United States Department of Agriculture

Animal and Plant Health Inspection Service

June 4, 2013

Version 2

Weed Risk Assessment for *Vitex rotundifolia* L. f. (Lamiaceae) – Beach vitex

Left: Infestation in South Carolina growing down to water line and with runners and fruit stripped by major winter storm (Randy Westbrooks, U.S. Geological Survey, Bugwood.org). Right: A runner with flowering shoots (Forest and Kim Starr, Starr Environmental, Bugwood.org).

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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 defined as "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 (Koop et al., 2012)—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 the PPQ 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 for any area within it. As part of this analysis, we use a stochastic simulation to evaluate how much the uncertainty associated with the analysis affects the model outcomes. We also use GIS overlays to evaluate those areas of the United States that may be suitable for the establishment of the plant. For more information on the PPQ WRA process, please refer to the document, *Background information on the PPQ Weed Risk Assessment*, which is available upon request.

Vitex rotundifolia L. f. – Beach vitex

Species Information

Family: Lamiaceae. Also placed in the Verbenaceae (NGRP, 2013).

Synonyms: This species is listed as a synonym of *V. trifolia* subsp. *litoralis* Steenis (The Plant List, 2013). However, because several other taxonomic sources consider it as *V. rotundifolia* (Kartesz, 2013; NGRP, 2013; Weakley, 2010; Zhengyi et al., 2013), we are using that name in this analysis.

Initiation: On July 29, 2005, Dr. Randy Westbrooks, United States Geological Survey, sent a weed risk assessment of this species to Dr. Al Tasker, National Noxious Weed Program Manager, APHIS. Dr. Westbrooks asked that it be considered for listing as a Federal Noxious Weed (Tasker, 2005). On August 2, 2005, Dr. Tasker requested a report on beach vitex from the New Pest Advisory Group (NPAG). Even though beach vitex has already been in the United States for 20 years, Dr. Tasker thought this was an NPAG issue because this plant was only recently recognized as a plant with significant invasive traits. NPAG recommended that a weed risk assessment be conducted to evaluate listing *V. rotundifolia* as a Federal Noxious Weed (NPAG, 2005). In this document we are revising that WRA to include new formatting and the Monte Carlo simulation of uncertainty.

Foreign distribution: *Vitex rotundifolia* is native to coastal habitats in the western Pacific from Korea and Japan southward throughout tropical southeastern Asia, as well as northern Australia, Fiji, and New Caledonia (NGRP, 2013; Yeeh et al., 1996). One record exists from southern Africa (GBIF, 2013), but this may be erroneous as no other report exists of it in Africa.

U.S. distribution and status: *Vitex rotundifolia* is native to the Hawaiian islands (NRCS, 2013; Starr and Starr, 2013; Wagner et al., 1999). In the continental United States, it is present in numerous locations along the coasts of South Carolina and North Carolina (CISEH, 2013). It has also been detected in one or two counties in Alabama, Florida, Georgia, Virginia, Maryland, and New Jersey

(BVTF, 2013; CISEH, 2013; Dorell, 2009; Kartesz, 2013; True, 2009). Virginia established a temporary quarantine to keep *V. rotundifolia* from spreading from four locations in the state in 2009 (VDACS, 2009), and these quarantines became permanent in 2010 (VDACS, 2012). North Carolina made *V. rotundifolia* a state noxious weed on January 22, 2009 (BVTF, 2010). Many local ordinances have banned beach vitex (BVTF, 2010). The Beach Vitex Task Force website documents strong public interest and involvement in eradicating this species (BVTF, 2013).

WRA area[1]: Entire United States, including territories.

1. *Vitex rotundifolia* analysis

Establishment/Spread Potential Only 10 years after it became available in the horticultural trade, *V. rotundifolia* began to show its invasive potential in the United States. This species has a very rapid growth rate and a short generation time, reproduces sexually and asexually, and is readily dispersed by water (BVTF, 2010; Suiter, 2010). Although herbicide treatments are effective, stem fragments can readily form new plants when disposal is inadequate (Suiter, 2005). High drought and salt tolerance make *V. rotundifolia* a strong competitor (Gresham and Neal, 2005). We had low uncertainty for this risk element.

