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Application of an Aquatic Plant Risk Assessment to Non-Indigenous Freshwater Plants in Trade in Canada

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

The economic and ecological costs associated with invasive species in North America are high, with some estimates reaching $150-170 billion/year (Pimentel et al. 2000; Colautti et al 2006). Ecological risk assessment tools that pre-screen species for invasiveness and are combined with effective regulations to keep high-risk species out is one way to significantly reduce these costs. For plants, we evaluated a questionnaire-style risk assessment developed by Biosecurity New Zealand and tested previously at the University of Florida and the University of Notre Dame (Gordon et al. 2012). This assessment accurately distinguished between established species and those that were introduced but failed to establish in the United States. We modified the Gordon et al. (2012) risk assessment so that all questions are relevant to Canada and then used it to evaluate species from that paper. We excluded any species that did not have a USDA hardiness zone match with Canada. The risk assessment worked well at categorizing this sample of established and not established species in Canada. An additional sample of species in trade was assessed with high accuracy for not established species, but low accuracy for established species (although the established sample size was small; 4 species).The reason an existing protocol was adapted to Canada rather than developing a new risk assessment model is that the latter would take extensive research on introduction dates, establishment and impact of non-native species, specifically for Canada. The modified Gordon et al. (2012) tool has been peer reviewed, applied successfully in several countries, and worked well to accurately distinguish established invasive from non-established species when applied to Canada.

Application d’une évaluation des risques des plantes aquatiques aux plantes d'eau douce non indigènes apparaissant dans le commerce au Canada

RÉSUMÉ

Les coûts sur les plans économique et écologique associés aux espèces envahissantes en Amérique du Nord sont élevés; on estime qu'ils atteignent entre 150 et 170 G$ chaque année (Pimentel et al. 2000; Colautti et al. 2006). Les outils d'évaluation du risque écologique qui permettent d'effectuer une présélection des espèces selon leur caractère envahissant et qui sont combinés avec des règlements efficaces pour empêcher l'arrivée d'espèces à haut risque est une manière de réduire considérablement ces coûts. Pour les plantes, nous avons évalué une évaluation du risque sous forme de questionnaire élaborée par Biosecurity New Zealand et testée à l'Université de la Floride et à l'Université of Notre Dame (Gordon *et al.* 2012). Cette évaluation permettait de distinguer avec précision les espèces établies et ceux qui ont été introduites mais qui n'ont pas réussi à s'établir aux États-Unis. Nous avons modifié l'évaluation du risque de Gordon et al. (2012) pour faire en sorte que les questions s'appliquent au Canada, puis nous l'avons utilisée pour évaluer les espèces inclus dans ce document. Nous avons exclu toutes les espèces pour lesquelles les cartes des zones de rusticité du département de l'Agriculture des États-Unis (USDA) excluaient l’établissement au Canada. L'évaluation du risque fonctionnait bien pour catégoriser cet échantillon d'espèces établies et non établies au Canada. Un autre échantillon d'espèces apparaissant dans le commerce a été évalué avec une très haute précision pour les espèces non établies, mais avec une précision faible pour les espèces établies (toutefois, le petit échantillon d'espèces établies ne comptait que quatre espèces).La raison pour laquelle on a adapté au Canada un protocole déjà en place plutôt que d'élaborer un nouveau modèle d'évaluation du risque est qu'un nouveau modèle nécessiterait beaucoup de recherches sur les dates d'introduction, l'établissement et les impacts des espèces non indigènes, spécifiquement pour le Canada. L'outil modifié de Gordon et al. (2012) a fait l'objet d'un examen par des pairs, il a été appliqué avec succès dans plusieurs pays et a permis permet de distinguer avec précision les espèces envahissantes établies et non établies lorsqu'il a été appliqué au Canada.

INTRODUCTION

Aquatic invasive species (AIS) are species that have been introduced beyond their native range, become established, and cause harm to their new ecosystems. They threaten global biodiversity (Sala et al. 2000) and are the second leading cause for decline of Canadian freshwater species at risk (Dextrase and Mandrak 2006). The establishment of AIS can reduce the abundance and productivity of sport, commercial, and culturally important species and can cause habitat alteration (Rahel 2002). Preventing the arrival, establishment, and spread of AIS is an important step for protecting aquatic environments (Kolar 2004).

Fisheries and Oceans Canada (DFO) is mandated to manage and protect Canada's aquatic ecosystems, the health of which is currently jeopardized by the arrival of AIS. To aid in the development of DFO regulation, legislation, and management plans to protect Canadian aquatic environments from the impacts of AIS, DFO's Centre of Expertise for Aquatic Risk Assessment (CEARA) is tasked with identifying, assessing, and prioritizing the threats of current and potential aquatic non-indigenous species (NIS). Biological risk assessment protocols provide an appropriate approach to meet this need, as they generate science advice for informed decision making to prevent potential, or deal with ongoing, invasions by predicting the identity, range, and/or impact of potential invaders (Kolar 2004).

CEARA is developing a three-stage biological risk assessment process for aquatic species (Chapman et al. 2006, DFO 2009). The three stages comprise:

a) *rapid assessment process* (RAP) to assess a species within a few days using minimal information;

b) *screening-level risk assessment* (SLRA) to assess and prioritize a species in about a week using additional information that is readily available; and,

c) *detailed-level risk assessment* (DLRA) to assess a species within several months using detailed information (Mandrak et al. 2012).

Depending on the goal of the risk assessment, increasingly more detailed risk assessments can then be undertaken with the DLRA providing the strongest defensible advice with the least amount of uncertainty.

Non-indigenous species are introduced into Canadian fresh waters in various ways, many of which are associated with the live trade pathway. An increasing number of aquatic plant species are imported into North America every year for sale in the aquarium and garden trades (Kay and Hoyle 2001, Maki and Galatowitsch 2004). In the United States, the number of households with water gardens quadrupled between 1998 and 2003, with annual retail sales reaching an estimated US$1.56 billion in 2003 (Crosson 2005). At a global level, the trade in species for aquaria and water gardens is growing by 14% per year (Padilla and Williams 2004).

These trades pose the risk of non-indigenous plants being introduced into, and/or spreading within, Canada. These species can be released accidentally or through deliberate but unauthorized release. Recent surveys found that about 1% of aquarium and water garden owners released plants into the wild in Canada (Marson et al. 2009a, b). The Canadian Food Inspection Agency (CFIA) regulate invasive plants under the *Plant Protection Act* and other policies but, to date, there is no national regulation of aquatic plant species imported to Canada related to invasiveness. There are also no guidelines for assessment and prioritization as to which aquatic plant species in trade are of highest risk should they be accidentally or intentionally introduced into Canadian fresh waters. Using appropriate risk assessment protocols, freshwater plant species in trade can be identified and ranked based on the biological

risk they pose to Canada. In this document, we report on the development of an SLRA for this purpose.

BACKGROUND

In 2010, DFO's Aquatic Invasive Species program was tasked by both the Office of the Auditor General and an internal evaluation to establish a protocol to provide a scientifically defensible and relatively quick way of screening aquatic NIS based on their invasion threat. A national-level ranking of these species, based on the biological risk they pose to Canadian aquatic ecosystems, is necessary to determine which species should be included in AIS regulatory proposals and to prioritise national and regional AIS program activities and resource allocation. DFO's Legislative and Regulatory Affairs, also a client in this process, requested science advice to support the development of a national regulatory proposal for addressing aquatic NIS. Specifically, it requested:

1) a protocol to prioritise aquatic NIS; and,
2) a list of high risk aquatic NIS including those already present in some regions of Canada whose transport to other areas should be limited.

This protocol would allow the ranking of aquatic NIS for national priorities and would be used as a biological screening tool for aquatic NIS to rapidly determine if a detailed-level risk assessment or a risk management evaluation is required based on existing information.

