# An Invasive Plant Watch List for the National Capital Regional National Parks (USA)

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CONSERVATION ISSUES

# An Invasive Plant Watch List for the National Capital Regional National Parks (USA)

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**ABSTRACT**: Early detection and rapid response (EDRR) are critical tools for managing invasive plants. A watch list made up of high-priority early detection species that are not yet known to occur in the target area is an important EDRR tool. To make a watch list I used the EDDMapS database of plant occurrences to identify nonnative plants reported within 150 miles of the District of Columbia. I sorted the list to include only species not reported by park staff to be invasive in park natural areas. The resulting 97 candidate species were prioritized using NatureServe's Invasive Species Assessment Protocol (ISAP) to produce an Invasive Species Impact Rank (I-Rank). The ISAP includes questions in four categories (Ecological Impact, Current Distribution and Abundance, Trend in Distribution and Abundance, and Management Difficulty). Each category contributes to an overall I-Rank. The 20 species with the highest I-Rank became the basis for a priority watch list. The watch list will be used to guide presence/absence data collection and treat all identified populations on park land. Removing these populations will protect natural areas and reduce management costs in future years.

*Index terms:* biological invasions, risk assessment, watch list

## INTRODUCTION

Ecological impacts of invasive plants can include inhibiting native plants (Pratti and Bossdorf 2003; Greer at al. 2014; Brouwer et al. 2015), creating reproductive sinks (Schmidt and Whelan 1999; Borgmann and Rodewald 2004; Keeler and Chew 2008), changing soil conditions (Reinhart and Callaway 2006; Rout et al. 2013), and reducing the pollination of native plants (Brown et al. 2002; Tscheulin and Petanidou 2013; Spellman et al. 2015). Because resources are limited, species targeted for control must be prioritized (Fox and Gordon 2004; Krug et al. 2010). Prioritization schemes can identify species for treatment (e.g., Hiebert and Stubbendieck 1993; Nel et al. 2004; DPI 2008; Ou et al. 2008; Brunel et al. 2010; Essl et al. 2011), sites for protection (e.g., Goodall and Naudé 1998; Dawson et al. 2014), populations for treatment (e.g., Frey et al. 2015), or through a combination of species and site prioritization (Downey et al. 2010; Williams et al. 2014). The work described here involves prioritizing species for treatment. Species prioritization protocols have been developed by government agencies (e.g., Self 1986, cited in Hiebert and Stubbendieck 1993; Heffernan et al. 2001; Gross and Olin 2011; Jordan et al. 2012) and nongovernmental organizations (e.g., Washington Invasive Species Council, n.d.; Fox et al. 2009; Cal-IPC 2012) for at least 30 years.

In the early 2000s, the National Park Service (NPS) collaborated with NatureServe to create the Invasive Species Assessment Protocol (ISAP; Morse et al. 2004; Randall et al. 2008). NatureServe created the ISAP to build upon the organization's assessments of native species and to assess the impact of nonnative species on native biodiversity (Randall et al. 2008). The ISAP was designed to be used "in a large geographical area such as a nation, state, province, or ecological region" (Morse et al. 2004). The ISAP results in an Invasive Species Impact Rank (I-Rank). NatureServe used the ISAP to rank 538 plant species for the United States (NatureServe 2014). In addition, the ISAP has been used in its published form or in a modified form to rank at least 183 species in New York State (Jordan et al. 2012), 52 species in Nebraska (Williams 2013), and 134 species in Vietnam (Tan et al. 2012). I chose the ISAP as a prioritization tool because it had been used for many species in many areas, included important factors (ecological impact, rate of spread, and similar habitats invaded elsewhere), and included a way to express uncertainty. Ecological impact is an important factor because nonnative species are only a concern when they have ecological impacts (Hulme et al. 2013; Ricciardi et al. 2013; Simberloff et al. 2013) and can spread from where they are introduced. Rate of spread is an important factor because a fast-spreading species has the potential to impact a larger area than a species that spreads slowly. Similar habitats invaded elsewhere is the factor that is most predictive for invasiveness (Mack 1996; Reichard and Hamilton 1997; Kolar and Lodge 2001; Gordon et al. 2008).

Before species can be prioritized one must determine which species are candidates for prioritization. Treating invasive species

when they are rare (early detection and rapid response) is an efficient strategy for managing invasive plants (Cusack et al. 2009). Early detection and rapid response are critical aspects to the management of nonnative invasive species (Mehta et al. 2007; Hauser and McCarthy 2009; Goldberg et al. 2013). Rejmanek and Pitcairn (2002) evaluated noxious plant eradication efforts in California and concluded that efforts on populations larger than 100 ha were often unsuccessful, whereas eradication efforts on populations smaller than 1 ha were much more likely to succeed. Pluess et al. (2012) conducted a worldwide review of eradication efforts for many taxa. For plant eradication efforts they concluded that the likelihood of success was greater if the efforts were initiated within the first four years of the invasion process. I chose candidate species for prioritization that were believed to be absent from, but found near, National Capital Region (NCR) parks.