Risk score = 16 Uncertainty index = 0.10

Impact Potential *Vitex rotundifolia* outcompetes native strand and dune species, including Federal Threatened and Endangered plant species; significantly reduces light levels underneath its canopy; and forms dense mats that affect native species (Gresham and Neal, 2005). It also restricts nesting by endangered sea turtles (BVTF, 2010). Although it was initially promoted for dune stabilization, beach vitex is actually less effective at stabilizing dunes than native dune grasses that have more fibrous root systems (BVTF, 2010; ISSG, 2010). Increased dune erosion not only impacts natural communities, but can significantly impact the economies of coastal towns and cities (BVTF, 2010). We had low uncertainty for this risk element.

Risk score = 3.0 Uncertainty index = 0.14

Geographic Potential Based on three climatic variables, we estimate that about 28 percent of the United States is suitable for the establishment of *V. rotundifolia* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *V. rotundifolia* represents the joint distribution of Plant Hardiness Zones 6-13, areas with 20-100 inches (51-254 cm) of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, humid subtropical, and humid continental warm summers.

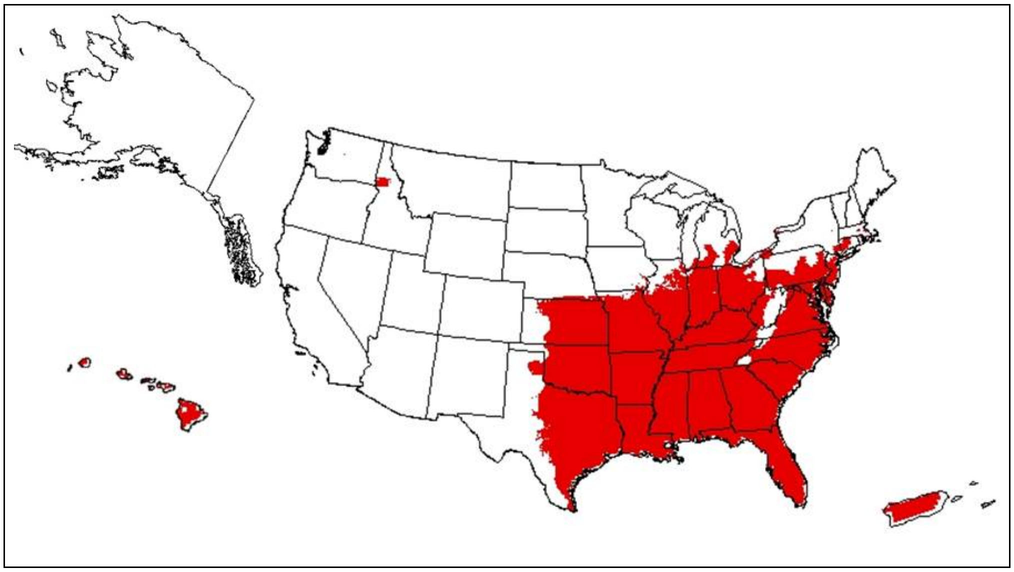
The area estimated represents a conservative estimate as it only uses three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. In particular, *V. rotundifolia* occurs in a specialized niche, coastal strands, and dunes (Kim, 2005; Ohwi, 1984; Wagner et al., 1999). Thus, a much smaller portion of the United

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area" (IPPC, 2012).

States is likely suitable for this species. With respect to coastal environments, one study reports that *V. rotundifolia* can survive from Rhode Island south through the rest of the Gulf Coast states, and across the entire western United States (Olsen and Bell, 2005). Our analysis indicated that the western United States is unsuitable for its establishment; however, this may be because this species has not had an opportunity to extend into Mediterranean and marine west coast climates.

