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Weed Risk Assessment for Non-Herbicide Tolerant and Herbicide Tolerant Types of *Poa pratensis* L., Kentucky Bluegrass

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Executive Summary

We assessed the weed risk potentials of non-herbicide tolerant (hereafter, "non-genetically engineered", or non-GE) and herbicide tolerant (hereafter, "GE") types of *Poa pratensis* L., Kentucky bluegrass, to determine whether or not the species (which encompasses both types) is a candidate for listing. The Plant Protection Act (7 U.S.C. § 7701-7786, 2000) defines a noxious weed as "any plant or plant product that can directly or indirectly injure or cause damage to crops…, livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment." To determine that, we used a weed risk assessment tool that was validated using data on 204 plant species with known noxious behavior in the United States. The model predicts weed risk potential based on scores for Impact Potential (i.e., harm), and Establishment/ Spread Potential. The model was developed to assess basic invasive/weedy potential, however, and not to distinguish between plants with different genotypes. Except for being herbicide tolerant, we have no evidence that the growth and behavior of the GE type will differ significantly from that of the non-GE type.

The model measures Impact Potential with 18 scored questions about the types of damage to crops or the environment that a species may cause (e.g., reducing crop yields, requiring control, changing community structure or function, adverse effects on human property). We assess Establishment/Spread potential using 27 scored questions on species biology and history (e.g., invasiveness elsewhere, dispersal mechanisms). Our uncertainty about the risk scores discussed below was small because of the abundance of information about the biology, behavior, and performance of Kentucky bluegrass in the United States.

The Establishment/Spread Potential scores for the two types of Kentucky bluegrass were 23 for the non-GE type, and 24 for the GE type, which are high on the scale of -25 to 32. The one point difference, which is not significant, is due entirely to the herbicide tolerance of the GE type.

For Impact Potential, both types scored 2.5 on a scale of 1 to 5.1. That score is greater than all scores for non-invasive species we evaluated during model validation, but is low or moderate when compared with High risk species: the most harmful species (e.g., Canada thistle, *Cirsium arvense*) have scores of 4 or greater. In this case, because the model is qualitative, the score for Impact Potential may overestimate the true damage this species can cause. For example, although Kentucky bluegrass can act as an agricultural weed, we found very few reports for that in U.S. crops. It is also reported to be a weed of production crops in only two other countries, despite a wide distribution through Europe and Asia. It seems most problematic in grassland systems, yet no states regulate it or have it prioritized for control.

Based on those scores, the predictive logistic regression model indicated that both the non-GE and GE types have High weed risk potentials. Therefore, the species Kentucky bluegrass, *P. pratensis* (including both types), can be considered for regulation as a Federally listed noxious weed. That decision is explained separately.

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1. Introduction to the PPQ Weed Risk Assessment Process

1.1. Authority

PPQ regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). Our weed risk assessment guidelines (see below) were developed to determine whether or not species are candidates for listing as Federal noxious weeds. Such species are generally prohibited or restricted from entering the United States or moving through it (interstate). For transparency with stakeholders, these species are listed under the Federal Noxious Weed regulations (7 CFR § 360, 2010). Except for plant species unlikely to contaminate import or export pathways, most Federal noxious weeds are co-listed as noxious weed seeds (see 7 CFR § 361, 2010).

1.2. Background

PPQ WRA is consistent with international guidelines

In this document, we assess the weed risk potential of several plant species using Plant Protection and Quarantine's (PPQ) weed risk assessment guidelines (PPQ, 2009). The weed risk assessment (WRA) process and the predictive model utilized are consistent with the general guidance provided by international and North American standards for risk assessment (IPPC, 2009: ISPM Nos. 2 & 11; NAPPO, 2008: RSPM No. 32). The weed risk assessment below contain information relevant for the initiation, species categorization, and risk assessment phases. These phases correspond to Stage 1 (initiation) and Stage 2 (risk assessment) of risk analysis (IPPC, 2009: ISPM No. 2).

A weed risk assessment can be initiated for any number of reasons, including, but not limited to, evaluation for listing or delisting Federal Noxious Weeds or plants for propagation which are designated as "Not Allowed Pending Pest Risk Assessment" (NAPPRA) (APHIS, 2011). We note the reason for initiation, along with other background information, in each assessment.

We combine pest categorization and pest risk assessment

One of the phases of risk analysis is categorization of the species of interest, in which it is evaluated to determine whether it has the characteristics of a quarantine species or a regulated non-quarantine species (IPPC, 2009: ISPM No. 2). The intent of this phase is to identify (i.e., screen out) species that clearly do not meet these definitions before subjecting them to a potentially lengthy risk assessment process. However, because some plants that do not have evidence of spread or impact elsewhere later become weeds (IPPC, 2009: ISPM No. 2; Whitney and Gabler, 2008), PPQ subjects most plants to the full weed risk assessment process to evaluate their weed potential based on their inherent biological traits (e.g., Mack, 1996; Reichard, 2001). Essentially, we combine the species categorization and risk assessment phases, and use the risk assessment as a screening tool to categorize the potential risk and weed status of the plant.