NPS has spent thousands of person-hours and millions of dollars in the NCR treating invasive species over the last 20 years. Most treatment efforts performed by NPS staff, volunteers, or contractors have focused on species that have had known negative ecological impacts. Target species have either been widespread (e.g., *Pueraria montana* var. *lobata* (Willd.) Maesen & S.M. Almeida ex Sanjappa & Predeep and *Ailanthus altissima* (Mill.) Swingle) or uncommon (e.g., *Buddleja davidii* Franch. and *Oplismenus hirtellus* ssp. *undulatifolius* (Ard.) U. Scholz). This paper covers a third group—watch list species. I define watch list species as those species likely to become early detection targets because they have both a high potential to impact ecosystems and are nearby but not yet documented in the area of interest. Faulkner et al. (2014) outlined a system to build a watch list for South Africa. Their list included nonnative species that were reported as invasive elsewhere, were absent from South Africa, were species for which occurrence data were available, were found in similar climates as the target area, and had the potential to be introduced. The system I describe here shares these characteristics but is on a smaller scale (i.e., the NCR parks are spread across a region of less than 25,000 $km^2$ whereas South Africa covers more than 1 million $km^2$), only considers species nearby, and ranks individual species relative to others on the watch list. My objective was to produce a prioritized regional watch list for national parks in the NCR.

Building a watch list is challenging because of limited time available to conduct assessments, limited data available about assessed species, and lack of knowledge about species that are not yet found in the area of interest. The number of detected invasive species is increasing (Aukema et al. 2010) and NPS resources are shrinking (National Park Foundation 2011), therefore limited person-hours are available to evaluate species. Choosing a protocol that can be conducted in only a few hours rather than a few days (e.g., Koop et al. 2012) increases the number of species that can be evaluated. Creating prioritized lists of invasive plants can be challenging because ecological impact data may not be available or may be hard to access for each evaluated species (McGeoch et al. 2012). Choosing a protocol that can reflect the uncertainty of the data reviewed can mitigate the problem of limited data. Although many prioritization schemes have been used to prioritize species for treatment, most land managers prioritize species for treatment ad hoc. Fox and Gordon (2004) reviewed 113 invasive plant priority lists and found only 10% were the result of a ranking process. Ad hoc prioritization does not make the most efficient use of limited resources. In addition, species that are uncommon or absent are hard for staff and volunteers to learn. If a species is not recognized, it may not get reported or treated. Producing a prioritized list reduces the number of species a manager must learn.

## METHODS

I obtained a list of plants reported as invasive in and around NCR parks from EDDMapS (Early Detection and Distribution Mapping System; EDDMapS 2013), an online repository of invasive species occurrence data. EDDMapS staff produced a list of records from within 241 km (150 miles) of Washington, DC, with a two-step process. First, staff queried the database for all records within a square area roughly 241 km (150 miles) on each side that is centered on Washington, DC (between 36°0′0″N and 42°0′0″N and between 74°0′0″W and 80°0′0″W; DMS). Second, EDDMapS staff overlaid the query results in ArcGIS (ESRI 2010) with a map layer of a circle with a 241-km radius around Washington, DC, and trimmed the output to exclude records outside the circle (Figure 1). The radius of 241 km was chosen because it included all NCR parks and at least a few counties beyond each park. Because the query was built on a latitude/longitude search, it did not include records that did not have a latitude and longitude associated with them. Records may never have had latitude and longitude or may have had it withheld when EDDMapS received the data. Many of the records without latitude and longitude were provided to EDDMapS from the USDA Plants Database (USDA NRCS 2015), the Biota of North America Program (Kartesz 2015), the USFS Forest Inventory and Analysis Database (USDA USFS 2015), or herbaria. Excluding these records may have excluded species in our area. However, because of the large number of records, it is likely that the vast majority of taxa are represented in both categories (those with and those without latitude/longitude data).

The EDDMapS records were summarized by taxa and exported to an Excel spreadsheet (Microsoft 2010). Records included record and taxa identification codes used by EDDMapS, latitude and longitude, and the state and county of the record. I removed synonyms based on ITIS (2013), removed names for species native in all three primary jurisdictions (Maryland, District of Columbia, and Virginia), and combined records that had subspecific taxa with those that were recorded to the specific level (hereafter, the *150-mile list*).

To obtain a list of species already known to be invasive in NCR parks I used a list that was assembled by NCR staff in 2012 and 2013 by polling park managers. Taxa were included on the list if the park manager reported the species as invasive in natural areas in NCR parks. I removed synonyms based on ITIS (2013) and consolidated species listed more than once (hereafter, the *park list*).