Screening-level risk assessment was identified as the appropriate level to support the development of these regulations by the Department. A suitable SLRA protocol is applicable in a variety of risk assessment contexts and is a means to quickly assess species known to occur in Canada, as well as species proposed for, or currently found in, trade and other pathways that could introduce them to Canada. Prioritization of aquatic NIS can be determined using the level of risk posed by the species, as quantified by the SLRA (Mandrak et al. 2012). Furthermore, with the establishment of appropriate threshold criteria, the SLRA can supply a risk-based biological screening of aquatic NIS, providing a prioritised list of those species for managers and decision makers that require either a detailed-level risk assessment or a risk management evaluation (Locke et al. 2011). An SLRA protocol would provide DFO with a scientifically defensible and relatively quick means of screening and prioritizing aquatic NIS based on the biological risk they pose to Canadian aquatic ecosystems.

In 2011, a national Canadian Science Advisory Secretariat (CSAS) science advisory process was initiated to provide science advice on the SLRA protocol for aquatic NIS. This process was to consist of at least two peer-review meetings attended by experts from DFO Science, Legislative and Regulatory Affairs, and other sectors of the Department, as well as invited external participants (e.g., from other governmental departments, provincial governments, and academia) who could meaningfully contribute to the science review. Part 1 was held in Montreal, Quebec on November 22-24, 2011 (DFO 2012). At that meeting, participants examined the criteria and methodology used to evaluate risk assessment protocols (Snyder et al. 2013) and then developed a framework for an SLRA protocol for aquatic NIS. Over 80 protocols were reviewed, of which, 13 protocols were evaluated in detail to determine their suitability protocols for screening NIS that may be introduced into Canada. Based on this peer review, it was identified that different SLRA protocols may be required for different aquatic NIS taxa given their diverse biology and, hence, prioritization using a single protocol may not be possible. Part 2 was held in Burlington, Ontario on March 19-21, 2013. Participants evaluated SLRA protocols for freshwater NIS currently in trade within Canada and lists of potentially invasive species generated from the application of a subset of the protocols. SLRA protocols were evaluated and applied to freshwater fishes, molluscs, and plants. Freshwater NIS currently

in trade within Canada were screened using those protocols. Additional meetings, not yet scheduled, will be required to evaluate SLRA protocols for marine NIS, and to assess the ability to prioritize all NIS using the chosen SLRA protocols.

Snyder et al. (2013) evaluated 13 SLRA protocols, including Australian Weed Risk Assessment (AWRA), using standardized scoring criteria for the determination of their conceptual, scientific, and pragmatic strengths and weaknesses. Some of the protocols were developed for specific taxonomic groups, while others can be applied across taxa. Out of a total possible score of 21, the Alberta Invasive Alien Risk Assessment Tool (IASWG 2008) ranked the highest with a score of 16.07, followed by Fish Invertebrate Invasiveness Scoring Kit (Copp et al. 2008) (12.41), and the AWRA (11.66) (Snyder et al. 2013).

SLRA protocols exist that can be used to screen freshwater plant NIS for invasiveness, many of which are based on the AWRA (Pheloung et al. 1999). Gordon et al. (2012) adapted the New Zealand Aquatic Weed Risk Assessment (AqWRA) (Champion and Clayton 2000, 2001) for freshwater plants in the United States after finding the AWRA to perform poorly when applied to aquatic plants (Gordon and Gantz 2011). Ideally, the accuracy of several of these protocols would be compared using a test data set that included the impact of established freshwater plant NIS in Canada; however, such comprehensive data do not exist. Therefore, the adaptation of the New Zealand AqWRA by Gordon et al. (2012) was chosen to screen the list of freshwater plant species known in North American trade and the species established in Canada as this tool had been previously peer reviewed and applied successfully in several countries. This approach has been tested extensively in the U.S. and New Zealand and published in the peer-reviewed literature. It is easily adaptable to other climates and geographies and applicable with the data currently available for NIS in Canada.

PURPOSE

This research document evaluates the application of a SLRA protocol (Gordon et al. 2012) for screening freshwater plants in trade within Canada under current climate conditions.

METHODS

Gordon et al. (2012) used the US Aquatic Weed Risk Assessment (U.S. AqWRA) tool to assess 127 species that have been introduced to the U.S. These species were divided into invaders (i.e., species that have established and that cause harm), established non-invaders (i.e., species established with no harm reported) and not established (i.e., species that failed to become established). The tool distinguished between established invaders and all others with 91% accuracy. It correctly identified invaders and not established species 85% and 98% of the time, respectively. Further validation using an additional 10 not established and 10 invasive species resulted in 100% accuracy for the former group and 80% accuracy for the latter.

The U.S. AqWRA is a ‘questionnaire-style’ risk assessment (*sensu* Keller and Drake 2009) composed of 38 questions pertaining to the life history, ecology, climate tolerance, and invasion history of each species. Each question is answered for each species, and the answer leads to a numeric score. After all questions are answered these question scores are summed to give a total score. Final scores can range between 3 and 91 with higher scores indicating species with a great risk of invasion.

The success of the New Zealand tool when applied to the U.S. strongly suggests that, with appropriate modifications, it would perform with high accuracy in Canada. In the following we describe the development and testing of the New Zealand tool for Canada. We note here that

our methods largely follow those of Gordon et al. 2012 who successfully modified the tool for use in the U.S. Wherever possible, data collected by Gordon et al. 2012 were used.

Risk assessment tools are developed by searching for patterns in species traits that have historically been associated with invasion and impacts. If strong patterns are found they can be applied to species that may be introduced in the future to determine the likely risk they pose. Thus, the first step to develop this tool for Canada was to gather information about those species that have previously been introduced to Canada, and whether or not they are now established. These data were obtained from several Canadian sources including VASCAN (Brouillet et al. 2013), Plants of Canada (CFIA and CFS 2011), Flora of Canada (Scoggan 1979), USDA PLANTS database (USDA, NRCS 2013), as well as expert opinion.

In our use of the tool, with the exception of data that do not vary by provenance (e.g., whether or not a species has rhizomes), all questions were answered using references from outside of Canada. Species in Gordon et al. (2012) were first evaluated for climate match in Canada and those species with an acceptable match were then assessed using the U.S. AqWRA. We assessed a total of 129 species (113 in Gordon et al. (2012) and 16 species subsequently assessed by Crysta Gantz) with tolerances to hardiness zones 1-10 (Appendix 1). Species were organized into three categories:

1) "Established in Canada" are established species in Canada. The definition of established follows that outlined in Table 1.
2) "Established – U.S. only" are species found to be established in the U.S., but not Canada,
3) "Not established*"* are species that we determined to have the opportunity to become established but that have not done so. This latter group of species was determined by identifying species that are in the trade but not established in Canada.

We developed a list of freshwater plant species in trade in Canada for assessment. This was largely derived from an original list provided by Eric Snyder (pers. comm. Ontario Ministry of Natural Resources). It was supplemented by water garden surveys undertaken in the Toronto area (OMNR, Aurora District, unpubl. data) and online (Marson et al. 2009b). The list was modified by excluding species that were:

1) on Snyder's original list, but not in trade;
2) not aquatic;
3) sold as aquarium species but not aquatic in the wild (e.g., *Lysimachia nummularia*); and,
4) already included on the list of species in Gordon et al. (2012) or assessed later by Crysta Gantz.

First dates of importation into Canada were not available for these species; therefore, it is unknown how long these species have been present in Canadian or global trade.

Of all assessed species, only 9 are not in trade or used for any commercial purposes. The species in trade in this data set represent a large proportion of total freshwater aquatic plant species in trade.

While some of the species categorized as "Not established" may be naturalized somewhere in Canada, we did not find this information in a thorough search of the literature and online databases. Also, we did not have specific introduction date information for the data set for Canada, however since the species have been present in the U.S. (established and/or in the trade) for at least 30 years, it is likely that they have an equally long history in Canada.

In the U.S. AqWRA, certain “default scoring” rules were developed to assist in answering questions for which little or no information might be available. A species must have at least a 30 year history in the global trade in order to respond to a question with a default scoring rule. This time frame was picked somewhat arbitrarily to account for lag time, however it may be conservative. Species belonging to primarily freshwater aquatic plant families are more likely to be invaders than species from most other plant families (Daehler 1998). The invasion process could occur more quickly than a 30-year time frame would suggest.

