker et al. formula but which are important in determining the overall level of damage a species may cause if it continues to spread and resists control

The Four Sections. Section I, Ecological (five questions), is based on the premise that species with the largest negative ecological impacts are the most severe problems, particularly if they harm rare or keystone species, communities, or ecosystem processes. The questions in this section evaluate the species' overall effects on native biodiversity on a rough per-unit area basis. These effects should be assessed for areas with abundances of the species (cover, density, frequency, etc.) that are commonly seen in the field. The questions are arranged in hierarchical order, with the first question addressing the most wide-ranging and severe types of impacts, those on ecosystem processes and parameters. The next question addresses impacts on the communities that make up ecosystems, and so on. In general, species that have strong impacts on ecosystem processes or parameters will have strong impacts on all lower scales, including community composition and structure and native species populations.

Section II, Current Distribution and Abundance (four questions), is based on the premise that the greater the species' range, abundance, and variety of habitats it can invade, the greater the overall damage it can cause. Some nonnative species are widespread in a given region but are known or suspected of causing harm to biodiversity in only part of that region. For example, tamarisks (*Tamarix* spp.) are severe riparian and wetland pests from California to western Texas and north at least to Kansas and Montana. Although they escape occasionally in the eastern United States, they have not been reported as a problem east of the Mississippi, and they are not a problem in upland habitats anywhere in their invaded range. Therefore, one question in this section is designed to determine the rough proportion of the range occupied where the species under evaluation has significant impacts.

Section III, Trends in Distribution and Abundance (seven questions), is based on the premise that a species with a high potential for further spread has the potential to cause greater damage, especially if it is deemed likely to spread to and become established in distant portions of the area under consideration. The questions in this section are therefore designed to assess the likelihood that the species under evaluation will spread to new areas and/or increase in abundance in areas it already occupies, and how quickly it is likely to do so if not controlled. Some estimates of the species' current range, its ultimate potential range, and its speed of spread are needed to answer these questions.

Section IV, Management Difficulty (four questions), is based on the premise that species that are more difficult to manage (control or prevent from spreading) are less likely to be controlled and therefore more likely to continue causing damage. The questions in this section assess the ease of control, the accessibility of invaded sites, and the likelihood that known control measures will cause collateral damage to native species.

Calculation of Subranks and I-Rank. We designed the Invasive Species Assessment Protocol recognizing that a nonnative plant species can impact native biodiversity in a variety of ways and that some forms of impact may be mutually exclusive. For example, a species that already occupies the entire area of interest and all appropriate habitats within it (resulting in a Section II subrank of High) can not continue to expand its range in that area (resulting in a Section III subrank of Low or Insignficant). We also recognized that it may not be possible for evaluators to answer all questions precisely, and that as a result it may be necessary to reply ''unknown'' or with a range of values (e.g., AB) to some of the questions.

The responses to each question are assigned point values. The point values are in the proportion 3 : 2 : 1 : 0, for replies A, B, C, and D, respectively, with greater values reflecting greater impacts. The various questions in each section are weighted differently to reflect their relative contributions to the subrank. For example, species that significantly alter ecosystem processes will have profound impacts on biodiversity (Section I). As a result, question 1, which addresses this, is weighted more heavily than any other question in Section I

The maximum possible point total for each section is divided into four equal intervals representing subranks of High, Medium, Low, and Insignificant (break points between the intervals are rounded to integers where necessary). When a species is evaluated, the points for each answer in a section are tallied to yield a total which is used to determine the corresponding subrank. In situations where one or more questions are answered with a letter range (e.g., AB) or with ''unknown'' (effectively the range A to D), the score sheet can be used to calculate minimum and maximum possible scores for the section. This is done by tallying the lowest and highest possible point values for each answer separately. The maximum and minimum scores may both fall in a single subrank score interval and therefore yield a one-letter (precise) subrank (e.g., A), or they may fall into different intervals and yield a subrank range (e.g., AB). If the maximum and minimum scores yield a subrank range of A to D, the subrank is listed as ''unknown.''

For some users, the four subranks, or certain combinations of subranks, may be at least as informative as a species' overall I-Rank. For example, if a species is assigned a high or medium subrank for ecological impacts (section I), a low or insignificant subrank for current range (section II), and

Table 3. Invasive Species Impact Rank (I-Rank) point calculation.

Section	Subrank values				Points possible
	High	Medium	Low	Insignificant	
I. Ecological impact	50	33	17	0	0–50
II. Current distribution and abundance	25	17	8	0	0–25
III. Trend in distribution and abundance	15	10	5	0	0–15
IV. Management difficulty	10	7	3	0	0–10

high subrank for trends in distribution and abundance (section III), it could be designated as an "alert" or "early-warning" species. This "alert" designation would indicate it has high potential to spread and cause more widespread impacts in the future and is thus important to target for prevention and early detection efforts.

