United States Department of Agriculture

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Animal and Plant Health Inspection Service

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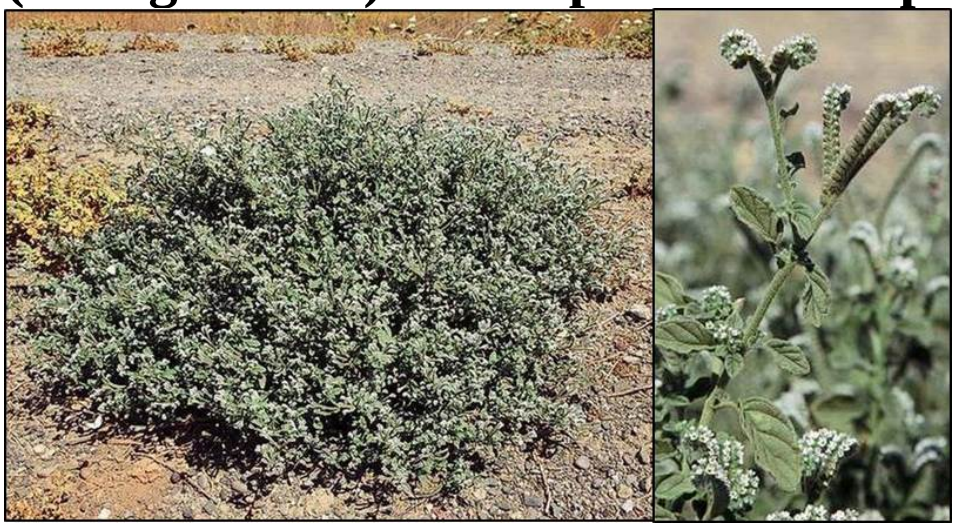
Version 1

Weed Risk Assessment for *Heliotropium europaeum* L. (Boraginaceae) – European heliotrope



Habit (left) and inflorescence of *H. europaeum* (right) (source: Joseph M. DiTomaso, University of California - Davis). Bugwood image numbers: 5374626 and 5374627, respectively.

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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.

Heliotropium europaeum L. – European heliotrope

Species Family: Boraginaceae

Information Synonyms: We found no recent synonyms that are relevant to our WRA. For a complete list of historical synonyms see The Plant List (2014). Although not synonyms, *H. europaeum* is often confused with *H. lasiocarpum*, *H. dolosum*, and *H. ellipticum* (Robson et al., 1991), none of which are known to be naturalized in the United States.

Common names: European heliotrope, barooga weed, caterpillar-weed, common heliotrope, European turnsole, hemp-agrimony (Clement and Foster, 1994; Holm et al., 1997; NGRP, 2014).

Botanical description: *Heliotropium europaeum* is an erect or semi-prostrate branched annual growing 10 to 50 cm tall and produces a well-developed taproot (Holm et al., 1997; Parsons and Cuthbertson, 2001). It is relatively hairy, produces flowers in indeterminate scorpioid cymes (Zhengyi et al., 2014), and has a somewhat aromatic odor when crushed (Parsons and Cuthbertson, 2001). For a full description see Zhengyi et al. (2014).

Initiation: APHIS received a market access request from South Africa for corn seeds for planting in the United States (South Africa Department of Agriculture Forestry and Fisheries, 2012). During the development of that commodity pest risk analysis, *H. europaeum* was identified as a weed of potential concern to the United States. The PPQ Weeds Cross Functional Working Group decided to evaluate this species with a weed risk assessment.

Foreign distribution: *Heliotropium europaeum* is reported to be native to southern and central Europe, northern Africa, and western Asia (NGRP, 2014; Parsons and Cuthbertson, 2001). Two European sources indicate it is an exotic species in Europe that was introduced long ago (i.e., an archaeophyte; Hanf, 1983; Pyšek et al., 2002). Beyond this range, this species is also present in Afghanistan (GBIF, 2014), Australia (Parsons and Cuthbertson, 2001), Belgium (Verloove, 2006),

China (Weber et al., 2008), India (Kaul, 1986), Mexico (Villaseñor Ríos and Espinosa García, 1998), Pakistan (GBIF, 2014), Russia (Zhengyi et al., 2014), and South Africa (CABI, 2014). We are unsure whether it was native to or introduced into Afghanistan, Pakistan, and India.