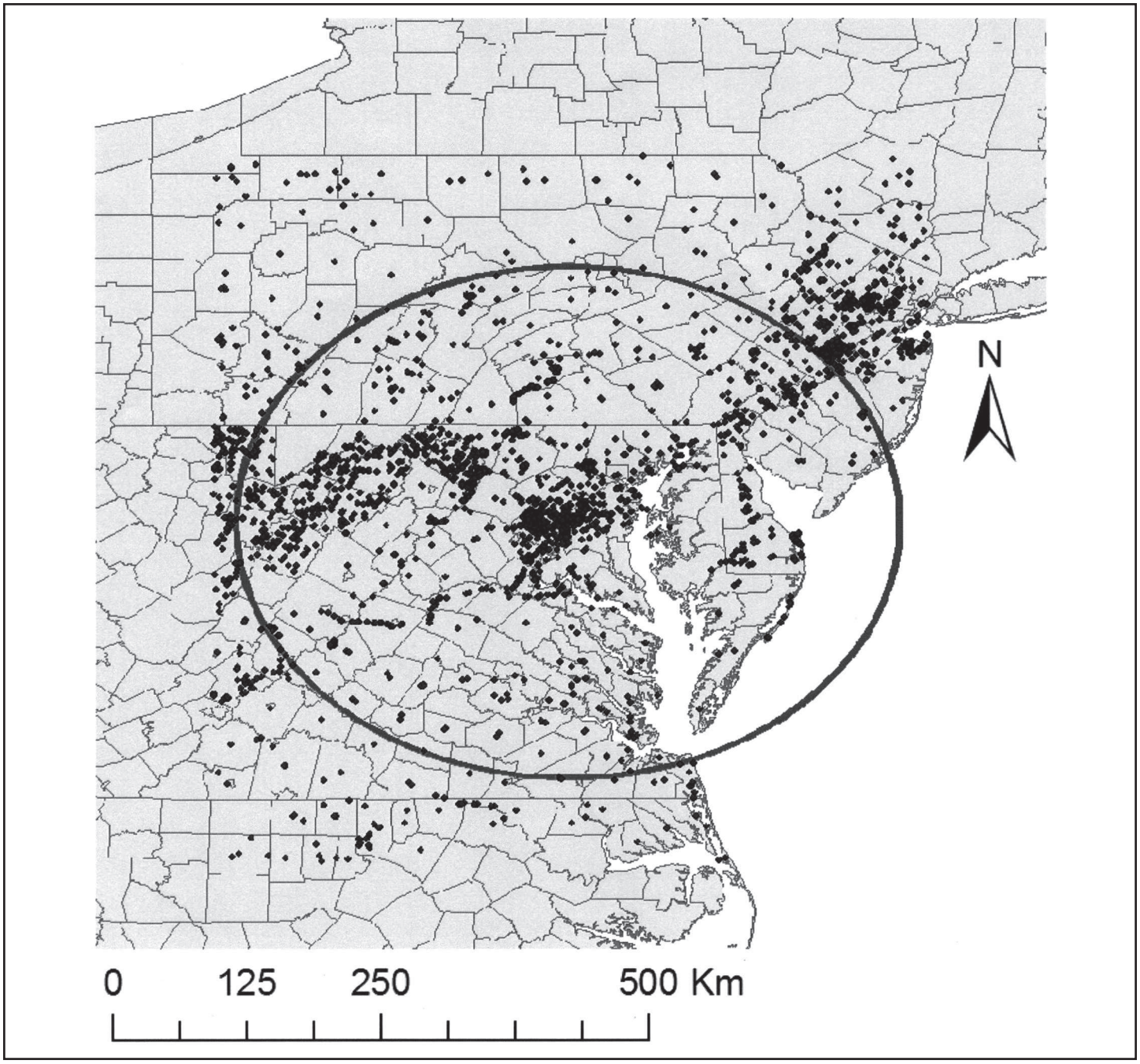


**Figure 1. The EDDMapS records used to build the 150-mile list.**

To identify invasive species not yet found in NCR parks I removed species on the *park list* from the *150-mile list*, yielding the *candidate list* (Table 1). In addition to species not yet found in NCR parks, the species on the *candidate list* might have belonged to two other categories: (1) species not well known and, therefore, not reported by park staff, or (2) species known but not considered by a park manager to be invasive in natural areas.

I prioritized species on the *candidate list* using the ISAP and used the highest-priority species to create the *watch list*. Taxa on the *candidate list* were looked up in the NatureServe Explorer (Natureserve 2014). Any taxa with a completed I-Rank had its I-Rank reviewed and, if needed, modified for our region. Modifications were performed if additional information was available since the ranking had been conducted by NatureServe or if there was evidence that the behavior of the species in the Mid-Atlantic differed from the behavior of the species nationally. Species without an existing I-Rank were put through the NatureServe ISAP (Morse et al. 2004; Randall et al. 2008). Initial assessments were conducted by volunteers and then reviewed

**Table 1. Candidate list. The x indicates species on the watch list. Many Candidate species are known to occur in parks. They occur on this list because they are not considered invasive in park natural areas, they are poorly known, or they were not known to occur in park natural areas at the time the Park List was created.**

