# Weed Risk Assessment for *Nymphoides indica* (L.) Kuntze (Menyanthaceae) – Water snowflake

United States Department of Agriculture

Animal and Plant Health Inspection Service

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Version 1

*Nymphoides indica* plant in flower (source: Lock, 2010).


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**Introduction** Plant Protection and Quarantine (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). We use weed risk assessment (WRA) —specifically, the PPQ WRA model[1]—to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

Because our WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States or any area within it. We use a climate matching tool in our WRAs to evaluate those areas of the United States that are suitable for the establishment of the plant. We also use a Monte Carlo simulation to evaluate the consequences of uncertainty on the outcome of the risk assessment. For more information on the PPQ WRA process, please refer to the document, *Introduction to the PPQ Weed Risk Assessment Process*, which is available upon request.

| ***Nymphoides indica* (L.) Kuntze – Water snowflake** | |
|---|---|
| **Species** | Family: Menyanthaceae |
| **Information** | Initiation: On October 28, 2010, Rick Iverson, weed specialist with the North Carolina Department of Agriculture and Consumer Services, notified Al Tasker (Plant Protection and Quarantine) of his intent to regulate three species of *Nymphoides* as state Noxious Weeds in North Carolina (Iverson, 2010). Rick asked if PPQ had assessed these species. The Plant Epidemiology and Risk Analysis Laboratory had completed one assessment and agreed to collaborate on completing assessments for the other two species: *Nymphoides indica* (herein) and *N. peltata* (Iverson, 2010).<br>Foreign distribution: *Nymphoides indica* is native to tropical America (Mexico, Central America, the Caribbean, South America), Asia (India, China, Korea, Taiwan, Japan), and Australia (Ohwi, 1984; Ornduff, 1969). It is an endangered species in Japan (Shibayama and Kadono, 2007a).<br>U.S. distribution and status: *Nymphoides indica* is native to Puerto Rico (Ornduff, 1969; NRCS, 2011), but is a naturalized exotic plant in Texas (Saunders, 2004) and Florida (Kartesz, 2010; Wunderlin, 1982). In Florida, herbicides trials are being conducted to control *N. indica* in natural environments (Puri and Haller, 2010).<br>WRA area: Entire United States, including territories |

1. *Nymphoides indica* analysis

**Establishment/Spread Potential** *Nymphoides indica* is an aquatic plant that has naturalized in Texas and Florida, and is spreading rapidly in Florida (Saunders, 2004; Jacono, 2002). It reproduces sexually through seed, and vegetatively through the production of turion-like propagules in the

[1] Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294. DOI:10.1007/s10530-011-0061-4

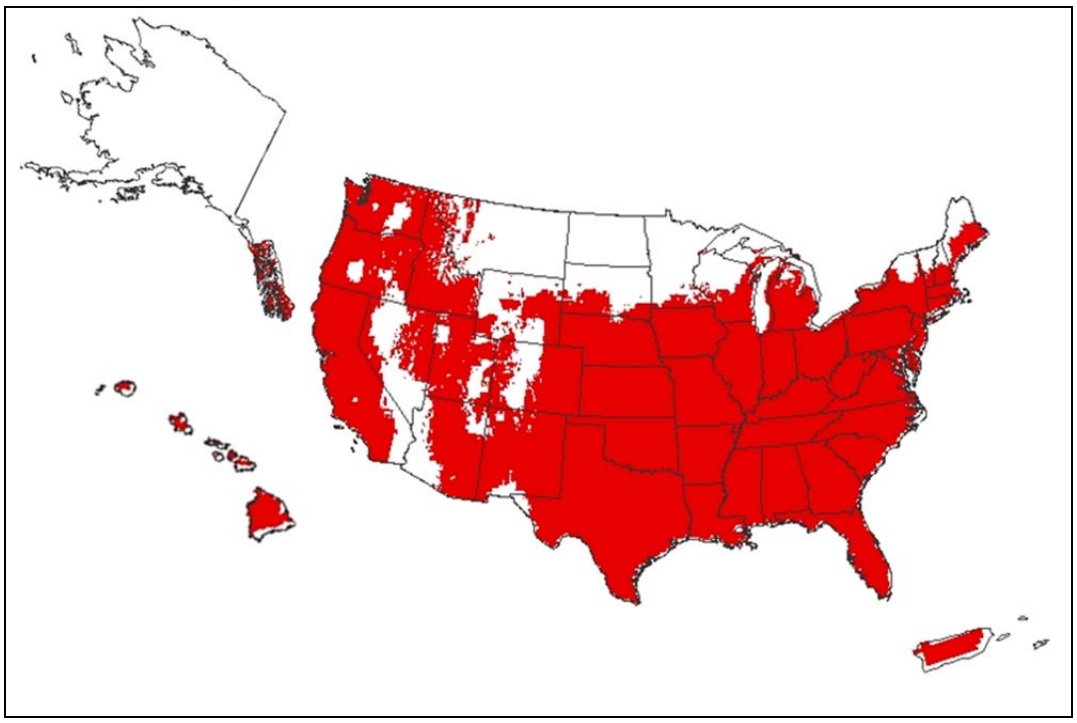
roots (Lock, 2010; Shibayama and Kadono, 2003). Its seeds can persist over three years at the bottom of ponds (Shibayama and Kadono, 2007a). The seeds of *N. indica* are dispersed by water (Chuang and Ornduff, 1992) and likely by birds (Barker and Vestjens, 1990). Seeds may also be dispersed unintentionally by humans, since seeds of the related *N. peltata* are spread by boats and fishing gear (Nault and Mikulyuk, 2009). This risk element had moderate uncertainty.
Risk score = 14 Uncertainty index = 0.13