U.S. distribution and status: This species has been present in the United States since at least 1830 (Ward, 1881). It is known to be present in about 50 counties across the eastern United States, Texas, and California (Kartesz, 2014). It is not clear how prevalent it is in the eastern United States or if it is persisting in all locations. For example, a flora of the Washington D.C. area reported that it had disappeared by 1880 (Ward, 1881). A flora of Virginia, the Carolinas, Georgia, and northern Florida reports it is rare (Weakley, 2010). In contrast, *H. europaeum* appears to be sporadically common in northern California (DiTomaso, 2014; Jepson Flora Project, 2014; Kelch, 2014). Herbarium records from California for this species date back to 1957 and have steadily increased since then (Univ. of California, 2014). We found no evidence this species is considered a noxious weed in the United States or is currently a management target. We also found no evidence it is cultivated.

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

1. *Heliotropium europaeum* analysis

Establishment/Spread Potential

Heliotropium europaeum is an annual species with a rapid life cycle. It begins producing flowers three to four weeks after germinating, and seeds a few weeks later (Holm et al., 1997; Parsons and Cuthbertson, 2001). It continues growing and reproducing continuously until frost kills the plants (Parsons and Cuthbertson, 2001). Based on seed production rates of about 551 seeds per plant (Hasan and Aracil, 1991) and plant densities of 3 to 32 plants per square meter (Hunt et al., 2013; Tepe et al., 2011), this species has a high reproductive capacity. Seeds are dispersed by water (Parsons and Cuthbertson, 2001) and animals (Clement and Foster, 1994; Parsons and Cuthbertson, 2001; Verloove, 2006), as well as by people in commerce as both a contaminant and hitchhiker (GTA, No Date; Holm et al., 1997; Verloove, 2006). It was detected near Philadelphia in a ballast dump (Holm et al., 1997). *Heliotropium europaeum* was first recorded in Australia in 1880 and since then spread throughout large portions of the continent (Parsons and Cuthbertson, 2001). We had low uncertainty in this risk element.

Risk score = 19 Uncertainty index = 0.10

Impact Potential

Heliotropium europaeum is an economically important weed because it is toxic to sheep, cattle, horses, pigs, and poultry (Burrows and Tyrl, 2001; Cavallaro et al., 2004; Parsons and Cuthbertson, 2001). It contains five pyrrolizidine alkaloids (Parsons and Cuthbertson, 2001) which cause liver damage and predispose animals to chronic copper poisoning and photosensitization over long periods of exposure (Holm et al., 1997; Parsons and Cuthbertson, 2001). In Australia, *H. europaeum* has directly caused losses of hundreds of millions of dollars to sheep production (Harris and Nowara, 1995; Holm et al., 1997). Those losses have caused "some farmers to shift from a wool production system to the production of fat lambs"

[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).

(Holm et al., 1997). Australian researchers have been trying to develop breeds of sheep that are more resistant to the toxic compounds (Holm et al., 1997), as well as searching for suitable biocontrol agents (Hasan and Aracil, 1991; Holm et al., 1997). Although *H. europaeum* can be controlled with herbicides, control requires repeated applications (Parsons and Cuthbertson, 2001). Lastly, a congener of this species has contaminated wheat grain resulting in human illness and fatalities in central Asia (Holm et al., 1997). We had a low amount of uncertainty for this risk element.
Risk score = 2.7 Uncertainty index = 0.10

Geographic Potential Based on three climatic variables, we estimate that about 76 percent of the United States is suitable for the establishment of *H. europaeum* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes georeferenced localities and areas of occurrence. The map for *H. europaeum* represents the joint distribution of Plant Hardiness Zones 5-11, areas with 0-80 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, and humid continental warm and cool summers.

The area estimated likely 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. *Heliotropium europaeum* occurs mainly in disturbed areas, fallows and degraded pastures, roadsides, lakeshores, and riparian areas (Parsons and Cuthbertson, 2001; Weber et al., 2008). It is well adapted to drought stress (Holm et al., 1997).

Entry Potential We did not assess the entry potential of *H. europaeum* because it is already present in the United States (Kartesz, 2014).