| | Species | Common name | NatureServe I-Rank | NCR I-Rank |
|---|---|---|---|---|
| | *Agrostis gigantea* Roth | water bentgrass | Medium/Low | Medium/Low |
| | *Alnus glutinosa* (L.) Gaertn. | black alder | Medium | Medium |
| | *Alopecurus geniculatus* L. | water foxtail | NA | Low |
| | *Alternanthera philoxeroides* (Mart.) Griseb. | alligator weed | Medium | Medium |
| | *Ambrosia artemisiifolia* L. | common ragweed | NA | Medium/Low |
| | *Arctium lappa* L. | great burdock | Insignificant | Insignificant |
| | *Artemisia annua* L. | annual wormwood | Low | Low |
| | *Asparagus officinalis* L. | asparagus | Medium/Insignificant | Medium/Insignificant |
| | [a]*Bambusa bambos* (L.) Voss | thorny bamboo | NA | Medium/Insignificant |
| | *Barbarea vulgaris* W.T. Aiton | yellow rocket | Insignificant | Insignificant |
| | *Berberis julianae* C.K. Schneid. | wintergreen barberry | NA | Medium/Low |
| | *Buxus microphylla* Siebold & Zucc. | littleleaf boxwood | NA | Insignificant |
| | *Buxus sempervirens* L. | common boxwood | NA | Insignificant |
| | *Callitriche stagnalis* Scop. | pondwater starwort | Low | Low |
| | *Cardamine impatiens* L. | Narrowleaf bittercress | Low | Low |
| | *Carduus acanthoides* L. | plumeless thistle | Medium | Medium |
| | *Carduus crispus* L. | curled thistle | Insignificant | Insignificant |
| x | [b]*Cenchrus setaceus* (Forssk.) Morrone | fountaingrass | High/Medium | High/Medium |
| | *Centaurea macrocephala* Puschk. ex Willd. | big-headed knapweed | Low | Low |
| | *Centaurea nigra* L. | black knapweed | Insignificant | Insignificant |
| | *Chenopodium album* L. | lambsquarters | NA | Low/Insignificant |
| | *Chenopodium glaucum* L. | oak-leaf goosefoot | NA | Low |
| | *Crupina vulgaris* Cass. | common crupina | Low | Medium/Low |
| | *Dipsacus laciniatus* L. | cutleaf teasel | Medium/Low | Medium/Low |
| | *Echinochloa crus-galli* (L.) P. Beauv. | barnyard grass | Low | Low |
| x | *Egeria densa* Planch. | brazilian elodea | High/Medium | High/Medium |
| | *Eichhornia azurea* (Sw.) Kunth | anchored water hyacinth | NA | Medium/Low |
| x | *Eichhornia crassipes* (Mart.) Solms | common water hyacinth | High | High |
| | *Epilobium hirsutum* L. | hairy willow herb | Medium/Low | Medium/Low |
| | *Eragrostis curvula* (Schrad.) Nees | weeping lovegrass | Medium/Low | Medium |
| | *Eranthis hyemalis* (L.) Salisb. | winter aconite | NA | Insignificant |
| x | *Fallopia sachalinensis* (F. Schmidt) Ronse Decr. | giant knotweed | High/Medium | High/Medium |
| | *Fatoua villosa* (Thunb.) Nakai | hairy crabweed | NA | Low |
| | *Forsythia viridissima* Lindl. | greenstem forsythia | NA | Medium/Insignificant |

*Continued*

**Table 1. (Continued)**

| | Species | Common name | NatureServe I-Rank | NCR I-Rank |
|---|---|---|---|---|
| | *Galega officinalis* L. | goat's rue | Low/Insignificant | Low/Insignificant |
| x | *Glossostigma cleistanthum* W.R. Barker | mudmats | NA | High/Medium |
| | *Hibiscus syriacus* L. | rose of Sharon | NA | Low/Insignificant |
| | *Holcus lanatus* L. | velvetgrass | Medium | Medium |
| x | *Hypericum perforatum* L. | common St. John's wort | High/Medium | High/Medium |
| | *Juncus inflexus* L. | European meadow rush | NA | Medium |
| | *Koelreuteria paniculata* Laxm. | golden rain tree | Insignificant | Insignificant |
| x | *Lamium galeobdolon* (L.) L. | yellow archangel | NA | High/Low |
| | *Landoltia punctata* (G. Mey.) Les & D.J. Crawford | dotted duckmeat | NA | Low |
| | *Lapsana communis* L. | nipplewort | NA | Low |
| | *Lonicera fragrantissima* Lindl. & Paxton | sweet breath of spring | NA | Low |
| | *Lotus corniculatus* L. | bird's foor trefoil | Medium/Low | Medium/Low |
| x | *Ludwigia grandiflora* (Michx.) Greuter & Burdet | large-flower primrose-willow | High | High |
| | *Ludwigia peploides* (Kunth) P.H. Raven | creeping water primrose | NA | Low |
| | *Lycopus europaeus* L. | gypsywort | NA | Insignificant |
| | *Lysimachia vulgaris* L. | garden loosestrife | NA | Medium |
| | *Marsilea mutica* Mett. | Australian water clover | NA | Medium/Low |
| | *Marsilea quadrifolia* L. | European water clover | NA | Medium/Low |
| | *Mentha aquatica* L. | water mint | NA | Low/Insignificant |
| | *Mentha spicata* L. | bush mint, spearmint | NA | Insignificant |
| | *Mentha x gracilis* Sole (pro. sp.) | gingermint | NA | Insignificant |
| | *Mollugo verticillata* L. | carpet-weed | NA | Insignificant |
| | *Myosotis scorpioides* L. | forget-me-not | NA | Medium/Low |
| | *Myosoton aquaticum* (L.) Moench | giant chickweed | NA | Low/Insignificant |
| x | *Myriophyllum aquaticum* (Vell.) Verdc | parrot feather | High/Medium | High/Medium |
| x | *Myriophyllum spicatum* L. | Eurasian watermilfoil | High | High |
| x | *Najas minor* All. | brittle waternymph | High/Medium | High/Medium |
| x | *Nandina domestica* Thunb. | heavenly bamboo | High/Low | High/Medium |
| | *Nelumbo nucifera* Gaertn. | sacred lotus | NA | Low/Insignificant |
| x | *Nymphoides peltata* (S.G. Gmel.) Kuntze | yellow floating heart | High/Medium | High/Medium |
| | *Oenanthe javanica* (Blume) DC. | Java waterdropwort | NA | Low |
| | Persicaria longiseta *(Bruijn) Kitag.* | Oriental lady's thumb | NA | Medium |

