United States Department of Agriculture

Weed Risk Assessment for *Echium plantagineum* L. (Boraginaceae) – Paterson's Curse

United States Department of Agriculture

Animal and Plant Health Inspection Service

March 22, 2017

Version 1

Left and middle: Flowering stage of *E. plantagineum* (Oregon Department of Agriculture 2017a). Right: Rosette stage (Oregon Department of Agriculture, 2017b).

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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 the PPQ weed risk assessment (WRA) process (PPQ, 2015) 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.

The PPQ WRA process includes three analytical components that together describe the risk profile of a plant species (risk potential, uncertainty, and geographic potential; PPQ, 2015). At the core of the process is the predictive risk model that evaluates the baseline invasive/weed potential of a plant species using information related to its ability to establish, spread, and cause harm in natural, anthropogenic, and production systems (Koop et al., 2012). Because the predictive model is geographically and climatically neutral, it can be used to evaluate the risk of any plant species for the entire United States or for any area within it. We then use a stochastic simulation to evaluate how much the uncertainty associated with the risk analysis affects the outcomes from the predictive model. The simulation essentially evaluates what other risk scores might result if any answers in the predictive model might change. Finally, we use Geographic Information System (GIS) overlays to evaluate those areas of the United States that may be suitable for the establishment of the species. For a detailed description of the PPQ WRA process, please refer to the *PPQ Weed Risk Assessment Guidelines* (PPQ, 2015), which is available upon request.

We emphasize that our WRA process is designed to estimate the baseline—or unmitigated—risk associated with a plant species. We use evidence from anywhere in the world and in any type of system (production, anthropogenic, or natural) for the assessment, which makes our process a very broad evaluation. This is appropriate for the types of actions considered by our agency (e.g., Federal regulation). Furthermore, risk assessment and risk management are distinctly different phases of pest risk analysis (e.g., IPPC, 2015). Although we may use evidence about existing or proposed control programs in the assessment, the ease or difficulty of control has no bearing on the risk potential for a species. That information could be considered during the risk management (decision-making) process, which is not addressed in this document.

	***Echium plantagineum* L. – Paterson's Curse**
Species Information	Family: Boraginaceae
	Synonyms: *Echium alonsoi* Sennen & Mauricio; *E. bonariense* Poir.; *E. longistamineum* Pourr. ex Lapeyr.; *E. lycopsis* L.; *E. orientale* Stephan; *E. plantaginifolium* L. ex Moris; *E. plantaginoides* Roem. & Schult.; *E. pseudoviolaceum* Schur; *E. sennenii* Pau; *E. violaceum* L. (The Plant List, 2013).
	Common names: Paterson's curse, salvation Jane, blue weed, Lady Campbell weed, purple bugloss, purple echium, purple viper's bugloss, riverina bluebell (Groves et al., 2005).
	Botanical description: *Echium plantagineum* is an annual herb that normally grows from 30-80 cm in height and sometimes up to 150 cm. It has rosette leaves that are up to 25 cm long and large purple flowers (about 2-3 cm in length) (Weber, 2003). Seeds have a hard coat and have an average weight of 360-390 mg per 100 seeds (Groves et al., 1995). The seed size is 2.6-3×2.1-2.3 mm (Bojňanský and Fargašová, 2007). For a full botanical description, see Groves et al. (1995) and Weber (2003).
	Initiation: PPQ received a market access request for wheat seed for human and animal consumption from the government of Ukraine (Government of Ukraine, 2013). A commodity import risk analysis revealed that *E. plantagineum* could be associated with this commodity as a seed contaminant. In this assessment, PERAL evaluates the risk potential of this species to the United States, to help policy makers determine whether it should be regulated as a Federal Noxious Weed.
	Foreign distribution and status: *Echium plantagineum* is primarily native to the Mediterranean region and elsewhere in the following countries: Albania, Bulgaria, the Canary Islands, Georgia, Germany, Jordan, the Madeira Islands, Portugal, the United Kingdom, and Ukraine (NGRP, 2016). It is naturalized in Argentina, the Azores, Chile, Eritrea, Ethiopia, Kenya, Lesotho, South Africa, Tanzania, and Zimbabwe (NGRP, 2016). Since its introduction to Australia in the mid-1800s, it spread to Victoria, New South Wales, Tasmania, Western Australia, Queensland, and the Northern Territory within a 100 years (Groves et al., 1995; Parsons, 1973; Ross and Walsh, 2003). In 1879 it was introduced to New Zealand and by the 1920s it was found throughout much of the North Island (Tomson, 1922).
	U.S. distribution and status: *Echium plantagineum* is currently found in five states (California, Oregon, Pennsylvania, New York, and Massachusetts) and within nine counties across those states (Kartesz, 2015; NRCS, 2016). It is currently spreading throughout Sonoma County, CA (Kelch, 2015). In Oregon it is considered a noxious weed (Kartesz, 2015) and is under a statewide management plan (Oregon Department of Agriculture 2017a). Wyoming considers *E. plantagineum* to be a "prohibited noxious weed,"