Entry Potential Assessment of entry potential was not necessary as *V. rotundifolia* is already in the United States (Kartesz, 2013). It was intentionally introduced several times for horticultural use (Olsen and Bell, 2005).

Figure 1. Predicted distribution of *Vitex rotundifolia* 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) = 80.8%
P(Minor Invader) = 18.4%
P(Non-Invader) = 0.7%

Risk Result = High Risk
Secondary Screening = Not applicable

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

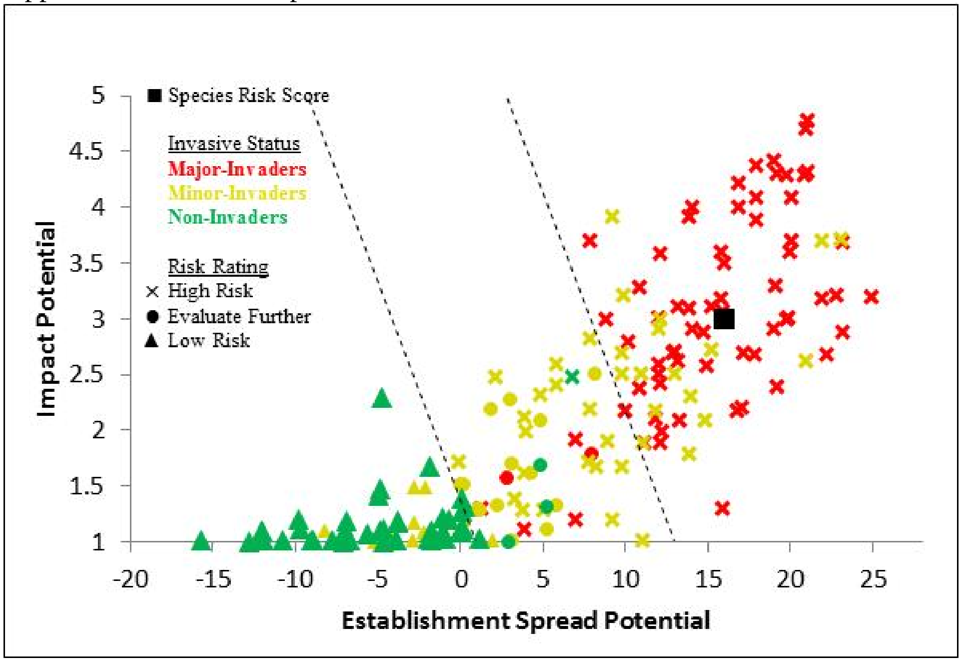
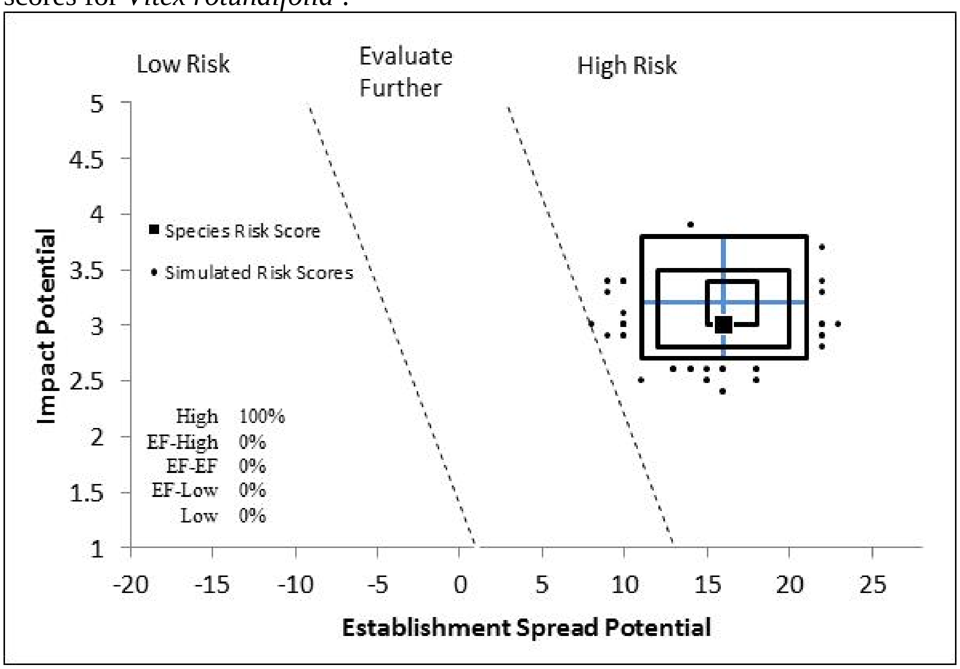