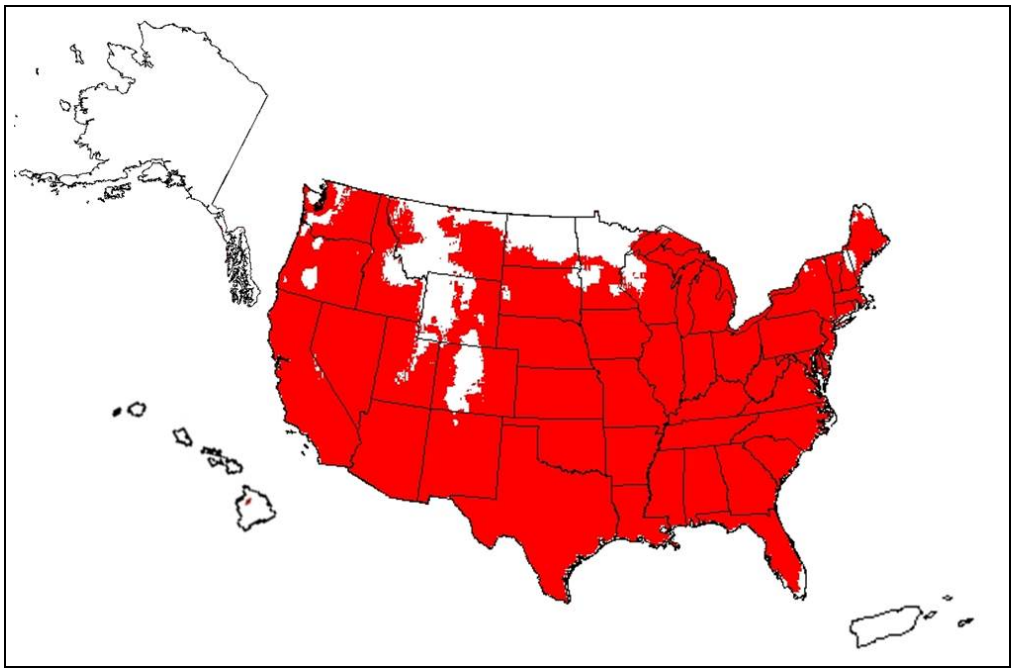

Figure 1. Predicted distribution of *Heliotropium europaeum* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results and Conclusion

Model Probabilities: P(Major Invader) = 87.7%
P(Minor Invader) = 11.9%
P(Non-Invader) = 0.4%

Risk Result = High Risk

Secondary Screening = Not Applicable

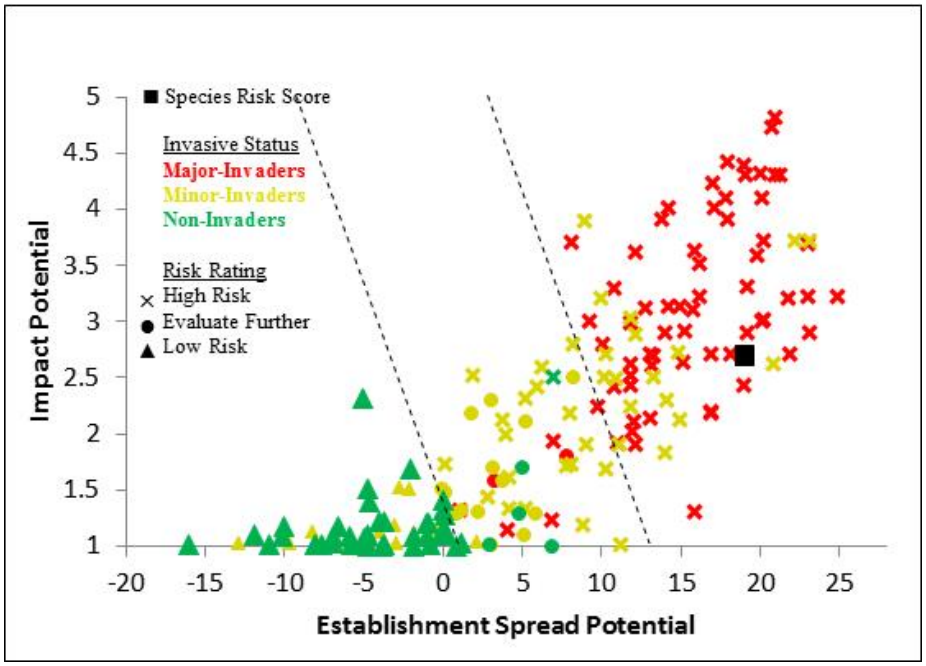

Figure 2. *Heliotropium europaeum* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