1.3. Terminology

Confounded weed terminology

Terminology in the weed/invasive plant literature is confounded, as words such as "weed" and "invasive" have variable and subjective meanings (Richardson et al., 2000). Development and validation of the PPQ model required some flexibility in terminology, particularly at different phases of the work. As with other studies that have developed and/or tested WRA systems (e.g., Gordon et al., 2008; Pheloung et al., 1999), we relied on information available in the literature to identify plants belonging to three categories of invasiveness: non-invaders, minor-invaders, and major-invaders. In this usage, invader broadly refers to a plant's overall ability to spread and cause negative impacts, and reflects two components of risk (IPPC, 2009: ISPM No. 11).

In the PPQ WRA system, we evaluate the establishment/spread potential and impact potential of a species as two separate risk elements. Under establishment and spread we adopt a stricter definition of invasive that refers to a species' capacity to establish and spread throughout a landscape (*sensu* Richardson et al., 2000). However, at the end of the PPQ WRA process, we return to the broad usage of the term invader because we relate a species' risk scores back to the dataset that was used to develop and test the WRA model. If introduced into the United States, Low risk plants are likely to become non-invaders, while High risk plants are likely to become major invaders.

1.4. Risk assessment overview

Model based on U.S. plants with known behavior

We developed and validated the WRA process (Stage 2) using 204 plants with known weed/invasive (noxious) behavior in the United States (non-invaders, minor-invaders, and major-invaders) (*manuscript in review*). The process consists of a weed risk model as well as a secondary screening tool developed to further evaluate plants with intermediate risk scores.

WRA process does not make policy recommendations

We do not use the PPQ WRA process to make policy recommendations. Instead, we categorize weed risk and relate a species' risk scores to the reference dataset of species with known invasiveness in the United States. This process results in one of three possible conclusions: "Low risk," "Evaluate further," and "High risk." While these conclusions are not official policy recommendations, the analytical and statistical methodologies behind them support management decisions of allowing entry for Low risk species, denying entry for High risk species, and evaluating further other species as appropriate. This yields results similar to outcomes reached using other weed risk assessment systems (e.g., Pheloung et al., 1999; Reichard and Hamilton, 1997).

Agency does risk management separately

PPQ program managers use weed risk assessments to evaluate what Federal action may be appropriate. If regulatory action is prudent, program managers evaluate which risk mitigation options would reduce risk to an acceptable level.

2. Guide for Interpretation of WRA Results

In this document, we summarize the results for one or more weed risk assessments. For a description of the WRA process and model, or a guide on answering questions used in the assessment, see the PPQ WRA Guidelines (PPQ, 2009).

Establishment/spread and Impact risk elements Below, we present risk scores for the establishment/spread and impact risk elements, along with their mean uncertainty. Risk scores can range from -25 to 32 and 1.0 to 5.1, respectively, with greater scores indicating greater risk. Descriptions with each risk element highlight the risk factors that contributed to that score. We used the scores from these two risk elements to characterize the overall risk potential of the species and estimate the likelihood that it will be a non-invader, minor-invader, or major-invader (see below).

Geographic and entry potential are separate Although we do not use the geographic and entry potentials of a species to estimate the overall invasive potential of a plant, these elements are none-the-less important components of risk. We report these elements separately so that regional and national managers can make appropriate decisions for their jurisdictions. Under geographic potential, we report the percent of the United States suitable for species establishment based on three climate variables: USDA cold plant hardiness zones, Köppen-Geiger climate classes, and ten-inch precipitation bands.. Under entry potential we evaluate the likelihood of species entry into the United States. All four scores can range from 0 to 1, with higher scores indicating higher risk.

Uncertainty For each of the risk scores described above, we report an index of uncertainty that describes the overall level of uncertainty associated with that risk element. The index ranges from zero to one, where a one corresponds to maximum uncertainty (i.e., all questions answered as unknown). The index considers the uncertainty rating given by the analyst to each question (negligible, low, moderate, high, or maximum) and the relative weight of each question in the risk element.

WRA model In the next section of each assessment, we present the results from the WRA model and secondary screening (2° screening). The core of the WRA model is a logistic regression model (Appendix A) that uses the scores from the establishment/spread and impact risk elements to determine the probabilities that a species will be a major-, minor-, and non-invader (*sensu lato*). Because most management decisions for plants will be to either allow or exclude entry, we used cutoff scores determined by Receiver Operating Characteristic (ROC) curve analysis (Appendix B) to categorize the overall risk of plant introduction (i.e., “low risk” or “high risk”) and facilitate management decisions. ROC curve analysis is an analytical tool used in decision making that maximizes the predictive ability of a model while minimizing false-positive and false-negative errors (Caley and Kuhnert, 2006; Metz, 1978).

Secondary screening of species classified as “evaluate further” Species classified as “evaluate further” are species with intermediate risk scores, and are subjected to a secondary screening tool (Appendix C). With this tool, we examine specific traits that by our analysis were highly associated with plant invasive status in the United States. This approach is designed to help resolve the risk potential of the species. However, even after secondary screening, some species may remain in the “evaluate further” category.