Figure 3. Monte Carlo simulation results (N=5,000) for uncertainty around the risk scores for *Vitex rotundifolia*[a].



[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 weed risk assessment for *V. rotundifolia* is High Risk (Fig. 2). Based upon the results of our uncertainty simulation (Fig. 3), we are very confident in this conclusion. In the relatively short 25 years since *V. rotundifolia* was initially promoted in the United States as a dune-stabilizing plant (Olsen and Bell, 2005), it has already demonstrated a very high invasive potential in coastal habitats along the southeastern United States, where it is disrupting native coastal ecosystems. Although this species differ little from many other invaders of natural areas, the public is very concerned about the spread of this plant because it is invading highly valued coastal habitats. This is obvious by the large amount of public, grass-roots support for the eradication of this species (BVTF, 2013).

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Appendix A. Weed risk assessment for *Vitex rotundifolia* L. f. (Lamiaceae). The following information came from the original risk assessment, which is available upon request (full responses and all guidance). We modified the information to fit on the page.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 (Status/invasiveness outside its native range)	f - negl	5	Naturalized in the southeastern United States, where populations have been established for at least 16 years and are actively growing and spreading (Westbrooks, 2005). A free-living population was found on an undeveloped island that is about one mile from the nearest planted population (Westbrooks, 2005). A population in Maryland is believed to have been started by birds (Dorell, 2009). Rapidly spreading in South Carolina (Smith, 2008). "Now spreading aggressively as an invasive species" (Weakley, 2008). No other evidence that this species has been introduced anywhere else outside of its native range, with a possible exception in southern Africa that may be an erroneous report (GBIF, 2013). Its extremely wide native distribution and its abundance in native habitats (at least within Korea) are also indicative of its invasive potential. Documented to spread 1000 feet five years after it was planted in one site in Virginia (BVTF, 2010). The general public and researchers clearly recognize this species as invasive (BVTF, 2013). While it is not clear how many of the extant populations were spontaneously produced through natural dispersal, the rapid vegetative spread of this species along coastal systems is evidence that it is an invasive species (*sensu* Richardson et al., 2000). Alternate choices for the uncertainty analysis are both "e."
ES-2 (Is the species highly domesticated)	n - low	0	Cultivated in some areas as a sand binder (Wagner et al., 1999). Planted for dune stabilization in the United States (Olsen and Bell, 2005; Weakley, 2008). But no evidence of domestication or breeding for traits associated with reduced weed potential.
ES-3 (Weedy congeners)	n - mod	0	*Vitex trifolia* and *V. agnus-castus* are sometimes considered invaders in the southeastern United States and elsewhere (Kaufman and Kaufman, 2007; Soubeyran, 2008), but there is no evidence that these should be considered significant weeds (*i.e.*, weeds with demonstrated impacts).
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	Thrives in full sun (Smith, 2008). Full sun plant that grows on coastal dunes (Kaufman and Kaufman, 2007). These descriptions indicate that it is not a shade-adapted species.
ES-5 (Climbing or smothering growth form)	y - low	1	Terrestrial shrub with vine-like procumbent branches (Wagner et al., 1999). Shrub/vine that can sprawl over 60 feet (Kaufman and Kaufman, 2007). This vine-like life form is conducive to smothering. Its dense canopy reduces light levels to 2% of full sun (Gresham and Neal, 2005). Using "low" uncertainty instead of "negl" because this is not a typical vine.