*Continued*

**Table 1. (Continued)**

| | Species | Common name | NatureServe I-Rank | NCR I-Rank |
|---|---|---|---|---|
| x | *Phellodendron amurense* Rupr. | Amur cork tree | NA | High/Low |
| | *Phyllostachys aureosulcata* McClure | yellow grove bamboo | NA | Medium/Low |
| | *Pinus thunbergii* Parl. | Japanese black pine | NA | Low |
| | *Pistia stratiotes* L. | water lettuce | NA | Medium |
| | *Poa trivialis* L. | rough bluegrass | Medium/Low | Medium/Low |
| x | *Poncirus trifoliata* (L.) Raf. | hardy orange | NA | High/Low |
| | *Populus alba* L. | white poplar | High/Low | Medium/Low |
| | *Potamogeton crispus* L. | curly pondweed | Medium | Medium |
| | *Puccinellia distans* (Jacq.) Parl. | European alkaligrass | NA | Low/Insignificant |
| x | *Rhamnus cathartica* L. | common buckthorn | High/Medium | High |
| x | *Rhamnus frangula* L. | glossy false buckthorn | High/Medium | High/Medium |
| | *Rorippa sylvestris* (L.) Besser | creeping yellow cress | Medium/Low | Medium/Low |
| | *Rosa lucieae* Franch. & Rochebr. ex | memorial rose | NA | Medium/Low |
| | *Rumex obtusifolius* L. | bitter dock | NA | Low/Insignificant |
| | *Salix alba* L. | golden willow | NA | Low |
| | *Salix fragilis* L. | crack willow | NA | Low |
| | *Salix purpurea* L. | basket willow | NA | Medium/Low |
| | *Setaria faberi* R.A.W. Herrm. | Chinese foxtail | NA | Low/Insignificant |
| | *Sonchus arvensis* L. | creeping sowthistle | Medium/Low | Medium/Low |
| x | *Spiraea japonica* L. f. | Japanese spiraea | High/Medium | High/Medium |
| | *Spiraea thunbergii* Siebold ex Blume | Thunberg's meadowsweet | NA | Low/Insignificant |
| x | *Tamarix parviflora* DC. | tamarisk | NA | High/Low |
| | *Taxus baccata* L. | English yew | NA | Low/Insignificant |
| | *Trapa natans* L. | water chestnut | Medium | Medium |
| | *Veronica beccabunga* L. | European speedwell | NA | Low/Insignificant |
| | *Viburnum setigerum* Hance | tea viburnum | NA | Low/Insignificant |
| | *Viburnum sieboldii* Miq. | Siebold's arrowwood | NA | Low/Insignificant |
| x | *Vincetoxicum nigrum* (L.) Moench | black swallow-wort | High | High |
| | *Vincetoxicum hirundinaria* Medik. | white swallow-wort | Low | Low |
| | *Vitex rotundifolia* L. f. | roundleaf chastetree | Medium/Low | Medium/Low |
| | *Yucca glauca* Nutt. | beargrass | NA | Insignificant |

[a] *Bambusa bambos* is likely a misidentified *Phyllostachys aureosulcata* McClure or *Pseudosasa japonica* (Siebold & Zucc. ex Steud.) Makino ex Nakai

[b] *Cenchrus setaceus* is likely a misidentified *C. compressus* (R. Br.) Morrone

The production of the Watch List encouraged the identification of and reporting of the species on the list. It is now known that these species do occur in NCR parks: *Cenchrus setaceua, Cenchrus compressus, Hypericum perforatum, Lamium galeobdolon, Myriophyllum spicatum, Najas major, Nandina domestica, Phellodendron amurense, Poncirus trifoliata, Rhamnus cathartica, and Spiraea japonica.*

by interns to ensure consistent treatment across taxa. I conducted a final review of all assessments for all candidate taxa. The ISAP comprises 20 questions divided into four sections (Figure 2). Answers range from A (High) to D (Insignificant). In cases where the information available is not sufficient to narrow the rank to a specific level (e.g., B; Medium), a range I-Rank (e.g., A/B; High/Medium) is assigned. U (Unknown) is given for a plant that warrants a ranking of AD (High/Insignificant). Uncertainty may be a reflection of conflicting published information or uncertainty about the quality of the published information. Any taxon with a ranking word including "High" (i.e., High, High/Medium, High/Low) was placed on the *watch list*. These rankings were chosen to capture the species that posed the highest potential threat to ecosystems in the NCR.

## RESULTS

EDDMapS provided a list of 12,707 records covering 257 taxa. After being trimmed of synonymous taxa, natives, and species-level duplicates, the *150-mile list* contained 116 species—species that were reported from within 150 miles of Washington, DC. The *park list* included 195 species—species that were reported as invasive in NCR natural areas. Once the species on the *park list* had been removed from the *150-mile list*, the *candidate list* had 97 species (Table 1)—species that were found in the area but had not been reported as invasive in national park natural areas. Forty-five of the species on the *candidate list* had ranks available on NatureServe; 11 of those were modified (Table 2). In some cases, new information was available since the creation of the I-Rank by NatureServe, and in other cases the behavior of the species in our region differed from the national-level behavior. The remaining 52 taxa were ranked using the ISAP (Table 1). The 20 species ranked as High, High/Medium, or High/Low make up the watch list (Table 2).

QUALIFYING QUESTIONS

i. Nonnative established outside of cultivation in region of interest?
ii. Occurs in conservation areas?