In the discussion section of each assessment below, we briefly review the available evidence and report our final conclusion. We also introduce additional information that may be relevant to decision-makers.

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4. Weed Risk Assessment

4.1. Non-GE *Poa pratensis* L., Kentucky Bluegrass

Background Information

Family: Poaceae

Initiation: The International Center for Technology Assessment and the Center for Food Safety (ICTA/DFS) formally petitioned APHIS requesting that the Agency list turf grass types of creeping bentgrass, *Agrostis stolonifera*, and Kentucky bluegrass, *Poa pratensis*, that had been genetically engineered (GE) for tolerance to the herbicide, glyphosate, as Federal Noxious Weeds under the noxious weed provisions of the Plant Protection Act. APHIS denied this request for creeping bentgrass based on a 2003 WRA. APHIS determined that GE creeping bentgrass did not meet the criteria to be regulated as a Federal Noxious Weed. The decision was subsequently challenged in Federal court.

The United States District Court for the District of Columbia vacated APHIS' denial and remanded the matter back to the Agency. In response to the Court, APHIS is publishing a WRA for both the non-GE and GE types of Kentucky bluegrass.

Foreign distribution: *Poa pratensis* is a common and widely cultivated species, and includes several infraspecific taxa (FNA Editorial Committee, 2007). Most infraspecific taxa are native to Europe and temperate Asia, although some also range south into northern Africa and northern India (NGRP, 2011). In general, *P. pratensis* is widely established throughout the temperate regions of the world (NGRP, 2001; FNA Editorial Committee, 2007).

U.S. distribution & status: Two subspecies of *P. pratensis* (subspp. *alpigena* and *colpodea*) have a circumpolar distribution and are native to North America. Subspecies *alpigena* ranges into the contiguous United States, but is not very common (FNA Editorial Committee, 2007). Most cultivated forms of *P. pratensis* resemble subsp. *irrigata*, *pratensis*, and *angustifolia* (FNA Editorial Committee, 2007). Thus, the naturalized populations recorded in several databases likely represent non-native taxa (Kartesz, 2010; Nature Serve, 2011; NGRP, 2011).

WRA area: The area considered here is the United States and its territories and possessions.

4.1.1.Analysis of Non-GE Kentucky Bluegrass

Establishment/Spread Potential

Risk score = 23 Mean uncertainty = 0.08

Kentucky bluegrass spreads aggressively (Nature Serve, 2011; Weber, 2003). It has escaped cultivation into native prairies (Grant et al., 2009). Still, we found very few reports of it invading managed agricultural systems (e.g., Bridges, 1992; see below).

Impact Potential

Risk score = 2.5 Mean uncertainty = 0.17

That score is greater than all those for non-invasive species in the validation dataset, but is low or moderate when compared with High risk species. The most harmful species (e.g., Canada thistle, *Cirsium arvense*) have Impact Potential scores of 4 or greater. In this case, because the model is qualitative, the score for Impact Potential may overestimate the damage the species could cause, for the following reasons.

Although Kentucky bluegrass can act a weed in U.S. agricultural systems, that is only reported by Bridges (1992) for a total of three crops—apples, spearmint, and peppermint—out of the hundreds of crops grown in the United States. In apples, we have found no evidence of it being a significant weed (e.g., listed but with no indication of severity in Rifai et al., 2002 [Nova Scotia, Canada]). Another report has volunteer bluegrass as a weed in bluegrass seed plots (Lee, 1978). Given both the long history of Kentucky bluegrass in the United States and the paucity of reports about weedy behavior in U.S. crops, it seems highly unlikely that it is a significant weed in managed agricultural systems in the United States.

Furthermore, it is reported to be a weed of production crops in only two other countries, despite a wide distribution through Europe and Asia. It is listed as an arable weed in Japan (Holm et al., 1979; Morita, 1997), but is not regulated or heavily controlled (NIES, 2011). In Australia, it is an agricultural weed, but was not ranked as either a noxious weed, or a serious, high impact weed (Randall, 2007).

Most of the evidence for invasiveness by Kentucky bluegrass comes from grassland (esp. prairie) ecosystems, as mentioned above for Establishment/Spread Potential. It may become problematic particularly when such areas are not managed properly (e.g., Grant et al., 2009). When Kentucky bluegrass invades native prairies, the recommended management is typically to apply general, adaptive (i.e., location specific) programs to control multiple species, not just Kentucky bluegrass (e.g., Grant et al., 2009; Hendrickson and Lund, 2010). Preferred methods of control are grazing and controlled burns (FEIS, 2009). Fire is usually a successful method of control for Kentucky bluegrass in these systems (Sather, 1996). When herbicides are used in such situations, invasive Kentucky bluegrass populations can be reduced to low levels in one or two seasons (Waller and Schmidt, 1983).

Kentucky bluegrass has demonstrated value in some natural areas, however. For example, it can be an important part of the diet of wildlife (e.g., elk, bighorn sheep) (FEIS, 2009), and Kentucky bluegrass is one of the most important forage species for cattle and sheep summering in mountain meadows in eastern Oregon (McInnis and Vavra, 1986).