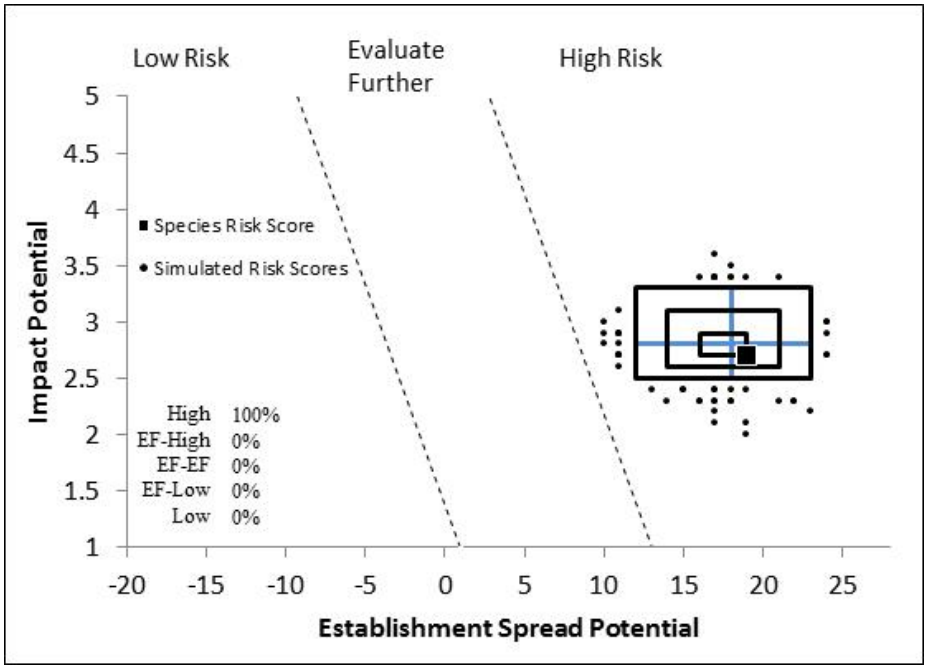

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *H. europaeum.* The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *H. europaeum* is High Risk (Fig. 2). Overall, we had low uncertainty and our conclusion was well supported by the results of the uncertainty simulation (Fig. 3). An independent evaluation with the Australian weed risk assessment led to a similar conclusion (Pheloung, 1995). *Heliotropium europaeum* is not as aggressive as many other weed species because it is susceptible to competition (Parsons and Cuthbertson, 2001). This is why it primarily occurs in disturbed areas where perennial species have been eliminated or depressed through overgrazing. It spreads readily, though, and is particularly toxic to animals and people (Holm et al., 1997).

This species has been present in the United States for almost 200 years (Ward, 1881). Why it has not become as problematic in the United States as in Australia is somewhat perplexing. We suspect that is because the eastern United States is not climatically ideal for its proliferation. *Heliotropium europaeum* is native to southern Europe, northern Africa, and central Asia where dry climates prevail (NGRP, 2014). The areas where it is prevalent in Australia are also dry. Hence, it may be better suited to the western United States. *Heliotropium europaeum* is widely distributed in northern California and sporadic to common in occurrence (Jepson Flora Project, 2014), but it does not form large patches (DiTomaso, 2014; Kelch, 2014). Because this species is not spreading much in California, it has not been prioritized as a significant problem (DiTomaso, 2014). It is not clear whether or not this will be the extent of this species' distribution in the United States; it may be in a quiescent phase of invasion.

The genus *Heliotropium* is well known for its toxicity (Burrows and Tyrl, 2001), and *H. europaeum* has cost Australian farmers millions of dollars due to the direct and indirect impacts associated with its toxicity (Holm et al., 1997). This species also poses a threat to human welfare. The genus *Heliotropium* is well known for its toxicity (Burrows and Tyrl, 2001). Humans have ingested toxic levels of pyrrolizidine alkaloids from species in *Heliotropium* either directly from herbal teas and contaminated wheat, or indirectly from eggs, milk, and meat (Edgar and Smith, 1999). Diseases and conditions associated with the toxins in this genus have been widespread in Asia (Cheeke, 1991). "The most recent and best investigated episode was in Afghanistan in 1974, with over 35,000 people affected and many mortalities" (Cheeke, 1991). *Heliotropium europaeum* has not yet been a problem in North America, but if plant populations increase, liver disease is a risk from long-term ingestion (Burrows and Tyrl, 2001).