I. ECOLOGICAL IMPACT

1. Impact on ecosystem processes and system-wide parameters
2. Impact on ecological community structure
3. Impact on ecological community composition
4. Impact on individual native plant or animal species
5. Conservation significance of the communities and native species threatened

II. CURRENT DISTRIBUTION AND ABUNDANCE

6. Current range size in region
7. Proportion of current range where species is negatively impacting biodiversity
8. Proportion of region's biogeographic units invaded
9. Diversity of habitats or ecological systems invaded in region

III. TREND IN DISTRIBUTION AND ABUNDANCE

10. Current trend in total range within region
11. Proportion of potential range currently occupied
12. Long-distance dispersal potential within region
13. Local range expansion or change in abundance
14. Inherent ability to invade conservation areas and other native species habitats
15. Similar habitats invaded elsewhere
16. Reproductive characteristics

IV. MANAGEMENT DIFFICULTY

17. General management difficulty
18. Minimum time commitment
19. Impacts of management on native species
20. Accessibility of invaded areas

**Figure 2. I-Rank questions answered for each evaluated species. Answers range from A (high) to D (insignificant). Answers can have two letters (e.g., AC). U (unknown) is given in place of AD.**

**Table 2. Summary of I-Ranks performed by NatureServe and by the process outlined in this paper. The first column lists each possible ranking, the second column lists the number of species ranked by NatureServe that were not modified by me, and the third column lists the number of species ranked by NatureServe that were modified by me. The fourth column lists the number of I-Ranks that were conducted for species for which NatureServe had not produced an I-Rank.**

| | By NatureServe | | New |
|---|---|---|---|
| | Not modified | Modified | |
| High | 4 | 0 | 0 |
| High/Medium | 9 | 1 | 1 |
| High/Low | 0 | 2 | 4 |
| Medium | 0 | 6 | 4 |
| Medium/Low | 8 | 1 | 9 |
| Medium/Insignificant | 1 | 0 | 2 |
| Low | 6 | 1 | 11 |
| Low/Insignificant | 1 | 0 | 13 |
| Insignificant | 5 | 0 | 8 |
| **Total** | **34** | **11** | **52** |

## DISCUSSION

The process outlined above took advantage of existing resources to produce a prioritized list of invasive species with a high likelihood of being found within NCR parks in the near future. These are critical species for park managers to learn to identify and to map and treat when they are found.

My approach mitigates the challenge of limited time available for species assessments by using preexisting data sources, volunteer labor to evaluate species, and a protocol that can be conducted in a few hours. Because the ISAP has been conducted for more than 900 species, time can be saved by modifying the existing ISAPs. The ISAP capacity for expressing uncertainty can also speed up the review process. Both the semi-quantitative nature of the ISAP and the ability to express uncertainty in responding to ISAP questions mitigate the consequences of limited published research on the impacts of invasion of individual species. The process has led to a formalized (i.e., not ad hoc) priority list. The production of the *watch list* encouraged NPS staff to look for and report the species on the list; it is now known that nine *watch list* species do occur in NCR parks (*Hypericum perforatum*, *Lamium galeobdolon*, *Myriophyllum spicatum*, *Najas major*, *Nandina domestica*, *Phellodendron amurense*, *Poncirus trifoliata*, *Rhamnus cathartica*, and *Spiraea japonica*).

The difficulties all rankers faced underscore the importance of sharing data. Without EDDMapS and NatureServe both sharing their data, a project like this would not be possible. However, additional occurrence data is needed to increase the robustness and usefulness of the *watch list* and early detection efforts generally.

The approach described above can be used inside or outside of the United States, at other regional groups of parks, or at larger or finer scales. A candidate list can be built if data are available on which species are found within the area of interest and which species are found in the broader region. Once a candidate list is built and prioritized the highest priority species form the watch list.

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## LITERATURE CITED

Aukema, J.E., D.G. McCullough, B. Von Holle, A.M. Liebhold, K. Britton, and S.J. Frankel. 2010. Historical accumulation of nonindigenous forest pests in the continental United States. BioScience 60:886-897.

Borgmann, K.L., and A.D. Rodewald. 2004. Nest predation in an urbanizing landscape: The role of exotic shrubs. Ecological Applications 14:1757-1765.

Brown, B.J., R.J. Mitchell, and S.A. Graham. 2002. Competition for pollination between an invasive species (purple loosestrife) and a native congener. Ecology 83:2328-2336.

Brunel, S., E. Branquart, G. Fried, J. Van Valkenburg, G. Brundu, U. Starfinger, S. Buholzer, A. Uludag, M. Joseffson, and R. Baker. 2010. The EPPO prioritization process for invasive alien plants. EPPO Bulletin 40:407-422.

Brouwer, N.L., A.N. Hale, and S. Kalisz. 2015. Mutualism-disrupting allelopathic invader drives carbon stress and vital rate decline in a forest perennial herb. AoB Plants 7:plv014. doi:10.1093/aobpla/plv014.

Cal-IPC. 2012. California Invasive Plant Inventory. Accessed 1 July 2015 <http://www.cal-ipc.org/ip/inventory/index.php>.

Cusack, C., M. Harte, and S. Chan. 2009. The Economics of Invasive Species. Prepared for the Oregon Invasive Species Council. Oregon Sea Grant, Oregon State University, Corvallis.

Dawson, J., S. Oppel, R.J. Cuthbert, N. Holmes, J.P. Bird, S.H. Butchart, D.R. Spatz, and B. Tershy. 2014. Prioritizing islands for the eradication of invasive vertebrates in the United Kingdom overseas territories. Conservation Biology 29:143-153.

Downey, P.O., M.C. Williams, L.K. Whiffen, B.A. Auld, M.A. Hamilton, A.L. Burley, and

P.J. Turner. 2010. Managing alien plants for biodiversity outcomes—The need for triage. Invasive Plant Science and Management 3:1-11.

DPI. 2008. Victoria weed risk assessment (WRA) method. Department of Primary Industries (DPI), Victoria, Australia. Accessed 15 August 2013 <http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/weeds_vic_nox_review>.