It is also important to note that Kentucky bluegrass is a recommended pasture grass in some eastern and western states (e.g., Tregoning, N/D; Wiedmeier et al., 2005), and of course is widely grown as a turf grass species in all 50 United States. It is a component of many grass mixes sold by major home improvement and gardening centers (pers. observation). Finally, no states currently regulate it, and we have found no evidence that any have prioritized it for control.

Geographic Potential Kentucky bluegrass is a cool-season grass with a high adaptive potential as evidenced by known occurrences spanning all USDA hardiness zones, all rainfall bands 0 to 100+ inches per year, and all bioclimatic climate classes except polar icecaps (GBIF, 2011; NAPPFAST, 2008) (Fig. 1). It has naturalized in all states of the United States (Kartesz, 2010) [Note: BONAP indicates it has been extirpated from Vermont, but we think this is unlikely]. Land conservationists assume that it has occupied most of its potential range in the United States (Nature Serve, 2011).

Entry Potential Kentucky bluegrass has already naturalized in all states of the United States (Kartesz, 2010). Therefore, assessment of its entry potential is not necessary.

Figure 1. Expected distribution of *Poa pratensis* in the entire United States. Alaska and Hawaii are shown on the left, and Puerto Rico on the right.

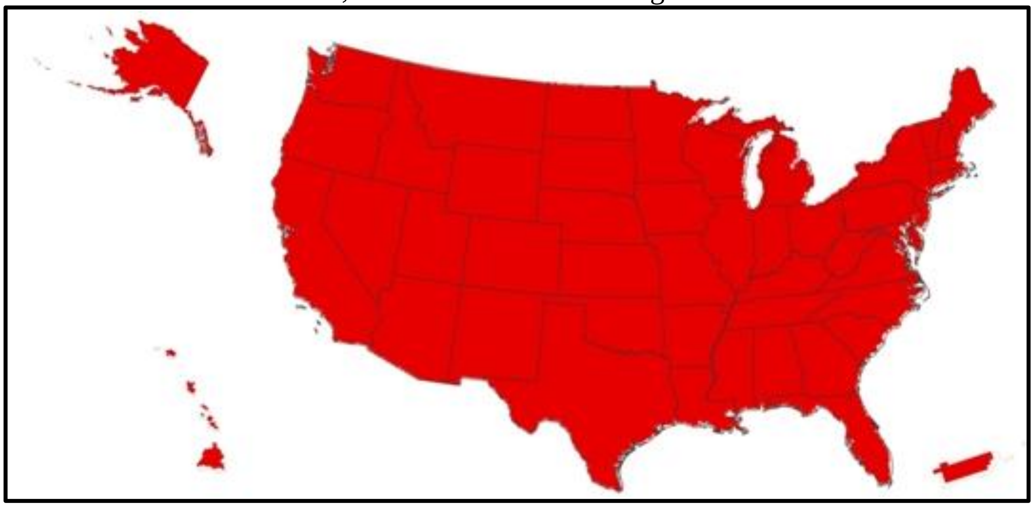
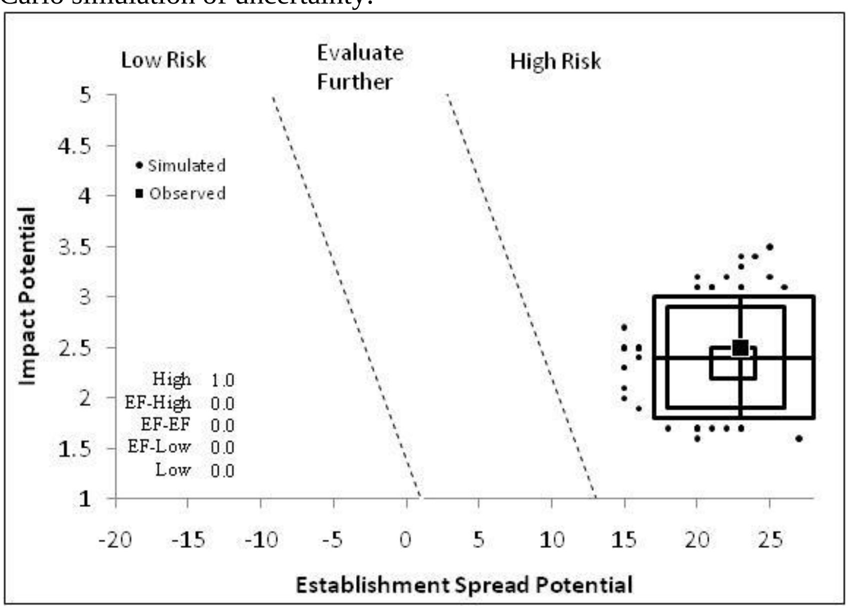
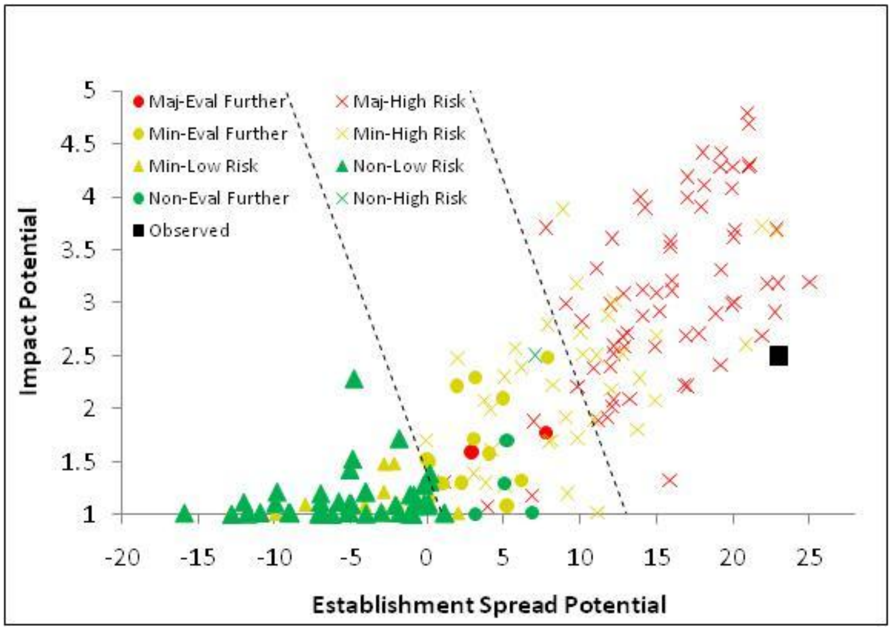