Following Gordon et al. (2012), we categorized aquatic plant species as attached-floating, erect emergent, free-floating, sprawling emergent, or submerged. See Cook et al. (1974) for a full description of each category. Some of these species have the ability to survive in both water and on dry land; however species that do not complete at least part of their life cycle in water were excluded from this analysis. The species belong to many families and all growth forms, although phylogenetic and growth form diversity were not the primary factors used in the species selection process. Presence in the trade and prior establishment in Canada and the U.S. were the primary factors.

As described above, Gordon et al. (2012) developed a three-tier scale of impacts, based on species’ invasion history in the United States. We have adopted this scheme with a slight change in terminology (Table 1). The purpose of this impact scale is to develop a model by looking at species with a known history of establishment and/or impact. The accuracy of predictions is best determined with this method. Because of the lack of data pertaining to invasive status of the species in Canada, we categorized the species for this assessment with the best information available, that is, whether or not the species is established in Canada. We did not develop a full Canada-specific model, but did have the ability to assess species, obtain a total score for each species, and determine an outcome based upon the score thresholds published in Gordon et al. (2012). Importantly, we modified the climatic range of the tool to be applicable to Canadian conditions.

Species and scores from the U.S. AqWRA modified for Canada were categorized by outcome (high or low risk) based upon two sets of thresholds. The threshold is the score (or scores in some cases) where classification accuracy is maximized for each group being compared (e.g., established vs. not established species). One threshold (score ≥40) represents the statistical grouping of “Established, not invasive” species (see Table 1 for definitions) with “Not established” species. This is a less conservative approach as it groups species that have not established with those that have, resulting in a higher threshold distinguishing invasive from non-invasive species. The other threshold (score ≥24, 29, 31; all have equivalent classification accuracy) groups “Established, not invasive” and “Established, invasive” species, resulting in a lower score threshold and more species screened as “high risk”. The analyses used to identify these thresholds are provided in Figures 1 and 2.

Table 1. Definitions of establishment and invasiveness for model developed in Gordon et al. (2012).

Established, invasive	Forming reproducing, self-sustaining populations; documented ecological impacts
Established, not invasive	Forming reproducing, self-sustaining populations; no documented ecological impacts
Not established	Not established, but in the trade for at least 30 years

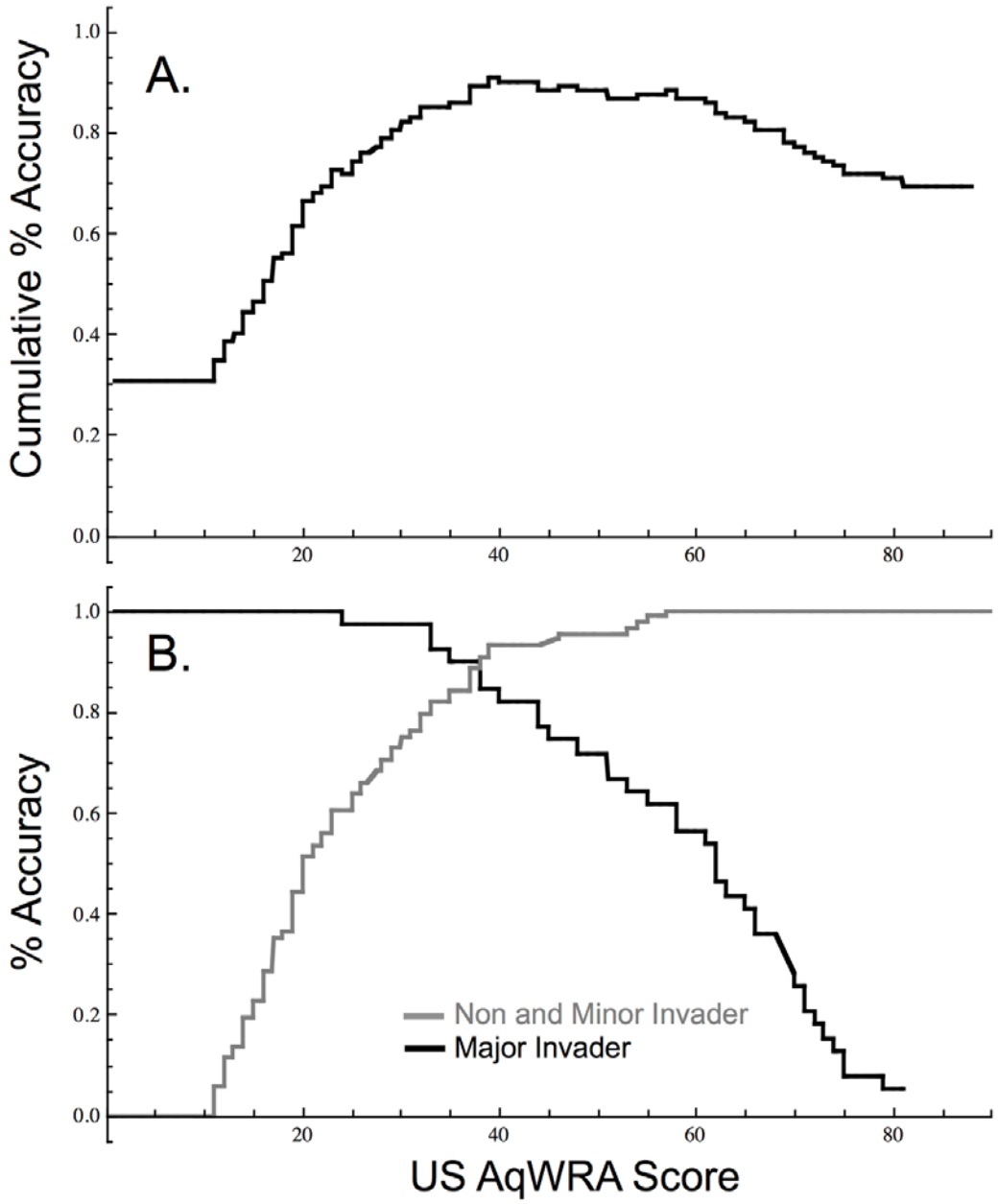

Figure 1. Accuracy of the model for the United States for not established and established, not invasive species combined, versus established, invasive species (n = 127). A. Cumulative percent accuracy, maximized at 90.6% at a threshold score of 40 differentiating the two groups. B. Independent percent accuracy for each of the two groups (Gordon et al. 2012).