EDDMapS. 2013. Early Detection & Distribution Mapping System. The University of Georgia – Center for Invasive Species and Ecosystem Health. Accessed 10 September 2013 <http://www.eddmaps.org/>.

ESRI. 2010. ArcGIS Desktop: Release 9.3. Environmental Systems Research Institute, Redlands, CA.

Essl, F., S. Nehring, F. Klingenstein, N. Milasowszky, C. Nowack, and W. Rabitscha. 2011. Review of risk assessment systems of IAS in Europe and introducing the German–Austrian Black List Information System (GABLIS). Journal for Nature Conservation 19:339-350.

Faulkner, K.T., M.P. Robertson, M. Rouget, and J.R. Wilson. 2014. A simple, rapid methodology for developing invasive species watch lists. Biological Conservation 179:25-32.

Fox, A.M. and D. Gordon 2004. Criteria for listing invasive plants. Weed Technology 18:1309-1313.

Fox, A.M., D.R. Gordon, J.A. Dusky, L. Tyson, R.K. Stocker, K.A. Langeland, and A.L. Cooper. 2009. IFAS Assessment of Non-native Plants in Florida's Natural Areas: Status Assessment. Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Frey, M., M. Perlmutter, A. Williams, and D. Gluesenkamp. 2015. The San Francisco Bay Area Early Detection Network. Management of Biological Invasions 6:231-241.

Goldberg, C.S., A. Sepulveda, A. Ray, J. Baumgardt, and L.P. Waits. 2013. Environmental DNA as a new method for early detection of New Zealand mudsnails (*Potamopyrgus antipodarum*). Freshwater Science 32:792-800.

Goodall, J.M., and D.C. Naudé. 1998. An ecosystem approach for planning sustainable management of environmental weeds in South Africa. Agriculture, Ecosystems and Environment 68:109-123.

Gordon, D.R., D.A. Onderdonk, A.M. Fox, R.K. Stocker, and C. Gantz. 2008. Predicting invasive plants in Florida using the Australian weed risk assessment. Invasive Plant Science and Management 1:178-195.

Greer, M.J., G.W. Wilson, K.R. Hickman, and S.M. Wilson. 2014. Experimental evidence that invasive grasses use allelopathic biochemicals as a potential mechanism for invasion: Chemical warfare in nature. Plant and Soil 385:165-179.

Gross, S., and E. Olin. 2011. Development of a management ranking system for terrestrial noxious weeds/invasive plant species. USDA Forest Service, Lake Tahoe Basin Management Unit, South Lake Tahoe, CA.

Hauser, C.E., and M.A. McCarthy. 2009. Streamlining 'search and destroy': Cost-effective surveillance for invasive species management. Ecology Letters 12:683-692.

Heffernan, K.E., P.P. Coulling, J.F. Townsend, and C.J. Hutto. 2001. Ranking Invasive Exotic Plant Species in Virginia. Natural Heritage Technical Report 01-13. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA.

Hiebert, R.D., and J. Stubbendieck. 1993. Handbook for ranking exotic plants for management and control. Natural Resources Report NPS/NRMWRO/NRR-93/08. National Park Service, Midwest Regional Office, Omaha, NE, and University of Nebraska, Department of Agronomy, Lincoln.

Hulme, P.E., P. Pyšek, V. Jarošík, J. Pergl, U. Schaffner, and M. Vila. 2013. Bias and error in understanding plant invasion impacts. Trends in Ecology and Evolution 28:212-218.

ITIS. 2013. Integrated Taxonomic Information System (ITIS). Accessed 10 September 2013 <http://www.itis.gov>.

Jordan, M.J., G. Moore, and T.W. Weldy. 2012. New York State Ranking System for Evaluating Non-Native Plant Species for Invasiveness. The Nature Conservancy, Cold Spring Harbor, NY; Brooklyn Botanic Garden, Brooklyn, NY; The Nature Conservancy, Albany, NY. Accessed 10 September 2013 <www.nyis.info/pdf/New_York_State_Invasive_Plant_Ranking_System_Rev_2012.pdf>.

Kartesz, J.T. 2015. The Biota of North America Program (BONAP). North American Plant Atlas, Chapel Hill, NC. <http://bonap.net/napa>. [Maps generated from Kartesz, J.T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP).]

Keeler, M.S., and F.S. Chew. 2008. Escaping an evolutionary trap: Preference and performance of a native insect on an exotic invasive host. Oecologia 156:559-568.

Kolar, C.S., and D.M. Lodge. 2001. Progress in invasion biology: Predicting invaders. Trends in Ecology and Evolution 16:199-204.

Koop, A.L., L. Fowler, L.P. Newton, and B.P. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14:273-294.

Krug, R.M., N. Roura-Pascual, and D.M. Richardson. 2010. Clearing of invasive alien plants under different budget scenarios: Using a simulation model to test efficiency. Biological Invasions 12:4099-4112.

Mack, R.N. 1996. Predicting the identity and fate of plant invaders: Emergent and emerging approaches. Biological Conservation 78:107-121.

McGeoch, M.A., D. Spear, E.J. Kleynhans, and E. Marais. 2012. Uncertainty in invasive alien species listing. Ecological Applications 22:959-971.

Mehta, S.V., R.G. Haight, F.R. Homans, S. Polasky, and R.C. Venette. 2007. Optimal detection and control strategies for invasive species management. Ecological Economics 61:237-245.