**Impact Potential** We found very little information about the impacts of *N. indica* on other plant species, animals, and humans. For this reason, the uncertainty for this risk element was very high. However, *N. indica* is listed as a weed of rice production systems in Asia (Waterhouse, 1993; Pieterse and Murphy, 1990; Enomoto, 2003). Furthermore, several herbicides have been tested for their ability to control *N. indica* in natural and production systems (Puri and Haller, 2010; Samanta et al., 2010). Thus, it seems likely to be causing some otherwise undocumented impacts in these systems.
Risk score = 2.3 Uncertainty index = 0.47

**Geographic Potential** *Nymphoides indica* is an aquatic plant that grows in standing water (eFlora, 2009). We estimate that about 65 percent of the United States is suitable for establishment of *N. indica* (Fig. 1). The predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence obtained primarily from GBIF (2011). The map for *N. indica* represents the joint distribution of USDA Plant Hardiness Zones 5-13, areas with 10-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, mediterranean, humid continental warm summers, humid continental cool summers, humid subtropical, and marine west coast.

**Entry Potential** Because *N. indica* is already present in the United States in Texas and Florida (Saunders, 2004; Kartesz, 2010; Wunderlin, 1982), we did not evaluate its entry potential.

**Figure 1**. Predicted distribution of *Nymphoides indica* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.



2. Results and Conclusion

Model Probabilities: P(Major Invader) = 63.4%
P(Minor Invader) = 34.9%
P(Non-Invader) = 1.7%

Risk Result = High Risk

Secondary Screening = Not Applicable

**Figure 2**. *Nymphoides indica* risk score (black box) relative to the risk scores of species used to develop and validate the WRA model (other symbols). See Appendix A for the complete assessment.