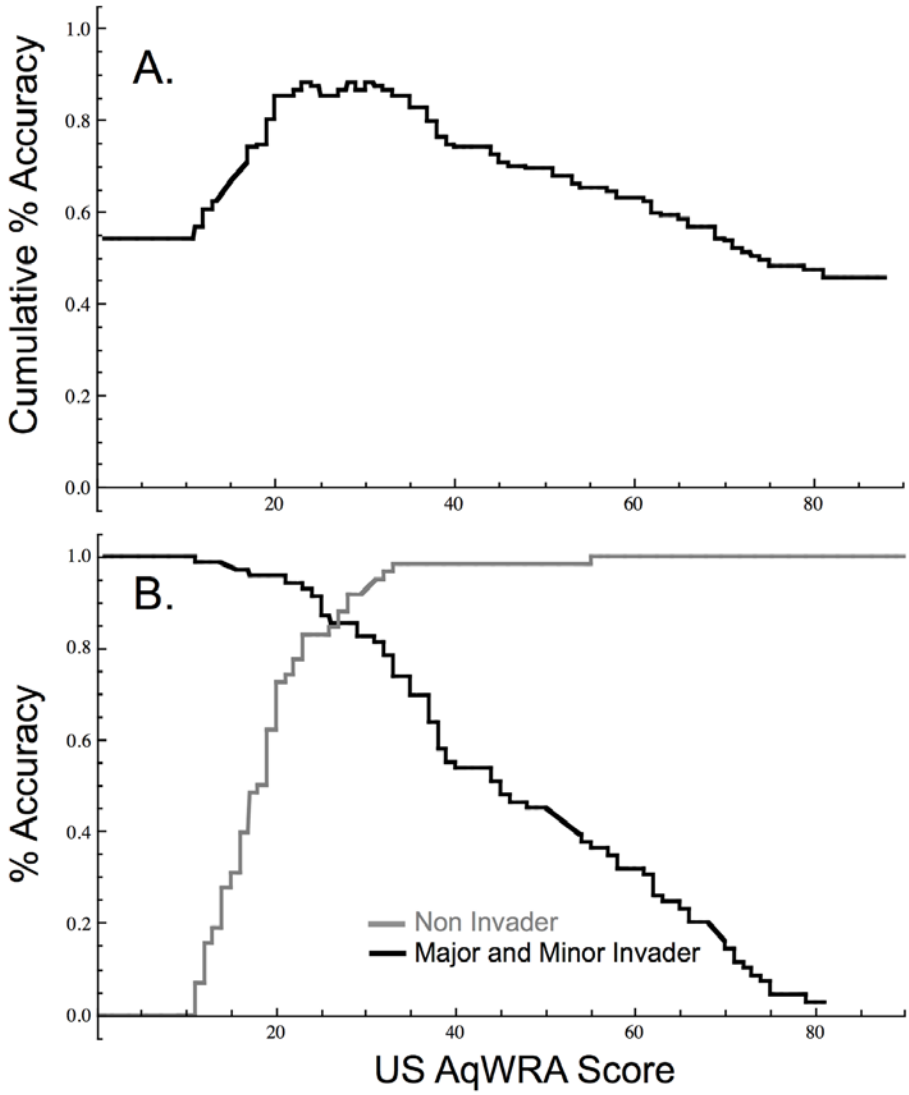

Figure 2. Accuracy of the model for the United States for not established versus established, not invasive and established, and invasive species combined (n = 127). A. Cumulative percent accuracy, maximized at 88.2% at threshold scores of 24, 29, and 31 equally differentiating the two groups. B. Independent percent accuracy for both groups combined (Gordon et al. 2012).

EVALUATING FRESHWATER PLANT SPECIES BASED ON CLIMATE TOLERANCE FOR CANADA

USDA hardiness zones, which range from 1-13 (Figure 3), can be used to evaluate climate similarity. The USDA hardiness zone system is currently used for screening plant introductions (Koop et al. 2011). The system is based upon average minimum temperatures in geographically defined areas (i.e., zones), which is a major indicator of survival for plants. Hardiness zones for each species were determined based on the general native and non-native established ranges (if applicable) derived from the Global Biodiversity Information Facility (GBIF) database, TROPICOs – an online meta-database of herbarium specimens and horticultural references. In some cases, hardiness zone information was obtained from the horticultural literature (e.g., Speichert and Speichert 2004). All hardiness zone matching was conducted

based upon recent climate data (2002-2011) and did not incorporate climate change projections.

Under current climate conditions, hardiness zones 1-10 are present in Canada; most of Canada is represented by hardiness zones 1-5, with the warmer zones occurring in southwestern British Columbia (especially Vancouver Island) (Figure 3).

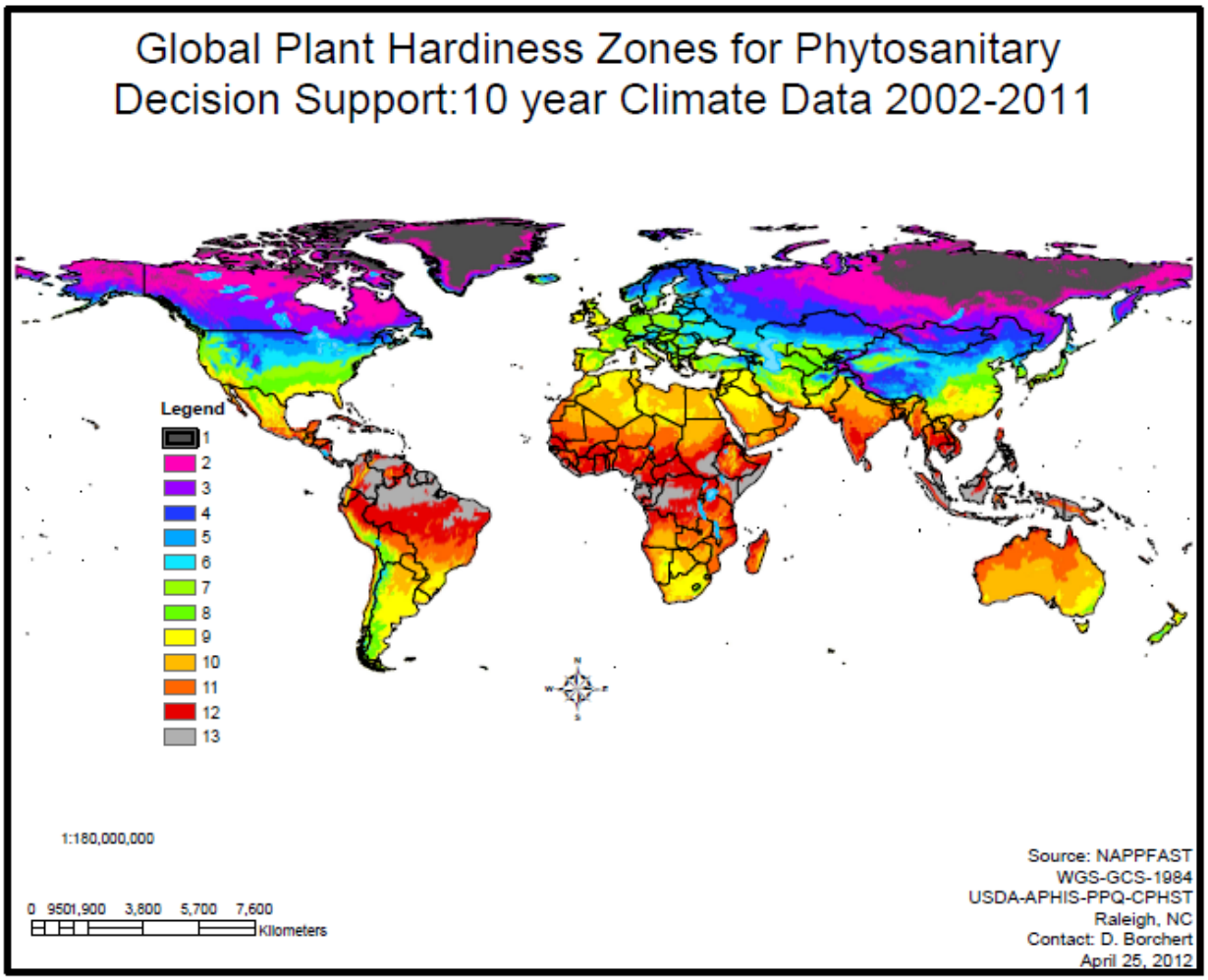

Figure 3. USDA Global Plant Hardiness Zones. 2012 Maps based on CFSR base data, not accounting for climate change (NAPPFAST 2012).

RESULTS

We evaluated each species and score using the thresholds outlined in Gordon et al. 2012 (Tables 2). Scores below each set of thresholds resulted in a “low risk” outcome; those above, a “high risk” outcome. An outcome was considered correct if it matched the *a priori* species category, that is, whether or not the species is established in Canada. Correct outcomes would therefore be all “low risk” for not established species and all “high risk” for established species. Outcomes for species only established in the U.S. were not considered.

At a threshold of 40, 91% (49/54) of the not established species were correctly identified as low risk (Table 2). Twenty-seven species on the list are established in Canada. One species, *Egeria densa*, is ephemeral, meaning that it is not established, but recurs in the wild on a near-annual

basis, usually from cultivation (Brouillet et al. 2013). If this species is included in the accuracy calculation, 75% (21/28) of the species established in Canada were correctly identified as high risk.

All of the species established in Canada (and the ephemeral species, *Egeria densa*) were correctly identified as "high risk" at thresholds 24/29/31 (Table 2). Seventy-four percent (40/54) of the not established species were correctly classified as low risk.