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Appendix A. Weed risk assessment for *Heliotropium europaeum* L. (Boraginaceae). The following information came from the original risk assessment, which is available upon request. 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	This species is generally native to southern Europe, northern Africa, and western Asia (NGRP, 2014), although it may be an ancient introduction to Europe and northern Africa (an archaeophyte) (Hanf, 1983; Pyšek et al., 2002). A casual species in the United Kingdom (Clement and Foster, 1994) and Belgium (Verloove, 2006). Naturalized in China (Weber et al., 2008), Mexico (Parsons and Cuthbertson, 2001), and the United States (Jepson Flora Project, 2014; Weakley, 2010). Also present in South Africa (CABI, 2014). In Australia it was first recorded in 1880 and since has spread throughout the entire continent except the Northern Territory and Tasmania (Parsons and Cuthbertson, 2001). Alternate answers for the Monte Carlo simulation were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	This species is used in traditional medicine (Maleš and Trojanović, 1999), but we found no evidence it is cultivated. Thus, it is highly unlikely to have been bred for traits associated with reduced weed potential.
ES-3 (Weedy congeners)	y - low	1	The genus *Heliotropium* has about 350 species (Mabberley, 2008) and several dozen have been identified as weeds (Randall, 2012). *Heliotropium amplexicaule*, *H. curassavicum*, and *H. indicum* are well documented as weeds (Randall, 2012). *Heliotropium amplexicaule* is an invasive species in Australia and is poisonous to livestock (Randall, 2007; Richardson et al., 2006). As a contaminant of bread flour, *H. popovii* has sickened thousands of people and resulted in the death of about a 1000 (Cheeke, 1991; Holm et al., 1997).
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	We found no direct evidence. Because this species occurs in open habitats such as disturbed areas, fallows, degraded pastures, roadsides, agricultural areas, lakeshores, and riparian areas (Parsons and Cuthbertson, 2001; Weber et al., 2008), it seems unlikely to be shade tolerant.
ES-5 (Climbing or smothering growth form)	n - negl	0	This species is not a vine or plant with a basal rosette of leaves. It is an erect or semi-prostrate branched annual growing 10 to 50 cm tall (Holm et al., 1997; Parsons and Cuthbertson, 2001).
ES-6 (Forms dense thickets)	n - mod	0	We found no evidence.
ES-7 (Aquatic)	n - negl	0	Species is a terrestrial herb (Holm et al., 1997; Parsons and Cuthbertson, 2001).
ES-8 (Grass)	n - negl	0	Not a grass; it is a member of the Boraginaceae family (NGRP, 2014).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no direct evidence. This species is neither woody (Holm et al., 1997; Parsons and Cuthbertson, 2001) nor a member of a plant family known to fix nitrogen (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Reproduces only by seed (Parsons and Cuthbertson, 2001). Produces viable seed (Holm et al., 1997).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-11 (Self-compatible or apomictic)	y - high	1	In one study that enclosed plants in clear, perforated bags at the beginning of flowering, mature seeds were collected from bagged plants (Hunt et al., 2009); although this study did not mention the size of the perforations, the fact that plants set seed in the bags suggests that selfing or apomixis may be occurring.
ES-12 (Requires special pollinators)	n - high	0	Given the evidence presented under ES-11, this species seems unlikely to require specialist pollinators. The establishment of this species in multiple areas beyond its native range (see ES-1) supports this idea.
ES-13 (Minimum generation time)	a - mod	2	*Heliotropium europaeum* is an annual that germinates in the spring, grows slowly at first while it develops its taproot, and then begins flowering during the summer (Holm et al., 1997; Parsons and Cuthbertson, 2001). Under greenhouse and field conditions, plants begin flowering three weeks after germinating and seed begins to ripen 3 to 5 weeks later (Holm et al., 1997; Parsons and Cuthbertson, 2001). Although cold stratification enhances germination, several generations can be produced in one season (Parsons and Cuthbertson, 2001). Alternate answers for the Monte Carlo simulation were both "b."
ES-14 (Prolific reproduction)	y - high	1	Growth, flowering, and seed production is continuous throughout summer and into fall until frost kills the plant (Parsons and Cuthbertson, 2001). It produces a lot of seed (Holm et al., 1997). In a study on plant susceptibility to a potential biocontrol agent, individuals at a density of about 8.8 plants per square meter produced a mean of 551 seeds per plant (Hasan and Aracil, 1991), or approximately 4867 seeds per square meter. Other studies have reported densities from 3 to 32 plants per square meter (Hunt et al., 2013; Tepe et al., 2011). It is not clear if high density populations also produce 551 seeds per plant; however, just a few more plants per square meter would produce over 5000 seeds per square meter. Because germination rates are 48 percent to 90 percent (Hasan and Aracil, 1991; Holm et al., 1997) and plants may produce multiple generations per year (ES-13), that populations are likely to produce more than 5000 viable seeds per square meter.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	Seeds are spread by people during agricultural activity (Kaul, 1986).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	Introduced in wool imports into Belgium (Verloove, 2006). A contaminant of grain (GTA, No Date). "A wool and oil-seed casual" alien in the United Kingdom (Clement and Foster, 1994), albeit rare (Stace, 2010). Ballast material was one of the pathways for its dispersal around the world (Holm et al., 1997). It was detected near Philadelphia in a ballast dump (Holm et al., 1997). "The weed was distributed along the east coast of the United States as chrome and manganese ores and coal were brought in and stored near the shore. It was brought in with pumice from Italy" (Holm et al., 1997). Seeds are also spread as a contaminant in fodder as "whole plants harvested with forage nearly always carry some ripe seeds" (Parsons and Cuthbertson, 2001). In one study, this species was found as a