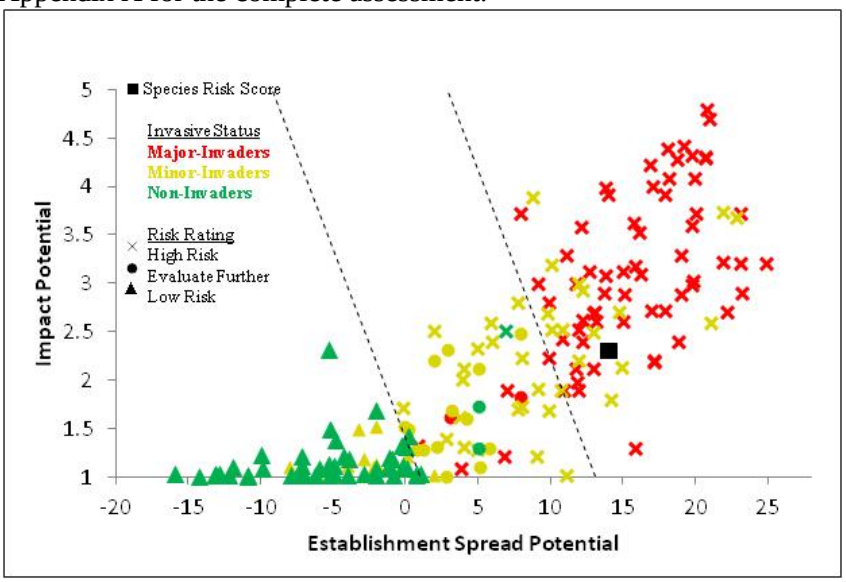
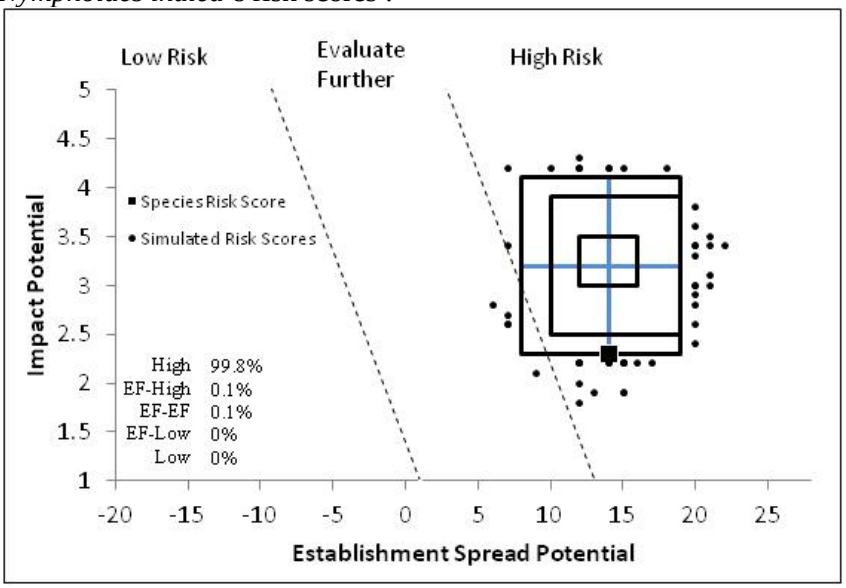



**Figure 3**. Monte Carlo simulation results (N=5000) for uncertainty around *Nymphoides indica*'s risk scores[a].




[a] The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

## 3. Discussion

The result of the assessment for *N. indica* is High Risk. *Nymphoides indica* is an aquatic plant that spreads by seed and vegetatively through underground roots. It has naturalized in Texas and Florida, and is considered to be spreading rapidly in Florida (Saunders, 2004; Jacono, 2002). Comparison of *N. indica* to the 204 species used in the WRA model validation study indicate that *N. indica* shares many of the same traits and impacts as other major- and high-scoring minor-invaders (Fig. 2). In the uncertainty analysis, 99.8 percent of

the simulated risk scores resulted in a conclusion of High Risk (Fig. 3). We found very little information about its impacts, but the fact that several herbicides have been tested for controlling it in natural and production systems (Puri and Haller, 2010; Samanta et al., 2010) indicates that *N. indica* has some apparently significant impacts.

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**Appendix A**. Weed risk assessment for *Nymphoides indica* (L.) Kuntze (Menyanthaceae). The following information was obtained from the species' risk assessment, which was conducted on a Microsoft Excel platform. The information shown below was modified to fit on the page. The original Excel file, the full questions, and the guidance to answer the questions are available upon request.

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| **Establishment/Spread Potential** | | | |
| ES-1 (Invasiveness elsewhere) | f - low | 5 | Naturalized in Texas and "spreading rapidly" in Florida (Saunders, 2004; Jacono, 2002). In Florida, "[p]robably escaped from cultivation" (Wunderlin, 1982). "This plant will naturally spread on its own....The plants may need thinning out from time to time as they can eventually cover the pond" (Lock, 2010). Ornduff (Ornduff, 1969) grouped plants with the name N. humboldtiana that were native to the new world with *N. indica* plants from the old world. *Nymphoides indica* was the name with priority. This means that *N. indica* is considered to be native to Mexico, Central America, the Caribbean, Puerto Rico, South America, India, Japan, China, and Australia (Ornduff, 1969; Ohwi, 1984). The alternate answer used in the Monte Carlo simulation is e. |
| ES-2 (Domesticated to reduce weed potential) | n - negl | 0 | No evidence and well studied. |
| ES-3 (Weedy congeners) | y - low | 1 | *Nymphoides peltata* has been observed in Massachusettes as being very agressive and capable of rapid growth and spread (Commonwealth of Massachusetts, 2011). "*N. peltata* is considered a noxious weed in New Zealand...is also declared as invasive in Sweden...and Ireland....Control efforts in Sweden involving the mechanical cutting and removal of *N. peltata* are estimated at costing...$4,500 U.S....per hectare..., or $9,000 U.S....annually if the recommended procedure of cutting twice a year is followed" (Nault and Mikulyuk, 2009). |
| ES-4 (Shade Tolerance) | n - low | 0 | Grows in full sun (University of Georgia, 2010) |
| ES-5 (Climbing or smothering growth form) | n - negl | 0 | Plant is not a vine. *Nymphoides indica* is an aquatic plant (Barrett, 1980; CABI, 2011; eFlora, 2009). |
| ES-6 (Dense Thickets) | y - mod | 2 | The related species *N. peltata* that has a similar life form and habit forms dense mats (Nault and Mikulyuk, 2009). |
| ES-7 (Aquatic) | y - negl | 1 | *Nymphoides indica* is an aquatic plant (Barrett, 1980; CABI, 2011; eFlora, 2009). |
| ES-8 (Grass) | n - negl | 0 | It is in the family Menyanthaceae (NGRP, 2011), not Poaceae. |
| ES-9 (N2-fixer) | n - negl | 0 | Not in a plant family known to have N-fixing capabilities (Martin and Dowd, 1990). |