The "Established in the U.S. only" category can be looked at from a more or less conservative perspective regarding risk management. A more conservative approach would be to consider these species as having a higher risk of establishing in Canada because they have already established in the U.S. Calculations of accuracy should include these counts into the numbers of species already established in Canada. In this case, at threshold 40, only 59% (44/75) of the established species would have been classified correctly. However at the lower thresholds, 24/29/31, 93% of the established species would have been classified correctly.

A less conservative approach would be to exclude species established in the U.S. only as a risk. Adding the "U.S. only" species to the not established category results in a correct classification percentage of 72% at threshold 40 and 45% at thresholds 24/29/31.

Table 2. U.S. AqWRA results for Canada (n=129 freshwater plant species). Number of species screened as low and high risk categories at each threshold, sorted by establishment status. See Appendix 1 for list of results by species.

	Threshold 40: Low Risk	**Threshold 40: High Risk**	**Thresholds 24/29/31: Low risk**	**Thresholds 24/29/31: High risk**
Not established	91% (49/54)	9% (5/54)	74% (40/54)	26% (14/54)
Established in the U.S. only	51% (24/47)	49% (23/47)	11% (5/47)	89% (42/47)
Established in Canada	25% (7/28)	75% (20 + 1 ephemeral/28)	0% (0/28)	100% (27 + 1 ephemeral/28)

SCREENING FRESHWATER PLANT SPECIES IN TRADE IN CANADA

We followed the same procedure for evaluating the additional set of species in trade as we did for the list above. All of the not established species were correctly classified at threshold 40; however only 25% (1/4) of the established species correctly had high risk outcomes. At thresholds 24/29/31, the not established species are correctly classified 67% of the time. The established species are correctly classified 25% (1/4) of the time.

Considering the "Established – U.S. only" category for this group of species as a higher risk (i.e., considering a "high risk" outcome as accurate), results in 20% accuracy at threshold 40 and 60% at thresholds 24/29/31. Including these species in the "low risk" category results in accuracies of 80% at threshold 40 and 40% at 24/29/31.

Table 3. U.S. AqWRA results for freshwater plant species in trade in Canada (n=20). Number of species screened as low and high risk categories by threshold, sorted by establishment status. See Appendix 1 for list of results by species.

	Threshold 40: Low risk	**Threshold 40: High risk**	**Thresholds 24/29/31: Low risk**	**Thresholds 24/29/31: High risk**
Not established	100% (11/11)	0% (0/11)	67% (6/9)	33% (3/9)
Established - U.S. only	80% (4/5)	20% (1/5)	40% (2/5)	60% (3/5)
Established - Canada	75% (3/4)	25% (1/4)	75% (3/4)	25% (1/4)

DISCUSSION

Overall, the U.S. AqWRA did a good job of predicting not established and established species at both sets of thresholds, with 91% and 75% accuracy for not established and established species, respectively at threshold 40 and 74% and 100% respectively at thresholds 24/29/31 (Table 2). If considering the "Established – U.S. only" species from a more conservative perspective (i.e., species established in the U.S. are more likely to establish in Canada), the 93% accuracy at thresholds 24/29/31 is more favorable. More species that are likely to establish would be kept out of the country at these lower thresholds.

If taking the less precautionary approach of including species that have established in the U.S. as correctly predicted at a "low risk" outcome, threshold 40 yields a better prediction accuracy (72%) than thresholds 24/29/31 (45%). These species may or may not become established in Canada but the lower prediction accuracies resulting from this approach mean that it is better to consider the "Established – U.S. only" species as a bigger risk. Using the lower thresholds also results in better prediction of both established and not established species overall.

We evaluated the additional species in trade list separately. The prediction accuracies for not established and established species were lower overall at both thresholds, although the sample size for this data set was significantly smaller. As with the above data set, prediction accuracy is better when evaluating the "Established – U.S. only" species at thresholds 24/29/31, however overall prediction is better at threshold 40.

Different outcomes at different thresholds have been presented. The reason for this is that determination of acceptable risk is a policy, not a science decision. The U.S. AqWRA modified for Canada works very well at both sets of thresholds. Decision-making will depend on what makes the most sense for all stake-holders involved in the process.

SUMMARY

The range of possible thresholds represents a range of risk tolerance. Identifying an acceptable level of risk tolerance is a risk management decision; therefore, screening results have been provided for a range of thresholds. Risk managers will need to decide which threshold best represents their risk tolerance.

A total of 129 species with native and/or introduced ranges in hardiness zones 1-10 were screened using the U.S. AqWRA (Appendix 1).

- 91% of the not established species were correctly classified at threshold 40. The majority (75%) of the established species (and the ephemeral species, *Egeria densa*) were correctly classified at this threshold.
- All of the species (100%) established in Canada (and the ephemeral species, *Egeria densa*) were correctly classified at thresholds 24/29/31. The majority (74%) of the not established species were correctly classified at these thresholds.
- The "Established – U.S. only" category can be looked at from a more or less conservative perspective regarding risk management. A more conservative approach considers these species as higher risk because they have already established in the U.S.; a less conservative approach excludes these species because they have not established in Canada.

A total of 20 freshwater plant species in trade in Canada were screened using the U.S. AqWRA.

- All of the not established species were correctly classified at threshold 40, however only 25% of the established species were correct. The remaining 75% in this category may be incipient invaders or established without exhibiting any invasive tendencies.
- At thresholds 24/29/31, 67% of the not established species were correctly classified; the remaining may be potentially invasive. Only 25% of the established species were correct at these thresholds. As with threshold 40, the remaining 75% may be incipient invaders or not invasive at all.

These results suggest that the U.S. AqWRA SLRA approach effectively distinguishes established NIS from not established NISin Canada. While other risk assessment methods for plants can still be developed and tested (e.g. rapid screening, trait-based approaches, detail-level risk assessments; see Keller and Drake (2009)), the AqWRA method has been applied to several countries (Champion and Clayton 2000, 2001), comprehensively tested for the United States (Gordon et al. 2012), and has been peer reviewed.

CONCLUSIONS

Following climate screening, the SLRA method of Gordon et al. (2012) was used to assess a total of 149 species. Under current climate conditions, 51 species had high risk outcomes at threshold 40 and 93 at thresholds 24/29/31. All species should also be assessed for climate tolerance under future climate scenarios.

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APPENDICES

Appendix 1. Species with native and/or naturalized range occurring in USDA Global Plant Hardiness Zones 1-10 (n = 129).

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Ceratophyllum muricatum subsp. *australe* (Griseb.) Les[3]	Prickly hornwort	9	11	U.S.	Low	Low
Echinodorus martii Micheli	Ruffled Amazon sword	9	11	No	Low	Low
Heteranthera zosterifolia Mart.	Stargrass	4	11	No	Low	Low
Eriophorum latifolium Hoppe	Grey cotton-grass	4	11	No	Low	Low
Cryptocoryne crispatula Engl.	Balansae crypto	9	12	No	Low	Low
Echinodorus palaefolius (Nees & Mart.) J.F. Macbr.	Mexican sword-plant	9	12	No	Low	Low
Echinodorus uruguayensis Arechav.	Uruguay Amazon sword	9	12	No	Low	Low
Potamogeton gayii A. Benn.	Slender pondweed	2	12	No	Low	Low
Aponogeton ulvaceus Baker	Compact aponogeton	10	13	No	Low	Low
Aponogeton crispus Thunb.	Ruffled sword plant	10	14	No	Low	Low
Elatine macropoda Guss.	Southern waterwort	4	14	No	Low	Low
Aponogeton natans (L.) Engl. & Krause	Floating lace plant	7	15	No	Low	Low