ES-6 (Forms dense thickets)	y - negl	2	The vine-like runners often root at the nodes, forming mats several meters in diameter (Wagner et al., 1999). Shrub/vine that can sprawl over 60 feet (Kaufman and Kaufman, 2007). It usually forms big patches by its long runners with a plant height varying from 15 to 61 cm (Yuan et al., 2008). Its ability to form roots at nodes allows it to form dense thickets. The fibrous root system of beach vitex traps sea turtles and impedes their nesting (SCBVTF, 2005).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-7 (Aquatic)	n - negl	0	Terrestrial shrub of sand dunes and coastal strands (Kim, 2005; Ohwi, 1984; Wagner et al., 1999).
ES-8 (Grass)	n - negl	0	In the Verbenaceae/Lamiaceae (Wagner et al., 1999).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	No evidence. Not a member of a family known to fix nitrogen (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Reproduces sexually and asexually (Yuan et al., 2008). Germination between 30 to 70% depending on the medium (Gresham and Neal, 2005). Difficult to propagate via seeds (Park et al., 2004). Patterns of population genetic structure indicate that there is a high proportion of sexual reproduction (Yuan et al., 2008). Recruits by seed in the United States (BVTF, 2010).
ES-11 (Self-compatible or apomictic)	y - high	1	Ted Whitwell, an environmental horticulturalist who has worked with beach vitex believes it is self-compatible, but has not data supporting this (Whitwell, 2010).
ES-12 (Requires special pollinators)	n - low	0	Visited by a variety of pollinators, particularly bees (Abe, 2006; Kato et al., 1999).
ES-13 (Minimum generation time)	c - high	0	Three to four years for sexual reproduction (two years in the greenhouse), and two years for vegetative reproduction (Whitwell, 2010). Under the right conditions, perhaps one year for stems and two years for sexual reproduction (Suiter, 2010). Not more than five years based on the spread of a plant in Virginia after it was planted (BVTF, 2010). One naturalist commented that these plants grow very fast and they would not be surprised if one produced seeds in its second year (Dewire, 2010). Alternate choices for the uncertainty analysis are “d” and “b.”
ES-14 (Prolific reproduction)	y - negl	1	On average, established populations of beach vitex produce 2,730 fruit/m^2 (Gresham and Neal, 2005). Given that fruit can contain 1 to 4 seeds, beach vitex has the potential to produce up to 10,000 seeds/m^2 (Gresham and Neal, 2005). However, on average there are 1.25 viable seeds per capsule (Cousins et al., 2006b). Propagation via seed is difficult and time consuming with little success (Park et al., 2004). Yet another study says that germination, at least with yellow-red fruit is about 71% (Park and Park, 2001). Germination between 30 to 70% depending on the medium (Gresham and Neal, 2005). The preponderance of the evidence indicates it is prolific; at the very least, it passes the 1000 seed per square meter threshold.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	Plants have established from yard clippings that are inappropriately dumped (Suiter, 2005). It is recommended that instead of composting garden clippings, the clippings be placed in plastic bags and taken to landfills so that clippings can't establish (ISSG, 2010).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	n - low	-1	No evidence. Does not seem likely given the unique habitat (coastal dunes) this species live in.
ES-17 (Number of natural dispersal vectors)	2	0	Fruit and seed description used to answer questions ES-17a-17e: Fruits are bluish black at maturity, slightly depressed globose, about 6 mm in diameter (Wagner et al., 1999). Fruit is a drupe (Wagner et al., 1999). Fruit persist on the plant during winter (Smith, 2008). Fruit containing up to four seeds (Cousins et al., 2006b).
ES-17a (Wind dispersal)	n - low		No evidence. Fruit morphology not conducive for wind dispersal