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| ES-10 (Viable seeds) | y - negl | 1 | Produces viable seeds (Shibayama and Kadono, 2003). "Propagation can also be done by seed" (Lock, 2010). "Seeds are brown and globose" (eFlora, 2009). |
| ES-11 (Self-compatible) | n - negl | -1 | The flowers of *N. indica* are self-incompatible (Ornduff and Mosquin, 1970). In *N. peltata* floral dimorphism is associated with a strong self-incompatibility system (Barrett, 1980). |
| ES-12 (Special Pollinators) | n - negl | 0 | The following four orders of pollinating insects were observed visiting the flowers of *Nymphoides indica*: Lepidoptera, Diptera, Hymenoptera, and Coleoptera (Shibayama and Kadono, 2003). |
| ES-13 (Min generation time) | b - negl | 1 | Mason and van der Valk "planted" seeds and then harvested seeds from those plants after one year (Mason and van der Valk, 1992). "[P]lants of Nymphoides often behave as annuals when they grow in temporary ponds, although they will persist for years when they occupy permanent bodies of water" (Ornduff, 1969). "Annual herb" (Reed, 1977). The alternate answers for the Monte Carlo simulation are a, then c. |
| ES-14 (Prolific reproduction) | ? - max | 0 | "Seeds 18-25 in each capsule" (Sivarajan and Joseph, 1993). Seed set rate of different *N. indica* populations varies from nine percent to 87 percent. (Shibayama and Kadono, 2007b). Flowers in clusters of 15-35 (Sivarajan and Joseph, 1993). No information found about the number of capsules produced. |
| ES-15 (Unintentional dispersal) | y - mod | 1 | The related species *N. peltata* is spread unintentionally by boats and fishing gear (Nault and Mikulyuk, 2009). |
| ES-16 (Trade contaminant) | ? - max | 0 | Unknown for *N. indica*, but for the related species *N. peltata*: "It is also possible for *N. peltata* to be a 'hitchhiker' plant, traveling with other species ordered through water garden catalogs" (Nault and Mikulyuk, 2009). |
| ES-17 (#Natural dispersal vectors) | 1 - | -2 | Seed description used to help answer the next five questions: "Seeds brown, globose, 1.2-1.5 mm; seed coat smooth" (eFlora, 2009). |
| ES-17a (Wind dispersal) | n - low | | No evidence of adaptations for wind dispersal (Chuang and Ornduff, 1992). |
| ES-17b (Water dispersal) | y - negl | | "Boesewinkel and Bouman (1984) suggest that the 'air-filled (seed) hairs of *Nymphoides* and *Villarsia*' and the air-filled cells of the testa of Menyanthes may serve to aid the dispersal of these seeds via water....The seeds of those members of Menyanthaceae we have studied...appear to have hydrophobic surfaces and will float for several days after their release from capsules, even from capsules that are submerged at maturity" (Chuang and Ornduff, 1992). Because *Nymphoides indica* is an aquatic plant, it also seems highly likely |