The four subranks are weighted and these weighted scores are summed to determine the overall I-Rank (Table 3 and 4). The Ecological Impact subrank is given the greatest "weight," accounting for 50% of the possible points. This means that, generally speaking, species with significant impacts on ecosystem processes, native species, and ecological communities will generally be assigned a High or Medium I-Rank, even if they are not particularly widespread and/or are relatively easy to control. Other factors which push a species' I-Rank upward are (1) wide distribution and high abundance where present (Section II); (2) ability to disperse to new areas, particularly relatively undisturbed ecological communities (Section III); and (3) difficulty of control (Section IV). On the other hand, a species with undetectable or negligible impact on ecosystem processes, native species, and ecological communities will generally be assigned an I-Rank of Low or Insignificant, regardless of its scores for other sections. Other factors that can push a species' I-Rank downward are lack of potential to spread beyond a small existing range, stable or decreasing abundance within the current range, and ease of control.

Using the Protocol. From our experience to date, we strongly recommend that species evaluations and rankings be conducted by small teams of biologists familiar with the protocol, the types of information needed to answer each of the questions, and the pertinent literature, Internet resources, and expertise for the area of interest. This will yield more reliable and consistent results than will having the evaluations conducted by a large number of contributors, even if each contributor is highly knowledgeable about the species he or she evaluates. A small group of trained evaluators can more consistently and efficiently complete the data forms and score sheets, using readily available reference materials as well as interviews with others personally familiar with the species and its distribution, impacts, and management requirements. They can also ensure that the available information is used for the appropriate questions.

Table 4. I-Rank Point Ranges.

I-Rank	I-Rank intervals
High	76–100
Medium	51–75
Low	26–50
Insignificant	0–25

The two initial screening questions should always be considered before effort is invested in further evaluating a species. Not all questions must be answered precisely to evaluate a species. Often an exact rank can be obtained even if some questions (especially those with lower weight) are left unaddressed. More approximate ranks (such as High/Medium or Low/Insignificant) can be obtained with less complete data, and additional research later may yield enough information to clarify the answers and narrow the I-Rank if necessary.

The geographical bounds of the area of interest must be clearly stated when using this protocol, because several of the questions address the distribution, abundance, or impacts of the species within this area. In addition, an appropriate system of classifying the biogeographic regions within the area of interest (e.g., ecoregions, biotic communities, or watersheds) must be selected in order to answer two questions in Section II. For example, NatureServe used ecoregions defined by Bailey (1995) and the Arizona Wildlands Invasive Plant Working Group used biotic communities identified by Brown (1994) and Brown et al. (1998) (see http://www.sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/2B_AboutList.asp). Where no such system is readily available one may be developed from published plant community descriptions, as the California Invasive Plant Council did for its list (see http://www.cal-ipc.org/ip/inventory/pdf/Inventory2006.pdf, Appendix 3, pp. 33–34).

This protocol has several limitations. It is not intended for use in prediction and risk analyses to identify likely invaders among species that have been proposed for importation but are not yet present in the area. It is also not intended for use in developing management priorities for a specific conservation area where impacts on specific populations of rare native species or community types would have to be considered. Nor is it useful for assessing priorities among invasive species for agricultural systems, ranchlands, production forests, or horticultural settings such as yards and urban parks because it does not assess impacts on these systems. Some of the criteria included in the protocol overlap with those needed for these other objectives, but each one of these tasks requires a specific and distinctive set of criteria (see Panetta et al. 2001). Fortunately, other people have crafted systems for use in making predictive risk assessments (e.g., Biosecurity Australia 2003; Pheloung 1995; Pheloung et al. 1999; Reichard 2001; Reichard and Hamilton 1997; Rejmánek 1996) and for prioritizing nonnative species for management in specific conservation areas (e.g., APRS 2001; Hiebert and Stubbendieck 1993, 2007).

NatureServe is now using the protocol to create a categorized U.S. national list of nonnative invasive plant species that negatively impact biodiversity and it has already completed over 500 evaluations (see http://www.natureserve.org/explorer/). This initial group of species was drawn primarily from the list of invasive species compiled by the Alien Plant Working Group (2005; J. Swearingen, unpublished data) and so were suspected to have significant negative impacts on biodiversity in the United States. They were therefore probably more likely to be assigned ranks of High or Moderate than was a random sampling of nonnative U.S. species. It is not a surprise, however, that some were assigned ranks of Low or Insignificant because some species that spread into conservation areas and are initially suspected of being "invasive" turn out to have minor or insignificant impacts on biodiversity when evaluated using more analytic criteria. NatureServe's ultimate aim is to evaluate all nonnative vascular plant species established outside cultivation in the United States to create a full, categorized national U.S. list, perhaps divided into separately developed lists for the contiguous states, Alaska, and Hawaii.