Microsoft. 2010. Microsoft Excel [computer software]. Microsoft Corporation, Redmond, WA.

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, VA. Accessed 10 September 2013 <http://digitalcommons.usu.edu/govdocs/537>.

National Park Foundation. 2011. Made in America: Investing in National Parks for Our Heritage and Our Economy. National Parks Conservation Association, Washington, DC. Accessed 1 February 2016 <https://www.npca.org/resources/2372-made-in-america-investing-in-national-parks-for-our-heritage-and-our>.

NatureServe. 2014. NatureServe Web Service. Arlington, VA. Accessed 1 June 2014 <http://services.natureserve.org>.

Nel, J.L., D.M. Richardson, M. Rouget, T.N. Mgidi, N. Mdzeke, D.C. Le Maitre, B.W. van Wilgen, L. Schonegevel, L. Henderson, and S. Neser. 2004. A proposed classification of invasive alien plant species in South Africa: Towards prioritizing species and areas for management action. South African Journal of Science 100:53-64.

Ou, J., C. Lu, and D.K. O'Toole. 2008. A risk assessment system for alien plant bio-invasion in Xiamen, China. Journal of Environmental Sciences 20:989-997.

Pluess, T., V. Jarošík, P. Pyšek, R. Cannon, J. Pergl, A. Breukers, and S. Bacher. 2012. Which factors affect the success or failure of eradication campaigns against alien species? PLoS ONE 7:e48157. <http://dx.doi.org/10.1371/journal.pone.0048157>.

Pratti, D., and O. Bossdorf. 2003. Allelopathic inhibition of germination by *Alliaria petiolata* (Brassicaceae). American Journal of Botany 91:285-288.

Randall, J.M., L.E. Morse, N. Benton, R. Hiebert, S. Lu, and T. Killeffer. 2008. The invasive species assessment protocol: A tool for creating regional and national lists of invasive nonnative plants that negatively impact biodiversity. Invasive Plant Science and Management 1:36-49.

Reichard, S.H., and C.W. Hamilton. 1997. Predicting invasions of woody plants introduced into North America. Conservation Biology 11:193-203.

Reinhart, K.O., and R.M. Callaway. 2006. Soil biota and invasive plants. New Phytologist 170:445-457.

Rejmanek, M., and M.J. Pitcairn. 2002. When is eradication of exotic pest plants a realistic goal? Pp. 249–253 *in* C.R. Veitch and M.N. Clout, eds., Turning the Tide—The Eradication of Invasive Species. International Union for Conservation of Nature, Species Survival Commission, Invasive Species Specialist Group, Gland, Switzerland.

Ricciardi, A., M.F. Hoopes, M.P. Marchetti, and J.L. Lockwood. 2013. Progress toward understanding the ecological impacts of nonnative species. Ecological Monographs 83:263-282.

Rout, M.E., T.H. Chrzanowski, T.K. Westlie, T.H. DeLuca, R.M. Callaway, and W.E. Holben. 2013. Bacterial endophytes enhance competition by invasive plants. American Journal of Botany 100:1726-1737.

Schmidt, K.A., and C.J. Whelan. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. Conservation Biology 13:1502-1506.

Self, D.W. 1986 Exotic plant inventory, rating and management planning for Point Reyes National Seashore. Pp. 85–95 *in* L.K. Thomas, ed., Proceedings of the Conference on Science in the National Parks. US Department of the Interior, National Park Service, Washington, DC.

Simberloff, D., J. Martin, P. Genovesi, V. Maris, D.A. Wardle, J. Aronson, F. Courchamp, B. Galil, E. García-Berthou, M. Pascal, P. Pyšek, R. Sousa, E. Tabacchi, and M. Vilà. 2013. Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution 28:58-66.

Spellman, K.V., L.C. Schneller, C.P. Mulder, and M.L. Carlson. 2015. Effects of non-native *Melilotus albus* on pollination and reproduction in two boreal shrubs. Oecologia 179:495-507.

Tan, D.T., P.Q. Thu, and B. Dell. 2012. Alien and invasive plant species and their risk in National Parks of Vietnam. Forests 3:997-1016.

Tscheulin, T., and T. Petanidou. 2013. The presence of the invasive plant *Solanum elaeagnifolium* deters honeybees and increases pollen limitation in the native co-flowering species *Glaucium flavum*. Biological Invasions 15:385-393.

USDA NRCS. 2015. The PLANTS Database. National Plant Data Team, Greensboro, NC. Accessed 9 June 2015 <http://plants.usda.gov>.

USDA USFS. 2015. USFS Forest Inventory and Analysis Database. FIA National Office, Washington, DC. Accessed 10 February 2016 <http://www.fia.fs.fed.us/tools-data/>.

Washington Invasive Species Council. n.d. Invasive Species Impact and Prevention/Early Action Assessment Tool. Washington State Recreation and Conservation Office, Olympia. Accessed 1 June 2014 <http://www.invasivespecies.wa.gov/documents/assessment_tool.pdf>.

Williams, A., S. O'Neil, S. Speith, J. Rodgers, M. Alvarez, and R. Steers. 2014. San Francisco Area Network Case Study. Pp. 169–193 *in* B.A. Welch, P.H. Geissler, and P. Latham, Early Detection of Invasive Plants—Principles and Practices. USGS Report 2012–5162, US Geological Survey Scientific Investigations, Reston, VA.

Williams, J.B. 2013. Predicting invasion risk of non-native plants using a modified I-Rank assessment. MS thesis, University of Nebraska, Lincoln.