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Nymphaea × *daubenyana* W.T. Baxter ex Daubeny	Dauben's waterlily	9	15	U.S.	Low	Low
Wolffia welwitschii Hegelm.	Pond bogmat	7	15	No	Low	Low
Echinodorus paniculatus Micheli	Amazon sword-plant	9	16	No	Low	Low
Ludwigia helminthorrhiza (Mart.) H. Hara	Rattlebox	3	16	No	Low	Low
Nymphaea colorata Peter.	Blue pygmy	10	16	No	Low	Low
Victoria cruziana A.D. Orb.	Santa Cruz water-lily	9	16	No	Low	Low
Bolbitis heudelotii (Bory ex Fée) Alston	African water fern	10	17	No	Low	Low
Limnophila indica (L.) Druce	Indian marshweed	9	17	U.S.	Low	Low
Nymphaea candida C. Presl	Hardy waterlily	2	17	No	Low	Low
Nymphoides crenata (F. Muell.) Kuntze	Wavy marshwort	7	17	No	Low	Low
Saururus chinensis (Lour.) Baill.	Chinese lizard's tail	5	17	No	Low	Low
Utricularia aurea Lour.	Golden bladderwort	3	17	No	Low	Low
Aponogeton madagascariensis (Mirb.) H. Bruggen	Laceleaf	10	19	No	Low	Low
Cyperus longus L.	Sweet cyperus	4	19	No	Low	Low

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Euryale ferox Salisb. ex K.D. Koenig & Sims	Gorgon	4	19	No	Low	Low
Lilaeopsis novae-zelandiae A.W. Hill	Micro sword	7	19	No	Low	Low
Monochoria hastata (L.) Solms[1,2,3]	Arrowleaf falsepickerelweed	9	19	No	Low	Low
Potamogeton wrightii Morong	Potamogeton	7	19	No	Low	Low
Regnellidium diphyllum Lindm.	Two-Leaf water clover	9	19	No	Low	Low
Acorus gramineus Sol. ex Aiton	Grass-leaf sweet-flag	5	20	No	Low	Low
Crinum erubescens Aiton	Swamp lily	9	20	No	Low	Low
Lasia spinosa (L.) Thwaites	Lasia	6	20	No	Low	Low
Nechamandra alternifolia (Roxb.) Thwaites	Nechamandra	6	20	No	Low	Low
Philydrum lanuginosum Banks & Sol. ex Gaertn.	Frogmouth	7	20	No	Low	Low
Utricularia stellaris L. f.	Star-shaped bladderwort	3	20	No	Low	Low
Cardamine lyrata Bunge	Chinese-ivy	2	21	No	Low	Low
Schoenoplectus glaucus (Lam.) Kartesz[3]	Tuberous bulrush	5	21	U.S.	Low	Low
Utricularia australis R. Br.	Bladderwort	3	22	No	Low	Low

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Marsilea drummondii A. Braun	Common nardoo	5	22	No	Low	Low
Bolbitis heteroclita (C. Presl) Ching	Asian water fern	4	23	No	Low	Low
Canna × *generalis* L.H. Bailey & E.Z. Bailey	Common garden canna	7	23	U.S.	Low	Low
Colysis pteropus (Blume) Bosman	Java fern	9	23	No	Low	Low
Gratiola peruviana L.	Austral brooklime	7	23	No	Low	Low
Murdannia keisak (Hassk.) Hand.-Mazz.[3]	Marsh dewflower	4	24	U.S.	Low	High
Eichhornia paniculata (Spreng.) Solms[3]	Brazilian water hyacinth	9	25	U.S.	Low	High
Iris ensata Thunb.	Japanese water iris	2	25	Canada & U.S.	Low	High
Nymphaea capensis var. *zanzibariensis* Conard	Cape blue water-lily	9	25	U.S.	Low	High
Cyperus serotinus Rottb.	Tidal marsh flat sedge	4	26	U.S.	Low	High
Ranunculus lingua L.	Greater spearwort	4	26	No	Low	High
Typha minima Funck in Hoppe	Dwarf cattail	3	27	No	Low	High
Aldrovanda vesiculosa L.	Waterwheel plant	6	27	No	Low	High
Gratiola officinalis L.	Gratiola	3	28	No	Low	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Hesperantha coccinea (Backh. & Harv.) Goldblatt & J.C. Manning	River-lily	6	28	No	Low	High
Hygrophila difformis (L.f.) Blume	Water-wisteria	9	29	U.S.	Low	High
Nymphoides indica (L.) Kuntze	Water-snowflake	4	29	U.S.	Low	High
Hottonia palustris L.	Water-violet	5	30	No	Low	High
Sagittaria sagittifolia subsp. *leucopetala* (Miq.) Hartog	Chinese arrowhead	6	30	No	Low	High
Cyperus prolifer Lam.	Dwarf papyrus	9	32	U.S.	Low	High
Ludwigia adscendens (L.) H. Hara[3]	Water-primrose	8	32	No	Low	High
Veronica beccabunga L.	European brooklime	5	32	Canada & U.S.	Low	High
Eichhornia azurea (Sw.) Kunth[1]	Anchored water-hyacinth	9	33	U.S.	Low	High
Hydrocotyle vulgaris L.	Marsh pennywort	5	33	No	Low	High
Limnophila sessiliflora (Vahl) Blume[1]	Asian marshweed	6	33	U.S.	Low	High
Rotala rotundifolia (Buch.-Ham. ex Roxb.) Koehne	Roundleaf toothcup	5	33	U.S.	Low	High
Nasturtium microphyllum Boenn. ex Rchb.	One-row watercress	3	35	Canada & U.S.	Low	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Oenanthe aquatica (L.) Poir.	Fine-leaf water-dropwort	5	35	U.S.	Low	High
Cyperus involucratus Rottb.	Umbrella sedge	7	35	U.S.	Low	High
Monochoria vaginalis (Burm. f.) C. Presl ex Kunth[1,2,3]	Heartshape false pickerelweed	6	36	U.S.	Low	High
Ottelia alismoides (L.) Pers.[1,3]	Duck-lettuce	6	37	U.S.	Low	High
Alisma plantago-aquatica L.	Water-plantain	3	37	Canada & U.S.	Low	High
Houttuynia cordata Thunb.	Chameleon-plant	5	37	U.S.	Low	High
Mentha aquatica L.	Water mint	5	37	Canada & U.S.	Low	High
Nelumbo nucifera Gaertn.	East Indian lotus	2	38	U.S.	Low	High
Myosotis scorpioides L.	Forget-me-not	3	38	Canada & U.S.	Low	High
Callitriche stagnalis Scop. emend. Kutz	European water-starwort	4	38	Canada & U.S.	Low	High
Landoltia punctata (G. Mey.) Les & D.J. Crawford	Dotted duckmeat	7	38	U.S.	Low	High
Canna indica L.	Edible canna	8	39	U.S.	Low	High
Nymphaea lotus L.	Egyptian lotus	7	39	U.S.	Low	High
Stratiotes aloides L.[2]	Water soldiers	3	40	No	High	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Schoenoplectus mucronatus (L.) Palla	Rice-field bulrush	4	40	U.S.	High	High
Alternanthera sessilis (L.) R. Br. ex DC.[1]	Sessile joyweed	8	44	U.S.	High	High
Nasturtium officinale R. Br.	Watercress	3	44	Canada & U.S.	High	High
Sparganium erectum L.[1,2]	Simplestem bur-reed	5	44	U.S. (Native + introduced)	High	High
Cyperus difformis L.[3]	Small-flower umbrella-plant	5	45	U.S.	High	High
Glyceria fluitans (L.) R. Br.	Floating manna grass	4	45	Canada & U.S.	High	High
Hydrocleys nymphoides (Willd.) Buchenau	Water-poppy	8	46	U.S.	High	High
Acorus calamus L.	Sweet-flag	2	48	Canada & U.S.	High	High
Colocasia esculenta (L.) Schott	Taro	8	50	U.S.	High	High
Limnobium spongia (Bosc) Rich. ex Steud.[2]	American spongeplant	4	50	U.S. (Native + introduced)	High	High
Typha × *glauca* Godr.[3]	Cattail	3	51	Canada & U.S. (Native and introduced in both countries)	High	High
Sagittaria sagittifolia L.[1,2]	Hawaii arrowhead	4	51	No	High	High
Aponogeton distachyos L. f.	Cape-pondweed	5	53	U.S.	High	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Hygrophila polysperma (Roxb.) T. Anderson[1]	Indian swampweed	9	53	U.S.	High	High
Persicaria hydropiper (L.) Delarbre	Marsh-pepper smartweed	3	54	Canada & U.S.	High	High
Hymenachne amplexicaulis (Rudge) Nees	West Indian marsh grass	9	55	U.S.	High	High
Limnocharis flava (L.) Buchenau	Sawah-flower rush	9	55	No	High	High
Salvinia natans All.[4]	Floating watermoss	2	57	U.S.	High	High
Iris pseudacorus L.	Yellow-flag iris	4	58	Canada & U.S.	High	High
Urochloa mutica (Forssk.) T.Q. Nguyen	Para grass	8	58	U.S.	High	High
Marsilea quadrifolia L.	European water-clover	5	61	Canada & U.S.	High	High
Butomus umbellatus L.	Flowering-rush	3	62	Canada & U.S.	High	High
Hydrocharis morsus-ranae L.	European frog's-bit	4	62	Canada & U.S.	High	High
Ipomoea aquatica Forssk.[1]	Chinese water-spinach	9	62	U.S.	High	High
Panicum repens L.	Torpedograss	8	63	U.S.	High	High
Ludwigia peruviana (L.) H. Hara	Peruvian primrosebush	8	65	U.S.	High	High
Trapa natans L.	European water-chestnut	5	66	Canada & U.S.	High	High
Najas minor All.[3]	Brittle naiad	6	66	Canada & U.S.	High	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Cabomba caroliniana A. Gray[2]	Carolina fanwort	6	67	Canada (Introduced) & U.S. (Native + introduced)	High	High
Lagarosiphon major (Ridley) Moss[1,2]	Oxygen-weed	5	67	No	High	High
Azolla pinnata R. Br.[1,2]	Feathered mosquitofern	7	67	U.S.	High	High
Potamogeton crispus L.	Curly-leaf pondweed	3	69	Canada & U.S.	High	High
Typha angustifolia L.	Narrow-leaf cattail	3	69	Canada & U.S. (Native and introduced in both countries)	High	High
Vallisneria spiralis L.	Eel-grass	4	69	U.S.	High	High
Crassula helmsii (Kirk) Berger[2]	Swamp stonecrop	7	70	No	High	High
Salvinia minima Baker	Water spangles	7	70	U.S.	High	High
Egeria densa Planch.	Brazilian elodea	5	71	Canada (Ephemeral) & U.S.	High	High
Glyceria maxima (Hartm.) Holmb.	Reed sweet grass	3	71	Canada & U.S.	High	High
Pistia stratiotes L.	Water-lettuce	7	72	U.S. (Native and introduced)	High	High
Salvinia molesta D.S. Mitch.[1,2]	Giant salvinia	7	72	U.S.	High	High
Lythrum salicaria L.	Purple loosestrife	2	73	Canada & U.S.	High	High
Nymphoides peltata (S.G. Gmel.) Kuntze	Yellow floating-heart	2	74	Canada & U.S.	High	High