Question ID	Answer - Uncertainty	Score	Notes (and references)
			contaminant of whole wheat seed at a rate of 4980 weeds seeds per kg of wheat (Hill et al., 1997).
ES-17 (Number of natural dispersal vectors)	3	2	Fruit and seed description for questions ES-17a through ES-17e: Fruit is a group of four individual nutlets with fine wart-like protuberances; seeds are brown, 2 mm long by 1 mm wide (Holm et al., 1997; Parsons and Cuthbertson, 2001).
ES-17a (Wind dispersal)	n - low		We found no evidence. Based on the morphology of the fruits and seeds, wind dispersal seems unlikely.
ES-17b (Water dispersal)	y - low		Seeds of heliotrope float for a long time (cited in Holm et al., 1997). "Local spread also occurs in water movement over the soil surface or in floods" (Parsons and Cuthbertson, 2001).
ES-17c (Bird dispersal)	n - mod		We found no evidence.
ES-17d (Animal external dispersal)	y - negl		"Seeds are mainly spread by stock or as a contaminant in fodder...[t]he hairy inflorescence and rough surface of the nutlets allow seeds to adhere to wool and fur" (Parsons and Cuthbertson, 2001). Seeds contaminate wool (Clement and Foster, 1994; Verloove, 2006).
ES-17e (Animal internal dispersal)	y - low		Whole plants and mature seeds are present in fodder; seeds usually pass through the digestive system of animals unharmed (Parsons and Cuthbertson, 2001).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - low	1	Seeds can remain dormant in the soil for a long time (Holm et al., 1997). One study used seed that was buried for at least 1.5 years in the soil (Hunt et al., 2009).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - mod	-1	*Heliotropium europaeum* produces a slender but deep taproot down to about one meter (Parsons and Cuthbertson, 2001), which is likely an adaptation to xeric environments. This adaptation may help it tolerate mutilation, but we found no evidence in the literature. Because this species is well known in Australia, we answered no with moderate uncertainty.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - mod	0	Seedlings of *H. europaeum* are susceptible to herbicides, but plants become "more resistant" as they mature (Parsons and Cuthbertson, 2001); in this case, we interpreted the use of “resistant” to really mean tolerant because of plant hairiness and the deep taproot. We found no other evidence this species is resistant to herbicides. No members of this genus are listed by Heap (2014).
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	y - high	0.1	Aqueous extracts from leaf, flower, and root extracts inhibited growth of oats, beans, and duckweed (Travlos and Paspatis, 2008). In the same study, "soil assays showed that root exudates released into the soil reduced seedling growth of bean" (Travlos and Paspatis, 2008). A different study found an inhibitory effect of aqueous extracts from leaves on dodder and radish seedling growth, at a wide range of concentrations (Abdulghader et al., 2008). Although we usually prefer

Question ID	Answer - Uncertainty	Score	Notes (and references)
			evidence from field studies to support a yes answer, because there were two studies that used tissue extracts and soil samples to investigate allelopathy, we answered yes with high uncertainty.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence. This species does not belong to a plant family known to contain parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	n - low	0	We found no evidence.
Imp-N2 (Change community structure)	n - low	0	We found no evidence.
Imp-N3 (Change community composition)	? - max		Categorized as a threat to rangeland biodiversity (Martin et al., 2006), but it is not clear whether it is significantly affecting biodiversity in natural systems, or is simply perceived as a threat. Consequently, we answered unknown.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	n - mod	0	We found no evidence. We used moderate uncertainty because it is unclear whether it is affecting community composition.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	n - low	0	We found no evidence. This particular impact seems unlikely given the species' overall profile.
Imp-N6 (Weed status in natural systems)	a - low	0	This species is present in some natural areas in California (Univ. of California, 2014), but we found no evidence it is considered a weed of natural areas. Alternate answers for the Monte Carlo simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	n - low	0	We found no evidence.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	Has a somewhat offensive odor when crushed (Parsons and Cuthbertson, 2001), but we found no evidence this has affected recreational use of an area.
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	n - mod	0	We found no evidence.
Imp-A4 (Weed status in anthropogenic systems)	a - mod	0	This species occurs on roadsides and waste places (Holm et al., 1997; Kelch, 2014), but it is not clear if it is considered a weed in these environments. Alternate answers for the Monte Carlo simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	*Heliotropium europaeum* is a major concern to sheep production in Australia because of its toxicity (Harris and Nowara, 1995; Holm et al., 1997). The "losses may begin after two or three heavy exposures or the life span of the sheep may be shortened from 8 to 5 or 6 yr" (Holm et al., 1997). "After many years of difficulties and losses of hundreds of millions of dollars from the mortality of sheep grazed on this weed, some farmers have had to shift from a wool production system to the production of fat lambs," which are harvested at the end of the first season of grazing (Holm et al., 1997). Infestations of this weed may be causing losses of $20 to $30 million