Figure 2. Risk score of non-herbicide tolerant Kentucky bluegrass, incorporating Monte Carlo simulation of uncertainty.[a]



[a] Central vertical and horizontal lines indicate the means of the simulated outcomes. The first (inner-most) box contains 50 percent of the outcomes, the second 95 percent, and the third 99 percent.

Figure 3. Risk score of non-herbicide tolerant Kentucky bluegrass relative to the validation dataset.



4.1.2. Results & Conclusion

Model Probabilities: P(Major Invader) = 0.942
P(Minor Invader) = 0.056
P(Non-Invader) = 0.002

Risk Result = High Risk
Secondary Screening = Not Applicable

The result of the weed risk assessment for non-GE Kentucky bluegrass is **High risk**.

4.1.3. Discussion

Non-GE Kentucky bluegrass is High risk (Figs. 2 and 3), and therefore the species, *P. pratensis* (including the GE type) is a candidate for regulation as a Federally listed noxious weed. When compared with other United States major-invaders examined in the validation study, however, its Impact Potential score was low to moderate (Fig. 3). We discussed above a few reasons why that score may overestimate its true damage potential. Most importantly, Kentucky bluegrass clearly does not behave like a significant weed in managed agricultural systems in the United States, and this is corroborated by the fact that no states regulate it. Finally, Kentucky bluegrass has wide use and economic status as a turf grass and pasture species, even in some natural areas. We believe these factors are significant.

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4.2. GE *Poa pratensis* L., Kentucky bluegrass

Background Information

Note: Nearly all of the information used in the analyses of both types of Kentucky bluegrass is exactly the same, regardless of type.

Family: Poaceae

Initiation: Please see above section for the non-GE type.

Foreign distribution: As discussed above, non-GE *Poa pratensis* is a common and widely cultivated species, and includes several infraspecific taxa (FNA Editorial Committee, 2007). Most infraspecific taxa are native to Europe and temperate Asia, although some also range south into northern Africa and northern India (NGRP, 2011). In general, *P. pratensis* is widely established throughout the temperate regions of the world (NGRP, 2001; FNA Editorial Committee, 2007).

U.S. distribution & status: The GE type of *P. pratensis* is not known to have established in the United States. For the distribution of the non-GE type, see above.

WRA area: The weed risk assessment area considered here is the United States and its territories and possessions.

4.2.1.Analysis of GE Kentucky Bluegrass

Establishment/Spread Potential

Risk score = 24 Mean uncertainty = .08

Characteristics which contributed to a relatively high establishment and spread risk score included the same factors as for non-GE Kentucky bluegrass (4.1.1). The only difference between the two is that the GE type scored one more point because it is herbicide tolerant. We have no reason to expect these would be significantly different (greater or lesser) for the GE type.