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Phragmites australis (Cav.) Trin. ex Steud.[2]	Common reed	2	75	Canada & U.S. (Native and introduced in both countries)	High	High
Myriophyllum aquaticum (Vell.) Verdc.	Parrot's-feather	5	75	Canada & U.S.	High	High
Alternanthera philoxeroides (Mart.) Griseb.	Alligator-weed	7	75	U.S.	High	High
Hydrilla verticillata (L. f.) Royle[1]	Hydrilla	3	79	U.S.	High	High
Myriophyllum spicatum L.	Eurasian water-milfoil	3	81	Canada & U.S.	High	High
Eichhornia crassipes (Mart.) Solms	Water-hyacinth	6	81	U.S.	High	High

[1] USDA Noxious Weed.
[2] Species not in Gordon et al. 2012, but assessed by authors after publication.
[3] Species not in trade or dispersed intentionally.
[4] Species in trade may actually be mislabeled *Salvinia minima*.

Additional notes:

Species *Ricciocarpos natans* (L.) Corda (Purple-fringed riccia) was assessed in Gordon et al. 2012, but is native to Canada and not included in this assessment.

Appendix 2. U.S. AqWRA results for freshwater plant species in trade in Canada (n=20).

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Nymphaea pygmaea (Salisb.) W. T. Aiton	Water lily	6	15	No	Low	Low
Typha lugdunensis P. Chabert	Cattail	5	15	No	Low	Low
Nymphaea nouchali Burm. f.	Blue lotus	6	16	No	Low	Low
Cyperus exaltatus Retz.	Tall flat-sedge	4	17	No	Low	Low
Sagittaria aginashi Makino	None	5	17	No	Low	Low
Nymphaea alba L.	European white waterlily	3	18	Canada	Low	Low
Trapa bicornis Osbeck	Horn nut	8	18	No	Low	Low
Wolffia brasiliensis Wedd.	Brazilian watermeal	5	21	Canada & U.S. (Native)	Low	Low
Nasturtium ×sterile (Airy Shaw) Oefelein	Sterile Nasturtium hybrid	6	22	Canada & U.S.	Low	Low
Orontium aquaticum L.	Golden-club	6	23	U.S. (Native)	Low	Low
Sagittaria guayanensis Kunth	Arrowhead-lily	8	23	U.S.	Low	Low

Scientific name	Common name	Lowest hardiness zone found	AqWRA score	Established in Canada &/or U.S.	Threshold 40 (US)	Thresholds 24,29,31 (US)
Potamogeton schweinfurthii A. Benn.	Pondweed	8	24	No	Low	High
Myriophyllum propinquum A. Cunn.	Common water milfoil	7	25	No	Low	High
Sagittaria subulata (L.) Buchenau	Awl-leaf arrowhead	4	26	U.S. (Native + introduced)	Low	High
Persicaria thunbergii (Siebold & Zucc.) H. Gross	Knoterid	3	27	No	Low	High
Egeria najas Planch.	Narrow leaf elodea	6	29	No	Low	High
Myriophyllum verrucosum Lindl.	Red water-milfoil	8	34	No	Low	High
Najas graminea Delile	Ricefield waternymph	7	38	U.S.	Low	High
Sagittaria platyphylla (Engelm.) J. G. Sm.	Delta arrowhead	7	61	U.S. (Native)	High	High
Myriophyllum heterophyllum Michx.	Broadleaf water-milfoil	5	72	Canada & U.S. (Native & introduced in both countries)	High	High

Appendix 3. The U.S. Aquatic Weed Risk Assessment Tool (AqWRA) (Gordon et al. 2012). Possible score range appears in bold prior to more specific guidance on the points associated with different responses in the scoring guidance for addressing each question. Questions and scores are modified from Champion and Clayton (2000, 2001) and Champion (pers. comm.).

Question	Scoring Guidance
Temperature tolerance (1.1)	**(0-3)** 3 if maintains photosynthetic tissue and summer growth form throughout winter, 2 if dies back to tuber/bulb/rhizome (or similar structure) during winter, 1 if adult plants completely die but viable seeds remain. 0 if the species is extirpated by summer or winter temperatures. Default to 1 for annual species.
Range of habitat (1.2)	**(1-3)** Score 3 if able to grow from water to dry land, 2 if water to wetland, or from shallow to deep (>5 m) water, 1 narrow range. Default = 1 if no information is available; 2 for free-floating plants, unless more information is available.
Water/substrate type tolerance (1.3)	**(1-2)** Score 2 if tolerant of sandy to muddy (or peaty) substrate, or oligotrophic to eutrophic waters, 1 if restricted by either. Default = 1 if no information is available.
Water clarity tolerance (1.4)	**(0-1)** Score 1 if unaffected by water clarity (i.e. floating or emergent, or submergents tolerant of very low light levels, such as *Myriophyllum spicatum* and *Hydrilla verticillata*). 0 if affected by water clarity.
Salinity tolerance (1.5)	**(0-1)** Score 1 if species can tolerate saline conditions, 0 if not. Habitat information can be used to determine a score of 0 if species is only found to occur in freshwater habitats.
pH tolerance (1.6)	**(0-1)** Score 1 if tolerant of both acidic and basic pH or no information is available, 0 if restricted to neutral, basic, or acidic pH.
Water level fluctuation - Tolerates periodic flooding/drying (1.7)	**(0-3)** Score 3 for species which have evidence of tolerating periodic flooding/drying with a specified time period longer than 1 month (e.g., "months"; "X months", "winter flooding"), 2 for evidence of tolerance of flooding/drying over a period of days/a couple of weeks, 1 for species that die back during periods of flooding/drying, and 0 for species that do not tolerate flooding/drying. Do not score if there is no information available.