Our experience to date suggests that much of the information necessary to complete this assessment is readily available for most species. Reliable data on impacts can be difficult to find or even unavailable for some species, although it is readily available for well-studied species such as cheat grass (*Bromus tectorum*) in the Intermountain West (e.g., Belnap and Phillips 2001; Evans et al. 2001; Melgoza et al. 1990; Whisenant 1990) or Amur honeysuckle (*Lonicera maackii*) in the eastern United States (e.g., Gould and Gorchov 2000; Hartman and McCarthy 2007; Luken and Goessling 1994; Luken and Mattimiro 1991; Schmidt and Whelan 1999). Data on an invader's effects at different levels of abundance, as presented in Standish et al. (2001) for *Tradescantia fluminensis* in New Zealand forests, is rare even for most well-studied species, however, as is data on changes in impacts over periods of many years or decades (Strayer et al. 2006). Fortunately, increasing numbers of experimental and observational studies of invasive plant species impacts on native species, communities, and ecosystems have been published in recent years and we anticipate that this trend will continue. We also found that published quantitative information on trends in distribution may be unavailable for some species although this too is readily available for most well-studied species such as yellow starthistle (*Centaurea solstitialis*; Gerlach 1997; Maddox et al. 1985; Pitcairn et al. 1998) and Amur honeysuckle (Deering and Vankat 1999; Hutchinson and Vankat 1998). However, for the large majority of other species we have been able to find qualitative information on trend in distribution in a variety of publications including floras, books, and articles on invasive plant biology and control and websites with data on invasive plant distribution such as the Invasive Plant Atlas of New England (http://nbii-nin.ciesin.columbia.edu/ipane/) and the Invaders Database (http://invader.dbs.umt.edu/) as well as quantitative data for a few more species in dissertations, government reports, and unpublished studies. We view this protocol as a version 1.0 and anticipate that as more people use and scrutinize it and as better quantitative information becomes available on the trends in distribution and impacts on biodiversity for more and more invasive species, it will be possible to develop more accurate and objective versions.

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APPENDIX

Definitions of important terms used in the Invasive Species Assessment Protocol and this paper. The Invasive Species Assessment Protocol was developed for use with the following definitions of key terms, consistent with the authors' usage elsewhere (Morse et al. 1999). These definitions were drawn from longstanding usage of many botanists, biogeographers, conservationists, and weed scientists. For further discussion of these and other definitions, see Kartesz (1999), Randall (1997), Richardson et al. (2000), and Swearingen et al. (2002).

Biodiversity may be defined as the variety of life on earth (Wilson 1988), but is often considered as the variety of naturally occurring life in a specified region of interest. This variety, at any scale, has several components: (1) genetic diversity, or variations in genetic structure among individuals of a species or population; (2) species diversity, or the variety of species (and infraspecific taxa) in a given area (from local to global); (3) higher taxonomic diversity, or the variety of higher taxonomic levels (e.g., families or orders) in a given area; (4) community diversity, or the variety of identifiable groups of species that occupy and interact in the same habitats; and (5) ecosystem diversity, or the variety of ecological units composed of biological communities interacting with the physical environment. See Wilson (1992), Huston (1994), and Redford (1994) for further discussion.

Conservation areas are lands and waters set aside specifically to protect and preserve undomesticated organisms, biological communities, and/or ecosystems.

Ecological communities are assemblages of species that co-occur in a defined area at certain times and that have the potential to interact with other assemblages of species in adjacent areas (Grossman et al. 1998).

Generalized range is the entire area within a line linking the most remote outlier sites (if any) occupied by the species.

Nonnative plants that negatively impact biodiversity are plants in a specified region that (1) are present but not native there, (2) maintain themselves in conservation areas or other native species habitats, and (3) negatively affect the native species and other natural biodiversity within the region, generally by killing, displacing, suppressing the reproduction of, or hybridizing with native species, or altering ecological communities or ecosystem processes. Similar terms include *harmful invasive plants* and *environmental weeds*.

Native plant species are those present in part or all of a specified region without direct or indirect human intervention, growing within their native range and natural dispersal potential. Other terms for native species include *indigenous* and *aboriginal*.

Native species habitats include not only conservation areas but also a wide variety of other places supporting viable or otherwise long-persisting occurrences of native plants, animals, fungi, or other species. Note that vegetation remnants within otherwise developed areas may be critical habitats for various native species, particularly those with restricted ranges.

Nonnative plant species are those present in a specified region only as a direct or indirect result of human activity. Other terms that are often used as synonyms for nonnative include *alien*, *exotic*, *introduced*, *adventive*, *nonindigenous*, and *nonaboriginal*. Nonnative species maintaining themselves outside of cultivation or other human care may be considered *naturalized*.