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(see ES-17).
ES-17b (Water dispersal)	y - negl		*Vitex rotundifolia* is a coastal strand plant (Wagner et al., 1999). Fruits readily float and are dispersed by ocean currents (Westbrooks, 2005). Stem fragments that are broken by high tides or storms can be moved by ocean currents and establish new populations elsewhere (Smith, 2008; Suiter, 2005; Yuan et al., 2008). Found on remote, undeveloped islands (BVTF, 2010).
ES-17c (Bird dispersal)	y - mod		Overall, there were comments for and against bird dispersal in the literature, none of which were supported with any kind of hard evidence (see text that follows). However, based on the weight of the evidence and a naturalization event beyond the primary dune, answering yes. EVIDENCE AGAINST: Fruits are reported to be eaten by birds and squirrels, which may disperse the seeds (Suiter, 2005). But "[t]he absence of a nourishing, fleshy fruit coating suggests that BV is not bird dispersed" (Cousins et al., 2009). "We have never seen any evidence of bird dispersal. Birds are never involved with the seeds when they are present on the plant" (Whitwell, 2010). EVIDENCE FOR: Seeds are bird-dispersed (ISSG, 2010). Two other *Vitex* species are bird-dispersed (Kannan and James, 1999; Wotton et al., 2008). An environmental resource manager believes that migratory birds took it up to Maryland (Dorell, 2009). A personal communication from a naturalist (Maureen Dewire) says she has seen cardinals taking the seed; however, she doesn't know if the seeds survive the digestion process or whether the birds may drop the seeds (Dewire, 2010). Dale Suiter believes that birds may disperse the seeds (Suiter, 2010). He says there is an undeveloped barrier island in North Carolina with a new infestation of beach vitex. Based on the location of the infestation (well behind the primary dune), he thought it was unlikely they got there via water dispersal (Suiter, 2010).
ES-17d (Animal external dispersal)	n - mod		No evidence. Nothing about the plant would make seeds stick to animals (Dewire, 2010).
ES-17e (Animal internal dispersal)	? - max		Unknown. Fruits are eaten by birds and squirrels which may disperse the seeds (Suiter, 2005). "Could be dispersed by animals but I do not think they care for the odor or other chemicals. The primary dispersal is by water or people" (Whitwell, 2010). A naturalist has not seen deer or any other animal (other than birds) eat the fruit (Dewire, 2010). Collared peccaries consume and disperse the seed of *Vitex mollis* (Martinez-Romero and Mandujano, 1995).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Seeds can remain viable in the soil for at least 1.5 years (Cousins et al., 2006b); researchers retrieved seeds from various depths in the soil at sites with an intact beach vitex canopy above and where it had been removed a few years earlier. The authors used tetrazolium to evaluate seed viability.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	Stems often rooting at nodes (Wagner et al., 1999). Because runners root at stem nodes, each section has the potential to establish a new plant if separated from the parent plant (Gresham and Neal, 2005). Plants have also established from yard clippings that are inappropriately dumped (Suiter, 2005). Stems root at leaf nodes which occur every 2-3 inches (Westbrooks, 2005).