Question	Scoring Guidance
Lentic - rivers, streams, drains, or other flowing waters, including their margins (2.1)	**(0-3)** Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.
Ponds, lakes and other standing waters, including their margins (2.2)	**(0-3)** Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.
Swamp, marsh, bog, or other wet areas not covered by 2.1 or 2.2 (2.3)	**(0-3)** Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed, 1 if present but not weedy, 0 if absent.
Establishment – into existing vegetation (2.4)	**(-5 to 0)** Score 0 if able to invade unmodified vegetation, -3 if the species can only colonize certain types of vegetation (e.g., turf-forming shoreline vegetation), -5 if there is no evidence that the species can move into intact vegetation. Default = 0 if there is evidence of establishment, but no specific information about level of invasion into existing vegetation and/or type of vegetation being invaded. Default = -3 for species that have not naturalized outside of their native range.
Establishment – into disturbed vegetation (2.5)	**(0 to 5)** Score 5 if able to aggressively colonize following vegetation clearance, newly constructed waterbodies or nutrient enrichment, 1 if the species grows in disturbed areas, but there is no other information, 0 if there is no evidence of establishment in disturbed areas. Information from either the native or introduced range may be used to answer this question. Default = 1 for no information.
Competition – between growth form (3.1)	**(0, 1, 2)** Score 2 if species forms dense stands that are documented to displace other growth forms (submerged, floating, emergent), 1 if some suppression, 0 if no displacement. Default = 0 if species has been in the trade globally for >30 years and there is no information about the species displacing other growth forms.
Dispersal outside catchment by natural agents, e.g. birds, wind (4.1)	**(0, 1, 3, 5)** Score 5 if species (including seeds, rhizomes, fragments etc.) well adapted, and likely to be frequently dispersed, by natural agents, 3 if transport by natural agents is possible but uncommon, 1 if propagule could be spread in bird crop, 0 if no, or extremely low, likelihood of dispersal by natural agents (e.g., Hydrilla is scored 1 because its turions can survive passage through duck guts, an agent of dispersal, but this is believed to happen rarely).

Question	Scoring Guidance
Dispersal outside catchment by accidental human activity (4.2)	**(1, 2, 3)** Score 3 major pathway, seeds/fragments adapted for easy transportation (e.g., via boat/trailer, fishing gear), 2 if the species is a floating plant or a macrophyte, but no explicit mention of high spread in the literature, 1 not mentioned, not likely to be spread by human activity based on growth form and life history. Default = 1 if no information is available.
Dispersal outside catchment by deliberate introduction (4.3)	**(0-1)** Score 1 if species is desirable to humans (e.g., or used for medicinal, food, ornamental, restoration, etc. purposes in the U.S. or elsewhere). If species is not used or no information exists, it should be scored a 0.
Effective spread within waterbody/ catchment (4.4)	**(0-1)** Score 1 for extensive spread within a waterbody or among waterbodies, 0 for no spread. Occurrence along stream or riverbanks or in rivers can be used as evidence, as well as evidence of water dispersal. Do not answer if there is no information available.
Generation time - Includes growth rate and time to maturity under ideal conditions. (5.1)	**(1, 2, 3)** Score 3 if rapid (reproduction in first year and >1 generation/year), 2 if annual or produces one generation every year including the first year, 1 if not reproductively mature in the first year. Default = 1 if no information is available.
Seeding ability - Quantity (6.1)	**(0-3)** Score 3 if >1000 seeds/plant/year, 2 100-1000, 1 <100 and/or evidence that seed are produced (in native or introduced range), 0 if seed not produced.
Seeding ability - Viability/persistence (6.2)	**(0-2)** Score 2 if highly viable for >3 years, 1 low viability or evidence of seed production with no information on viability, 0 no viable seeds.
Vegetative reproduction (7.1)	**(0, 1, 3, 5)** Score 5 for naturally fragmenting from rhizomes, stolons, or other vegetative growth into tissue capable of producing new colonies (e.g., *Egeria densa*), 3 if produces rhizomes/stolons, but there is no other information about the formation of new colonies elsewhere, 1 for clump-forming by vegetative spread, 0 for no vegetative spread.
Physical - water use (recreation) (8.1)	**(0-2)** Score 2 for major nuisance, 1 minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.

Question	Scoring Guidance
Physical – access (8.2)	**(0-2)** Score 2 for major nuisance, 1 minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.
Physical - water flow, power generation (8.3)	**(0-2)** Score 2 for major nuisance, 1 minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.
Physical - irrigation, flood control (8.4)	**(0-2)** Score 2 for major nuisance, 1 minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.
Aesthetic - visual, olfactory (8.5)	**(0-2)**. Score 2 for both visual and odor problems, 1 either, 0 neither or no mention of these impacts. Surface matting of macrophytes scores 1 for visual impact.
Reduces biodiversity (9.1)	**(0, 1, 3, 5)** Score 5 for extensive monospecific stands, 3 for species that become dominant, 1 for small monospecific stands, and 0 if species does not become dominant over other species. Default = 0 if species has been in the trade globally for >30 years and there is no information found or if the species is not naturalized outside of its native range.
Reduces water quality (9.2)	**(0, 1, 3)** Score 3 if evidence that this species causes deoxygenation (e.g., through extensive growth in shallow water) or other water quality loss (e.g., loss of water clarity because of high decomposition rates continuously during the growing season), 1 if deoxygenation or other water quality loss is likely based on seasonal growth cycles (e.g., macrophyte that gets to high density and dies off at end of summer), 0 otherwise. Default = 0 if species has been in the trade globally for >30 years and there is no information found.
Negatively effects physical processes (9.3)	**(0, 2)** Score 2 if species alters hydrology (e.g., increases the chance of flooding) or substrate stability (e.g., increases amount of sediment erosion or deposition), or other physical processes, 0 if the species has no history of modifying physical processes. Default = 0 if species has been in the trade globally for >30 years and there is no information found.

Question	Scoring Guidance
Health impairment, e.g. drowning, poisonous, sharp leaf edges, mosquito breeding habitat (10.1)	**(0-2)** Score 1 for one effect, 2 for 2 or more effects.
Weed of agriculture, including crops, livestock and aquaculture (10.2)	**(0-1)** Score 1 if a problem agricultural weed, 0 if no evidence that it is an agricultural weed, or if evidence states that species is in agricultural areas but not problematic.
Management - Ease of management implementation (11.1)	**(0-2)** Score 2 if accessibility to weed is difficult, e.g. dense tall impenetrable growths or growing in habitats that are difficult to access by roads or waterways (e.g., swamps). For species that have naturalized outside of their native range, default to a score between 0-2 based upon evidence about habitat and/or growth form if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.
Management - Recognition of management problem (11.2)	**(0-1)** Score 1 if difficult to assess weed, e.g. submerged; looks like another species. For species that have naturalized outside of their native range, default to a score between 0-1 based upon growth form evidence if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.
Management - Scope of control methods (11.3)	**(0-2)** Score 2 if no control method, 1 if only one control option. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.

Question	Scoring Guidance
Management - Control method suitability (11.4)	**(0-1)** Score 2 if control method not always acceptable, e.g. grass carp, unregistered herbicide. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.
Management - Effectiveness of control (11.5)	**(0-2)** Score 2 if ineffective, 1 if partial control. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2. Default = 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.
Management - Duration of control (11.6)	**(0-2)** Score 2 if no control, 1 if control for 3+ months. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.
Problem in other countries (12.1)	**(0, 1, 3, 4, 5)** Score 5 if species has been reported to be a widespread problem (i.e., a harmful weed in many other countries), 4 if species has been reported to be a harmful weed in 5 or fewer countries, 3 if species has been reported to be a widespread adventive (but not a harmful weed) in many other countries, 1 if species has been reported to be adventive in 5 or fewer countries, 0 if not adventive elsewhere.