Question ID	Answer - Uncertainty	Score	Notes (and references)
			dollars per year in Australia (Holm et al., 1997). Sheep losses have been as high as 30 percent (Parsons and Cuthbertson, 2001). Losses in cattle due to contaminated feed have also been reported (Hill et al., 1997).
Imp-P2 (Lowers commodity value)	y - negl	0.2	It has "become a particularly costly problem in animal husbandry in Australia" (Holm et al., 1997). In addition to the deaths reported under Imp-P1, the productive life of the remaining animals is often shortened a few years (Parsons and Cuthbertson, 2001), leading to changes from wool production to fat-lamb production (Holm et al., 1997). Based on speculation, some farmers in Victoria give their flock supplements of cobalt as a prophylactic to slow the progression of the disease, but one study suggests this may not be helpful (Peterson et al., 1992). Regardless, their use increases the costs of production.
Imp-P3 (Is it likely to impact trade)	y - negl	0.2	A noxious weed in Western Australia and a declared weed in Tasmania (Parsons and Cuthbertson, 2001). A quarantine pest in Honduras (Puerto, No Date), Brazil, Paraguay, Panama, Peru, Taiwan, and Thailand (APHIS, 2014). Introduced in wool imports to Belgium and the United Kingdom (Clement and Foster, 1994; Verloove, 2006). A contaminant of grain (GTA, No Date). Thus, this species is likely to impact trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	y - mod	0.1	Control of *H. europaeum* and volunteer wheat during the dry-summer fallow period between crops increased soil water and nitrogen availability, and ultimately crop yield during the following growing season (Hunt et al., 2013). Thus this plant species may also sometimes reduce crop yield by removing soil moisture between cropping periods. "Common heliotrope also competes for soil water and can cause serious reductions in crop yields, particularly in dry years" (cited in Hasan and Aracil, 1991). It is not clear whether this indirect impact on water availability across time occurs for other weed species or if *H. europaeum* has a particularly strong impact on water availability relative to other weeds. Given the evidence, we answered yes, but with moderate uncertainty.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	y - negl	0.1	It is economically important because it is toxic to sheep, cattle, horses, pigs, and poultry (Burrows and Tyrl, 2001; Cavallaro et al., 2004; Parsons and Cuthbertson, 2001). "*H. europaeum* is most notorious as a member of a group of plants containing pyrrolizidine alkaloids that are very toxic to many types of stock animals" (Holm et al., 1997). It contains five pyrrolizidine alkaloids (Parsons and Cuthbertson, 2001), which cause liver damage (atropic hepatosis) and predispose animals to chronic copper poisoning and photosensitization (Holm et al., 1997; Parsons and Cuthbertson, 2001). In sheep, "[t]he disease has several manifestations, but ultimately the deterioration of the liver, resulting in its altered metabolic activity, or the loss of kidney function, becomes fatal. Secondary reactions such as altered copper and nitrogen metabolism bring on other pathological disorders which in themselves may cause death" (Holm et al., 1997), particularly if the animals are stressed such as during pregnancy or eweing (Peterson et al., 1992). One account of the toxicity of *Heliotropium* species reports that copper is concentrated in the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			liver, which leads to chronic copper intoxication (Burrows and Tyrl, 2001). Repeated ingestion of the toxic alkaloids at low rates vs. consumption of large quantities produces different clinical symptoms (Burrows and Tyrl, 2001). *Heliotropium europaeum* is palatable to some breeds of sheep but not others (Parsons and Cuthbertson, 2001). Cattle are more susceptible to the toxins than sheep and symptoms may appear a few weeks after ingestion, especially if there isn't any other source of fodder (Parsons and Cuthbertson, 2001). Horses are particularly susceptible to *H. europaeum* (Parsons and Cuthbertson, 2001). While it is clear *H. europaeum* is toxic, much uncertainty still exists about how consumption of this species impacts animals and what factors determine the development and progression of disease, including environmental conditions, stock breed, stress levels, and other factors (Peterson et al., 1992).
Imp-P6 (Weed status in production systems)	c - negl	0.6	*Heliotropium europaeum* "infests 26 crops in 36 countries" (Holm et al., 1997). It is a serious weed of pastures in Australia and Italy, and of cotton in Iran. It is a principal weed of cereals, peanuts, sorghum, sesame, melons, and sugar beets in other countries (Holm et al., 1997), and considered a weed in its native range (Hanf, 1983). An important weed of irrigated crops and vegetables (Robson et al., 1991). Due to its impact to sheep husbandry, Australian workers have been trying to develop breeds of sheep that are more resistant to the toxic compounds in *H. europaeum* (Holm et al., 1997). There is ongoing work to find biocontrol agents for this weed (Hasan and Aracil, 1991; Holm et al., 1997) and several pests have been imported to Australia to help control it (Parsons and Cuthbertson, 2001). Integrated pest management strategies are needed to control this species because herbicidal management is too costly due to the need for repeated applications (Parsons and Cuthbertson, 2001). Extra land cultivation helps in control by killing seedlings and promoting germination of plants, but it contributes to erosion (Parsons and Cuthbertson, 2001). Alternate answers for the Monte Carlo simulation were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically-referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2014).
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence it occurs in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence it occurs in this zone.
Geo-Z3 (Zone 3)	n - low	N/A	We found no evidence it occurs in this zone.
Geo-Z4 (Zone 4)	n - high	N/A	One point in Afghanistan. Because this was the only record and because this is a mountainous region where global climate maps may not be very accurate, we answered no.
Geo-Z5 (Zone 5)	y - high	N/A	A few point in Afghanistan and Pakistan. One point in the United States (near Chicago) (GBIF, 2014; Kartesz, 2014).
Geo-Z6 (Zone 6)	y - low	N/A	A few points in Germany, Afghanistan, and Pakistan. One point each in Germany and Sweden.
Geo-Z7 (Zone 7)	y - negl	N/A	Germany, Spain, and the United States.
Geo-Z8 (Zone 8)	y - negl	N/A	Australia, France, and Spain.