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - negl	0	Herbicide control procedures described (Smith, 2008). No evidence of herbicide resistance (Cousins et al., 2006a; Heap, 2010; True, 2009). Using "negl" uncertainty given the amount of control information that is published about this plant on the Beach Vitex Task Force website (BVTF, 2010)
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	4	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	y - high	0.1	A thorough study found that soils under beach vitex stands were very hydrophobic due to long-chain alkane leachates from the canopy (Cousins et al., 2009); this will likely make it very difficult for many species to establish. A study that preceded this did not find any conclusive evidence for allelopathy, just some indications (Gresham and Neal, 2005).
Imp-G2 (Parasitic)	n - negl	0	No evidence that *V. rotundifolia* is parasitic. Neither Verbenaceae nor Lamiaceae is known to contain parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2009; Walker, 2010).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	? - max		Unknown. Because beach vitex does not retain sand as well as native species (see various observations and anecdotal evidence in BVTF, 2010), it leads to reduced stability of coastal dunes, which may affect other species.
Imp-N2 (Change community structure)	y - low	0.2	Populations form deep shade in U.S. coastal strands (Gresham and Neal, 2005; Westbrooks, 2005) and extensive mats of stems and branches (see pictures throughout BVTF, 2010). Because these populations are very different from the relatively open coastal strand communities, answering "yes."
Imp-N3 (Change community composition)	y - negl	0.2	Because of the density of its growth, beach vitex outcompetes native vegetation and other exotic plants (Socha and Roecher, 2004). Populations form monocultures that displace native species (BVTF, 2010; Gresham and Neal, 2005; Westbrooks, 2005). The fibrous root system of beach vitex traps sea turtles and impedes their nesting (SCBVTF, 2005).
Imp-N4 (Is it likely to affect Federal Threatened and Endangered species)	y - negl	0.1	At least one Federally listed Threatened plant, sea-beach amaranth (*Amaranthus pumilus*) (USFWS, 2005) would be placed in greater peril if beach vitex invades its habitat. The fibrous root system of beach vitex traps endangered sea turtles and impedes their nesting (SCBVTF, 2005). Invasion by beach vitex would also disrupt the habitat of several Federal Threatened and Endangered birds (Suiter, 2005). Outcompetes endangered species in the United States (Kaufman and Kaufman, 2007).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - low	0.1	A significant portion of the gulf coast and the extreme southeastern coast of the United States (Florida) are globally outstanding ecoregions (Ricketts et al., 1999). Beach vitex is a temperate to tropical maritime species capable of establishing as far north as plant hardiness zone 6 (see geopotential below).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			With the types of impacts it is already demonstrated to have (see Imp-N2, and Imp-N3), it could have significant impacts in these important ecoregions.
Imp-N6 (Weed status in natural systems)	c - negl	0.6	This species is being controlled in North and South Carolina; effective treatments are described and recommended (Smith, 2008). "Active community involvement and strategic mapping and eradication efforts are underway to limit the extent and impact that this exotic species has on the coasts of the Carolinas and prevent it from spreading into a wider geographical range" (ISSG, 2010). Alternate choices for the uncertainty analysis are both “b.”
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	y - mod	0.1	Coastal ecologists and beach volunteers have noted that it does not retain the sand as well as native vegetation; specifically, they noticed that dune profiles were lower where beach vitex was established (BVTF, 2010). The U.S. Army Corp of Engineers, which recently completed a $2 million beach restoration project in South Carolina, is concerned about the potential impact of this plant on coastal dunes (Socha and Roecher, 2004). Using “mod” uncertainty as this appears to be based on casual observation.
Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	Beginning to cover beach access trails in Virginia (BVTF, 2010). Lee Rosenberg with the City of Norfolk Dept. of Planning and Community believes that if allowed to spread, it could limit beach access (BVTF, 2010).
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	y - high	0.1	A gardener reports that it crowds out native beach grasses (Daves Garden, 2009). Displaces native beach dune species, including sea oats (Gresham and Neal, 2005). Because sea oats, among other dune species, are generally desirable by beach home owners, answering yes, but using “high” uncertainty because it is not very clear from the literature how homeowners feel about beach vitex in their gardens per se.
Imp-A4 (Weed status in anthropogenic systems)	c - negl	0.4	One study provides some recommendations for property owners wishing to remove this species (Gresham and Neal, 2005). Controlled in anthropogenic areas of the southeastern United States (True, 2009). Herbicide trials have been conducted to evaluate the most effective methods for killing this species (True, 2009). The Beach Vitex Task Force webpage documents a large amount of public support for and efforts in eradicating this species from public and private beaches (BVTF, 2010). Many local city ordinances have banned it (BVTF, 2010). Alternate choices for the uncertainty analysis are both “b.”
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - low	0	No evidence. Beach vitex is a terrestrial shrub of sand dunes and coastal strands (Kim, 2005; Ohwi, 1984; Wagner et al., 1999). It has been in the United States since 1955 (Olsen and Bell, 2005). Thus far, naturalized plants have only been detected along the coastline (CISEH, 2010; Kartesz, 2010). This species is being closely monitored (BVTF, 2010). It is extremely unlikely that it would establish in any production system, given its narrow niche. Consequently, using “low” uncertainty.
Imp-P2 (Lowers commodity value)	n - low	0	No evidence. See reasoning for answer and uncertainty under Imp-P1.
Imp-P3 (Is it likely to impact	n - low	0	No evidence. See reasoning for answer and uncertainty under