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| | | | that its seeds would be water dispersed. |
| ES-17c (Bird dispersal) | n - low | | The seeds of *N. indica* have been found in the stomach contents of plumed whistling ducks in Australia (Barker and Vestjens, 1990), but the viability of these seeds is likely destroyed during the digestion process (Smits et al., 1989). |
| ES-17d (Animal external dispersal) | n - low | | No evidence. Seed coat is smooth (eFlora, 2009). |
| ES-17e (Animal internal dispersal) | n - mod | | No evidence. |
| ES-18 (Seed bank) | y - negl | 1 | *Nymphoides indica* produces a seed bank that last over three years (Shibayama and Kadono, 2007a). |
| ES-19 (Tolerance to loss of biomass) | y - mod | 1 | Plants reproduce and spread vegetatively through leaves and underwater roots (Lock, 2010; Shibayama and Kadono, 2003). Because mechanical harvesting often spreads fragments of the related species *N. peltata* (Nault and Mikulyuk, 2009), it is very likely *N. indica* is dispersed similarly. |
| ES-20 (Herbicide resistance) | n - low | 0 | No evidence and well studied (Heap, 2011). |
| ES-21 (# Cold hardiness zones) | 9 | 0 | |
| ES-22 (# Climate types) | 9 | 2 | |
| ES-23 (# Precipitation bands) | 10 | 1 | |
| **Impact Potential** | | | |
| **General Impacts** | | | |
| Imp-G1 (Allelopathic) | n - low | 0 | No evidence. It is unlikely that an aquatic plant would express an allelopathic trait, since it would be hard for any allelopathic chemicals produced to build up to effective levels in a body of water . |
| Imp-G2 (Parasitic) | n - negl | 0 | *Nymphoides indica* is not in a plant family known to have members with parasitic traits (Heide-Jørgensen, 2008). |
| **Impacts to Natural Systems** | | | |
| Imp-N1 (Ecosystem processes) | ? - max | | We were unable to find any information about specific impacts that *N. indica* has in natural systems. However, because herbicide trials are being conducted to control this species in natural environments (Puri and Haller, 2010), *N. indica* is likely having some undocumented |

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| | | | impacts in these environments. Consequently, answering unknown for this question and the next two. |
| Imp-N2 (Community structure) | ? - max | | Unknown. |
| Imp-N3 (Community composition) | ? - max | | Unknown. |
| Imp-N4 (T&E species) | ? - max | | Unknown. |
| Imp-N5 (Globally outstanding ecoregions) | ? - max | | Unknown. |
| Imp-N6 (Natural systems weed) | c - negl | 0.6 | Herbicides trials are being conducted in FL to control *N. indica* in natural environments (Puri and Haller, 2010). The alternate answer for the Monte Carlo simulation is b. |
| **Impact to Anthropogenic areas (cities, suburbs, roadways)** | | | |
| Imp-A1 (Affects property, civilization, ...) | n - mod | 0 | No evidence. |
| Imp-A2 (Recreational use) | n - mod | 0 | No evidence. |
| Imp-A3 (Affects ornamental plants) | n - mod | 0 | No evidence. |
| Imp-A4 (Anthropogenic weed) | a - low | 0 | This plant is grown as an ornamental in water gardens (Dave's Garden, 2011). No evidence that this plant is considered a weed in urban/suburabn areas. Alternate answer is b. |
| **Impact to Production systems (agriculture, nurseries, forest plantations, orchards, etc.)** | | | |
| Imp-P1 (Crop yield) | ? - max | | In spite that this species is considered a weed in production systems and herbicide trials to control it have been conducted, there is no documented evidence of impact. Consequently, answering unknown for this impact and the next two questions as there are likely some undocumented impacts. |
| Imp-P2 (Commodity Value) | ? - max | | Unknown. |
| Imp-P3 (Affects trade) | ? - max | | Unknown. |
| Imp-P4 (Irrigation) | n - mod | 0 | No evidence. |
| Imp-P5 (Animal toxicity) | y - mod | 0.1 | Listed as a plant that is toxic to cattle in Argentina (Freire et al., 2005). |
| Imp-P6 (Production system weed) | c - low | 0.6 | Herbicide trials have been conducted to test herbicide control of *N. indica* in production systems (Samanta et al., 2010). *Nymphoides indica* is considered a Principal weed in Surinam (Holm et al., 1979). It is a weed in rice production systems in Southeast Asia (Waterhouse, 1993; Pieterse and Murphy, 1990) and is considered a |