and the seeds are prohibited from being sold as nursery stock (National Plant Board, 2017). *Echium plantagineum* is currently being cultivated at a nursery in California (Annie's Annuals & Perennials, 2017) and we found evidence of it being sold online (Amazon, 2017; eBay, 2017).

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

1. *Echium plantagineum* analysis

Establishment/Spread Potential

Echium plantagineum is an annual herb that is capable of having every growth stage present throughout the year (Groves et al., 1995; Parsons and Cuthbertson, 2001). It is a prolific seed producer (Piggin, 1978b; Konarzewski, 2012) and can form seed banks that can last up to five years (Parsons and Cuthbertson, 2001; Weber, 2003). *Echium plantagineum* can be unintentionally dispersed by humans (e.g., via harvested grain, fodder, soil, and vehicles) (Groves et al., 2005; Groves et al., 1995; Moerkerk, 2006) or naturally dispersed by water (Weber, 2003), ants (Piggin, 1978a), and livestock (Groves et al., 1995; Piggin, 1978a; Parsons and Cuthbertson, 2001). Due to its small, heavy seeds, *E. plantagineum* is not wind dispersed (Groves et al., 1995; Piggin, 1978a). Recent research has shown that in Australia and Brazil *E. plantagineum* has developed resistance to acetolactate synthase (ALS) inhibitors (B/2) (Heap, 2017). Because *E. plantagineum* is well studied, we had a low uncertainty for this risk element.

Risk score = 24 Uncertainty index = 0.08

Impact Potential

Echium plantagineum is mainly an agricultural weed of rangelands (Broster et al., 2012; Groves et al., 1995). It lowers wool yield if sheep graze mainly on *E. plantagineum* (Seaman et al., 1989). It can also lower the value of honey made from French lavender (*Lavandula stoechas*) because of the high rate of *E. plantagineum* pollen contaminating the honey (Bonvehi and Coll, 1993). *Echium plantagineum* is toxic to horses, pigs, sheep, cattle, and goats, producing symptoms ranging from gastrointestinal distress to death (Acamovic et al., 2004; Mendez et al., 1985; Parsons and Cuthbertson, 2001; Simmonds et al., 2000). *Echium plantagineum* may impact trade, as it is regulated and/or prohibited from several Australian states/territories (Northern Territory, South Australia, Western Australia, and Victoria) (Groves et al., 2005), South Africa (Nel et al., 2004), Canada (Canadian Food Inspection Agency, 2016), Colombia, the Republic of Korea, the Democratic People's Republic of Korea, Ecuador, Peru, and Taiwan (APHIS, 2017). Despite having limited information on *E. plantagineum* in natural and anthropogenic systems, we had enough information about its impacts in agricultural settings to have low uncertainty for this risk element.

Risk score = 2.8 Uncertainty index = 0.08

[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).

Geographic Potential Based on three climatic variables, we estimate that about 76 percent of the United States is suitable for the establishment of *Echium plantagineum* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and general areas of occurrence. The map for *Echium plantagineum* represents the joint distribution of Plant Hardiness Zones 5-12, areas with 0-80 inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical savanna, steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summer, and subarctic. It was not clear if *E. plantagineum* occurs in humid continental warm summers. For this prediction, we assumed that this climate was suitable since *E. plantagineum* is prevalent in surrounding climate classes.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only 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. *Echium plantagineum* has been found in agricultural settings, in pastures, along roadsides, and in grasslands (Broster et al., 2012; Groves et al., 1995; Parsons and Cuthbertson, 2001; Piggin, 1978b). To date, *E. plantagineum* has been found in places with variable rainfall (Frith et al., 1974; Groves et al., 1995; Hulting et al., 2007; Parsons and Cuthbertson, 2001) and soil types (Groves et al., 1995; Parsons and Cuthbertson, 2001; Retief and van Wyk, 1998). See the Geographic Potential section of Appendix A for a better understanding of *E. plantagineum*'s preferences.