Impact Potential

Risk score = 2.5 Mean uncertainty = 0.17

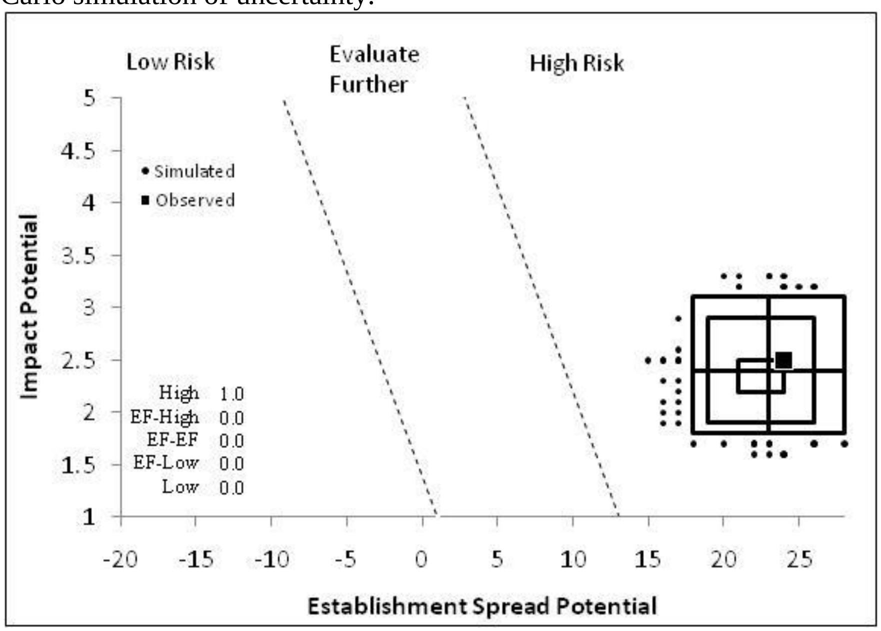
Based on our assessment questions the GE type had the same score as the non-GE type. Although one less herbicide would be available for the control of GE Kentucky bluegrass, in general it only has a low/moderate rating for difficulty of management (Nature Serve, 2011). We do not think tolerance to one herbicide would justify increasing that Nature Serve (2011) rating to high.

As discussed above, the Impact Potential score may overestimate the true damage that the species can cause. Kentucky bluegrass seems likely to be most problematic in natural grassland ecosystems, where typically only general management schemes are employed. In such systems, use of prescribed fires and grazing are often preferred to herbicides for management (e.g., FEIS, 2009; Grant et al., 2009; but see Hendrickson and Lund, 2010, for an example with the selective herbicide imazapic). Consequently, the GE type of Kentucky bluegrass might be no more difficult to control in those systems than the non-GE type.

Geographic Potential As discussed above, non-GE Kentucky bluegrass has naturalized in all states of the United States (Kartesz, 2010). Land conservationists assume that it has occupied most of its potential range in the United States (Nature Serve, 2011). We think the GE type could have a similar distribution potential.

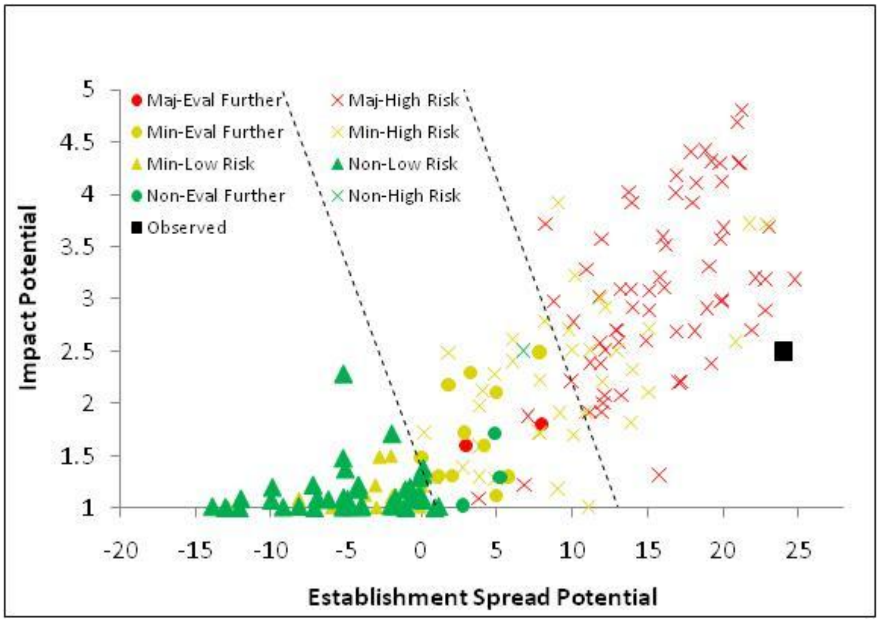
Entry Potential If the GE type is approved for release, introduction is certain.

Figure 4. Risk score of herbicide tolerant Kentucky bluegrass incorporating Monte Carlo simulation of uncertainty.[a]



[a] Central vertical and horizontal lines indicates means of the simulated outcomes. The first box contains 50 percent of the outcomes, the second 95 percent, and the third 99 percent.

Figure 5. Risk score of herbicide tolerant Kentucky bluegrass relative to the validation dataset.



4.2.2. Results & Conclusion

Model Probabilities: P(Major Invader) = 0.954
P(Minor Invader) = 0.045
P(Non-Invader) = 0.001

Risk Result = High Risk
Secondary Screening = Not Applicable

The result of the weed risk assessment for GE Kentucky bluegrass is **High Risk**.