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| | | | weed in Japan (Enomoto, 2003). The alternate answer used for the Monte Carlo simulation is b. |
| **Geographic Potential** | | | Note: Below "PS" refers to geo-referenced point source (latitude/longitude) data. Unless otherwise noted, all data was obtained from (GBIF, 2011). |
| **Plant cold hardiness zones** | | | |
| Geo-Z1 (Zone 1) | n - negl | N/A | No evidence. |
| Geo-Z2 (Zone 2) | n - negl | N/A | No evidence. |
| Geo-Z3 (Zone 3) | n - negl | N/A | No evidence. |
| Geo-Z4 (Zone 4) | n - negl | N/A | No evidence. |
| Geo-Z5 (Zone 5) | y - low | N/A | Point Source (PS): South Korea |
| Geo-Z6 (Zone 6) | y - negl | N/A | PS: China, South Korea, Poland |
| Geo-Z7 (Zone 7) | y - negl | N/A | PS: Japan, South Korea |
| Geo-Z8 (Zone 8) | y - negl | N/A | PS: Australia, Japan |
| Geo-Z9 (Zone 9) | y - negl | N/A | PS: Australia, China |
| Geo-Z10 (Zone 10) | y - negl | N/A | PS: Australia, Mexico, Florida, Myanmar |
| Geo-Z11 (Zone 11) | y - negl | N/A | PS: Australia, Mexico |
| Geo-Z12 (Zone 12) | y - negl | N/A | PS: Australia, Mexico |
| Geo-Z13 (Zone 13) | y - negl | N/A | PS: Cote d'Ivoire, Mexico |
| **Koppen-Geiger climate classes** | | | |
| Geo-C1 (Tropical rainforest) | y - negl | N/A | PS: Papua New Guinea |
| Geo-C2 (Tropical savanna) | y - negl | N/A | PS: Australia, Myanmar, Florida |
| Geo-C3 (Steppe) | y - negl | N/A | PS: Australia, Botswana |
| Geo-C4 (Desert) | y - low | N/A | PS: Australia, Mali |
| Geo-C5 (Mediterranean) | y - high | N/A | PS: Columbia |
| Geo-C6 (Humid subtropical) | y - negl | N/A | PS: Australia, Mozambique, Florida |
| Geo-C7 (Marine west coast) | y - negl | N/A | PS: Australia, Madagascar |
| Geo-C8 (Humid cont. warm sum.) | y - negl | N/A | PS: South Korea |
| Geo-C9 (Humid cont. cool sum.) | y - mod | N/A | PS: Poland |
| Geo-C10 (Subarctic) | n - negl | N/A | No evidence. |
| Geo-C11 (Tundra) | n - negl | N/A | No evidence. |
| Geo-C12 (Icecap) | n - negl | N/A | No evidence. |
| **10-inch precipitation bands** | | | |
| Geo-R1 (0-10") | n - mod | N/A | No evidence. |

| Question ID | Answer - Uncertainty | Score | Notes (and references) |
|---|---|---|---|
| Geo-R2 (10-20") | y - low | N/A | PS: Bolivia, Botswana |
| Geo-R3 (20-30") | y - negl | N/A | PS: Australia, South Africa |
| Geo-R4 (30-40") | y - negl | N/A | PS: Australia, Botswana |
| Geo-R5 (40-50") | y - negl | N/A | PS: Australia, China, New York |
| Geo-R6 (50-60") | y - negl | N/A | PS: Australia, China, South Korea, Florida |
| Geo-R7 (60-70") | y - negl | N/A | PS: Japan |
| Geo-R8 (70-80") | y - negl | N/A | PS: Viet Nam, Japan |
| Geo-R9 (80-90") | y - negl | N/A | PS: Papua New Guinea |
| Geo-R10 (90-100") | y - negl | N/A | PS: Papua New Guinea |
| Geo-R11 (100"+) | y - negl | N/A | PS: Papua New Guinea |
| **Entry Potential** | | | |
| Ent-1 (Already here) | y - negl | 1 | Naturalized in Texas (Saunders, 2004) and Florida (Kartesz, 2010; Wunderlin, 1982). Native to Puerto Rico (Ornduff, 1969; NRCS, 2011). |
| Ent-2 (Proposed for entry) | | N/A | |
| Ent-3 (Human value & cultivation/trade status) | | N/A | |
| Ent-4 (Entry as a Contaminant) | | | |
| Ent-4a (In MX, CA, Central Amer., Carib., or China) | | N/A | |
| Ent-4b (Propagative material) | | N/A | |
| Ent-4c (Seeds) | | N/A | |
| Ent-4d (Ballast water) | | N/A | |
| Ent-4e (Aquaria) | | N/A | |
| Ent-4f (Landscape products) | | N/A | |
| Ent-4g (Container, packing, trade goods) | | N/A | |
| Ent-4h (Commodities for consumption) | | N/A | |
| Ent-4i (Other pathway) | | N/A | |
| Ent-5 (Natural dispersal) | | N/A | |