Entry Potential Although *Echium plantagineum* is already present in the United States (Kartesz, 2015; NRCS, 2016), we evaluated this risk element to determine the likelihood of additional plant material entering from other countries. On a scale of 0 to 1, where 1 represents a maximum likelihood to enter through multiple pathways, *E. plantagineum* scored 0.63. Because this species is cultivated as an ornamental plant (Annie's Annuals & Perennials, 2017; Matthei, 1995), the most likely pathway for it to enter the United States is intentionally for propagation. This species may also enter as a contaminant of harvested grain (Groves et al., 2005; Groves et al., 1995; Piggin, 1978a), hay (Hulting et al., 2007), and farming equipment and other vehicles (Groves et al., 1995; Hulting et al., 2007; Moerkerk, 2006).
Risk score = 0.63 Uncertainty index = 0.23

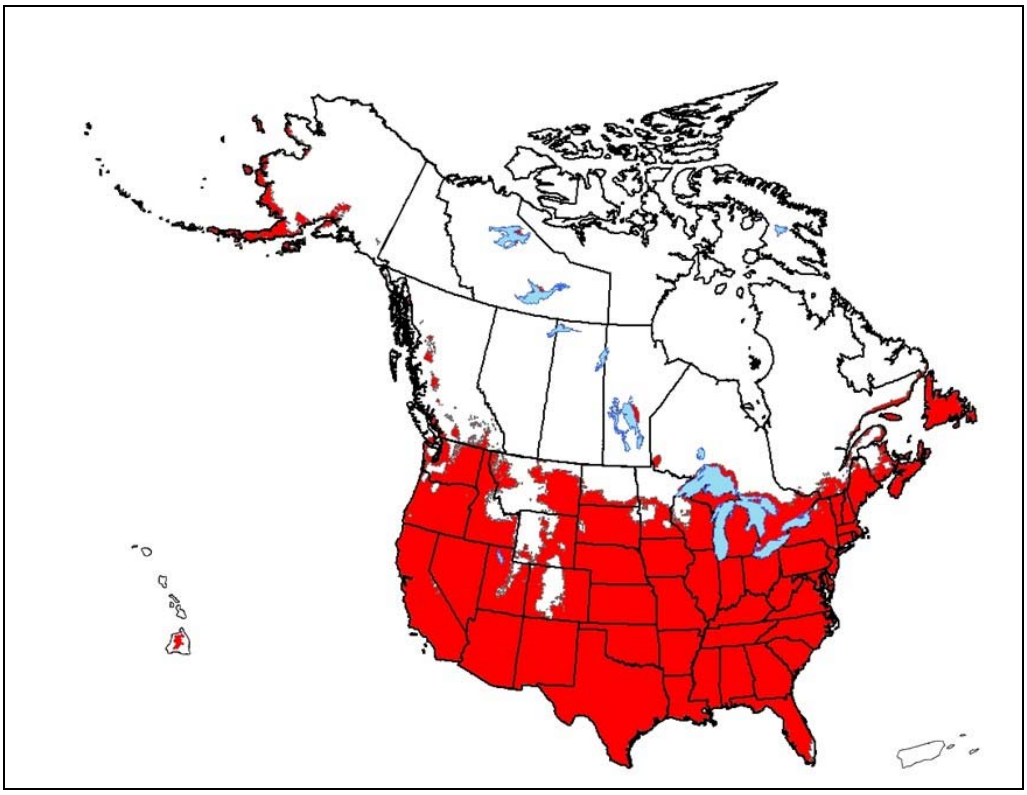

Figure 1. Potential geographic distribution of *Echium plantagineum* in the United States. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 96.1%
P(Minor Invader) = 3.8%
P(Non-Invader) = 0.1%