4.2.3. Discussion

The GE type of Kentucky bluegrass was High risk (Figs. 4 and 5). Compared to the analysis for the non-GE type above, the only change here was answering "Yes" to the following question: "Is tolerant to some herbicides or has potential to acquire herbicide resistance?" which increased the risk score by 1 point. While demonstrable (Figs. 2 and 4) the difference is not significant.

Therefore, as discussed for the non-GE type above, the species, *P. pratensis* (including the non-GE type) is a candidate for regulation as a Federally listed noxious weed. We discussed above, for the non-GE type of Kentucky bluegrass, some reasons why the Impact Potential score may not reflect its true damage potential: those significant factors also apply equally here to the GE type.

4.2.4. Literature Cited

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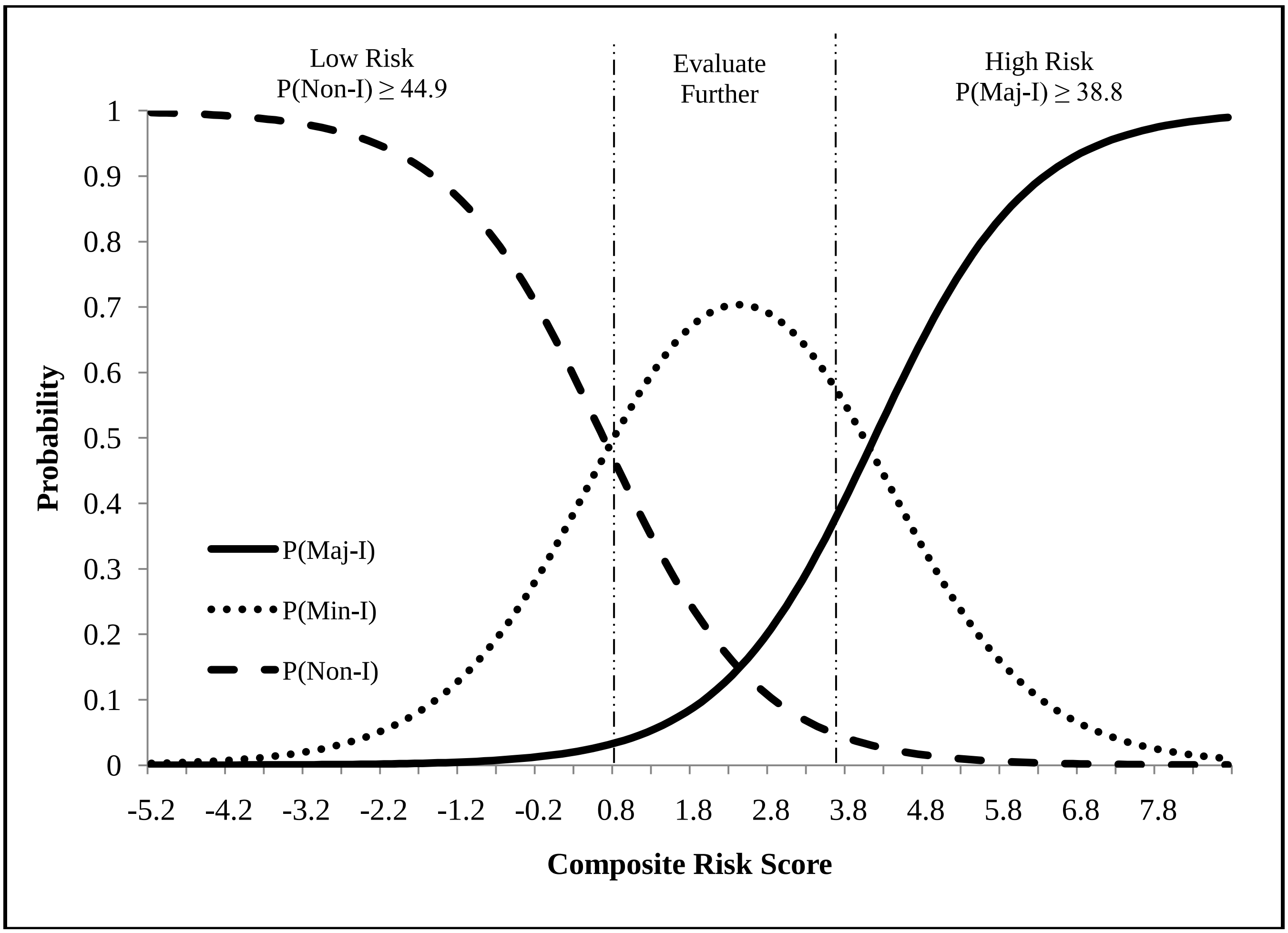
5. Appendices

Appendix A. Logistic regression model formulas

Below are the formulas for the logistic regression model of the probabilities of being a major-, minor-, and non-invader. E/S and Imp refer to the risk scores from the Establishment/Spread and Impact risk elements. All three probabilities sum to 1 for each plant.