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Geo-Z9 (Zone 9)	y - negl	N/A	Australia, Portugal, Spain, and the United States (CA).
Geo-Z10 (Zone 10)	y - negl	N/A	Australia.
Geo-Z11 (Zone 11)	y - negl	N/A	Australia, Israel, and Spain.
Geo-Z12 (Zone 12)	n - high	N/A	Two points in coastal regions of Australia, very near zone 11. We answered no because we found no other evidence supporting its presence in this zone and because, overall, this is a temperate species.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence it occurs in this zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence it occurs in this climate type.
Geo-C2 (Tropical savanna)	n - negl	N/A	We found no evidence it occurs in this climate type.
Geo-C3 (Steppe)	y - negl	N/A	Afghanistan, Australia, and Spain.
Geo-C4 (Desert)	y - negl	N/A	Afghanistan, Australia, Pakistan, and Spain.
Geo-C5 (Mediterranean)	y - negl	N/A	Australia, Greece, Portugal, and the United States (CA). It is usually most abundant in areas receiving winter rainfall (Parsons and Cuthbertson, 2001).
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia, and the United States (CA and OR).
Geo-C7 (Marine west coast)	y - negl	N/A	Australia, France, Germany, and Spain.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	Two points in Pakistan. In the United States, one point in northeastern IL and one on the edge in PA (GBIF, 2014; Kartesz, 2014).
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	A few points in Germany, Pakistan, Spain, and Sweden.
Geo-C10 (Subarctic)	n - high	N/A	A couple of points in Spain and France; however, we answered no because they may be errors and are not reflective of the overall distribution of the species.
Geo-C11 (Tundra)	n - low	N/A	We found no evidence it occurs in this climate type.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence it occurs in this climate type.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - low	N/A	Afghanistan, Australia, Pakistan, and Spain.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Australia and Spain.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Australia and Spain.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia, France, Portugal, Spain, and the United States (CA).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	France, Greece, Portugal, Spain, and the United States (CA).
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	Germany and one point in Spain. A couple of points in the United States (MS) (Kartesz, 2014).
Geo-R7 (60-70 inches; 152-178 cm)	y - low	N/A	A few points in France, Germany, and Spain. A couple of points in the United States (AL) (Kartesz, 2014).
Geo-R8 (70-80 inches; 178-203 cm)	y - high	N/A	A few points in India.
Geo-R9 (80-90 inches; 203-229 cm)	n - high	N/A	We found no evidence it occurs in this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	n - high	N/A	One point in India; however, because this was the only record and because this is a mountainous region where global climate maps may not be very accurate, we answered no.
Geo-R11 (100+ inches; 254+ cm))	n - high	N/A	One point in India; however, because this was the only record and because this is a mountainous region where global climate

Question ID	Answer - Uncertainty	Score	Notes (and references)
			maps may not be very accurate, we answered no.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	This species is present in the United States, where it is naturalized in about 50 counties across the eastern states, Texas, and California (Kartesz, 2014).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	
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	Ballast material was one of the pathways for its dispersal around the world (Holm et al., 1997). It was detected near Philadelphia in a ballast dump (Holm et al., 1997).
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	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	