Question ID	Answer - Uncertainty	Score	Notes (and references)
trade)			Imp-P1.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	No evidence. See reasoning for answer and uncertainty under Imp-P1.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	No evidence. See reasoning for answer and uncertainty under Imp-P1.
Imp-P6 (Weed status in production systems)	a - low	0	No evidence it is considered an agricultural weed. See reasoning for answer and uncertainty under Imp-P1. Alternate choices for the uncertainty analysis are both “b.”
GEOGRAPHIC POTENTIAL			Unless otherwise noted, all evidence below represents point-occurrences obtained from GBIF (2009).
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 - low	N/A	No evidence.
Geo-Z5 (Zone 5)	n - mod	N/A	No evidence
Geo-Z6 (Zone 6)	y - low	N/A	Korea (1 geo-referenced data point). It is hardy through zone 6b (Olsen and Bell, 2005).
Geo-Z7 (Zone 7)	y - negl	N/A	Japan, South Korea.
Geo-Z8 (Zone 8)	y - negl	N/A	Japan; North and South Carolina (BVTF, 2010).
Geo-Z9 (Zone 9)	y - low	N/A	Alabama (1 point).
Geo-Z10 (Zone 10)	y - negl	N/A	Taiwan.
Geo-Z11 (Zone 11)	y - negl	N/A	Northern Australia.
Geo-Z12 (Zone 12)	y - negl	N/A	Northern Australia.
Geo-Z13 (Zone 13)	y - low	N/A	Indonesia (presence data, ARS, 2009).
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	Queensland Australia; Indonesia (ARS, 2009).
Geo-C2 (Tropical savanna)	y - negl	N/A	Hawaii, Northern Territory Australia.
Geo-C3 (Steppe)	n - mod	N/A	No evidence.
Geo-C4 (Desert)	n - mod	N/A	No evidence.
Geo-C5 (Mediterranean)	n - mod	N/A	No evidence.
Geo-C6 (Humid subtropical)	y - negl	N/A	Japan and Taiwan.
Geo-C7 (Marine west coast)	n - mod	N/A	No evidence.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	Korea.
Geo-C9 (Humid cont. cool sum.)	n - mod	N/A	No evidence.
Geo-C10 (Subarctic)	n - low	N/A	No evidence.
Geo-C11 (Tundra)	n - low	N/A	No evidence.
Geo-C12 (Icecap)	n - negl	N/A	No evidence.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - mod	N/A	No evidence.
Geo-R2 (10-20 inches; 25-51 cm)	n - mod	N/A	No evidence.
Geo-R3 (20-30 inches; 51-76 cm)	y - low	N/A	Northern Australia.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R4 (30-40 inches; 76-102 cm)	y - low	N/A	Northern Australia.
Geo-R5 (40-50 inches; 102-127 cm)	y - low	N/A	Northern Territory Australia.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Northern Australia.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Japan, Hawaii.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	Taiwan, Japan.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	Taiwan.
Geo-R10 (90-100 inches; 229-254 cm)	y - mod	N/A	Japan.
Geo-R11 (100+ inches; 254+ cm)	? - max	N/A	One point occurs at edge of this precipitation band in Japan. We did not include this in our estimation of the U.S. area suitable for establishment.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Present and established in the United States (Smith, 2008).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	Has been used medicinally in Hawaii (Wagner et al., 1999) and Asian countries (Park et al., 2004). It is available for sale by some plant nurseries and botanical gardens (e.g., UC-Davis, 2004), both on the east and west coasts of the United States, but the extent of its availability is unknown.
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
Ent-5 (Likely to enter through natural dispersal)	-	N/A	