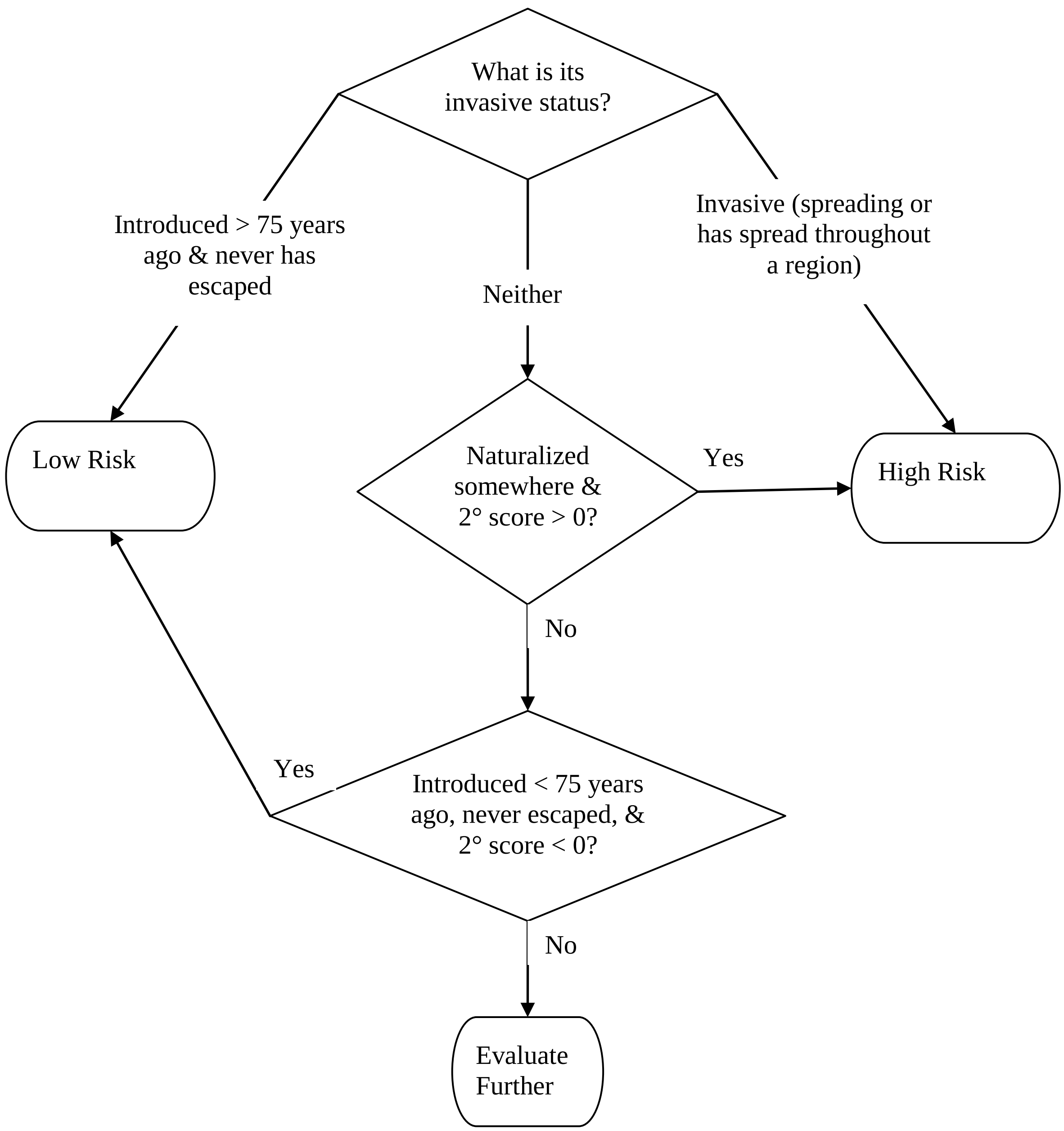
Appendix B. Model cut-off scores

In the diagram below we present the cut-off scores for the model probabilities for non-, minor-, and major-invaders. Composite Risk Score refers to a linear combination of the risk scores for the establishment/spread and impact risk elements. It is used in determining the probabilities and is calculated as (0.2356 × E/S) + (0.6019 × Imp). The cutoff scores below were determined by Receiver Operating Characteristic (ROC) curve analysis. This analysis maximizes the probabilities of accurately identifying non- and major-invaders, while minimizing errors. In the analysis, we assumed that the cost of a false-positive and false-negative error were equal.



Appendix C. Secondary screening system.

This system uses key questions that were strongly associated with invasive status in the United States. The first is question E/S-1 from the WRA model, and refers to the species invasive status anywhere in the world, including in the United States if recently established. The first part of the questions in the next two diamonds represents choices from E/S-1. The secondary score is the sum of the scores for six questions from the WRA model: 1) prolific reproduction; 2) minimum generation time; 3) shade adapted; 4) commodity contaminant; 5) number of natural dispersal vectors; and 6) forms dense thickets.



Appendix D. Risk score reference dataset.

Risk score distribution for the 204 species used to develop (N=102) and test (N=102) the PPQ WRA model. Marker color corresponds to the a priori classification for a species (major-, minor-, and non-invader). Marker type (triangle, circle, and x) corresponds to the conclusion following use of the model and secondary screening, if applicable.