Risk Result = High Risk

Secondary Screening = Not Applicable

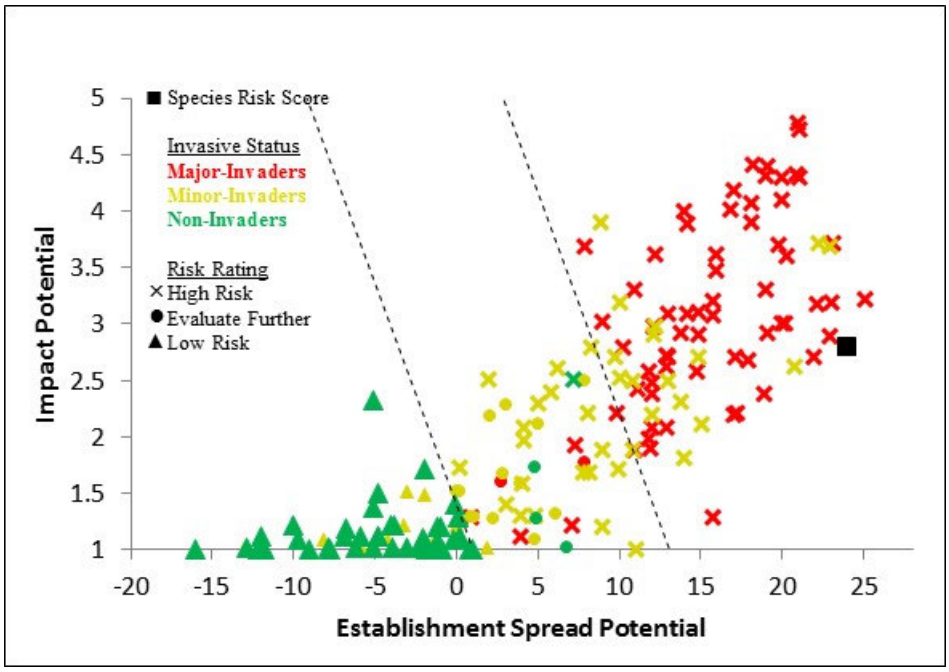

Figure 2. *Echium plantagineum* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

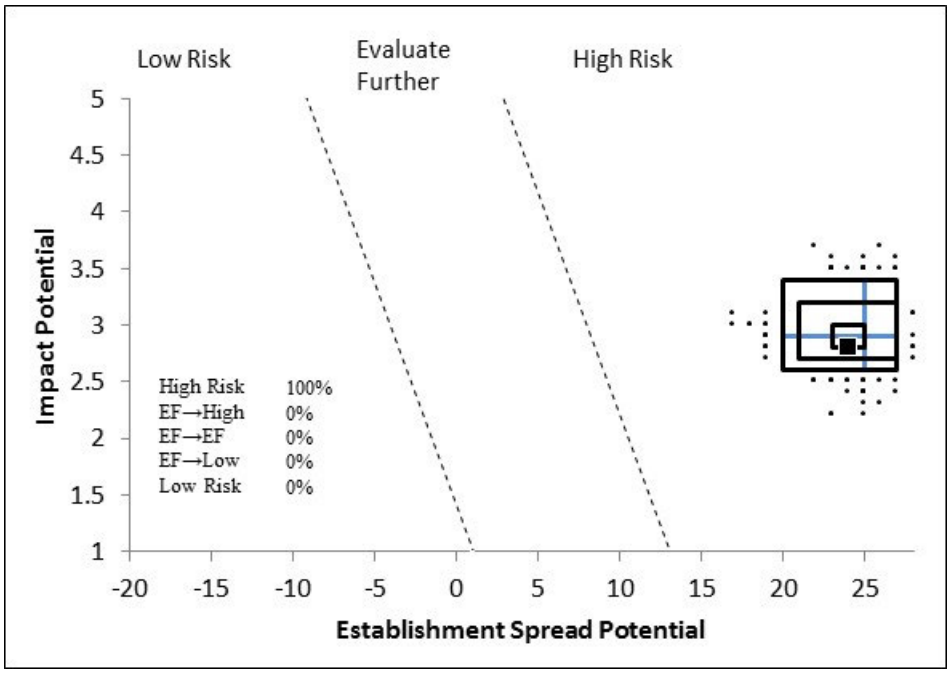

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Echium plantagineum*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Echium plantagineum* is High Risk (Fig. 2). While there is some uncertainty about its status and potential impacts in natural areas, enough information is available about its biology and role in production systems to leave us confident in our determination of high risk (Fig. 3). Our findings are similar to the Oregon Department of Agriculture and the California Department of Food and Agriculture, which also evaluated the risk of *E. plantagineum* (Kelch, 2015; Oregon Department of Agriculture, 2010). The Oregon Department of Agriculture classified *E. plantagineum* as an "A" noxious weed meaning it is a weed of known economic importance, but occurs in a small enough population to be controlled (Oregon Department of Agriculture, 2010). The California Department of Food and Agriculture determined *E. plantagineum* to be a "very bad weed" that can be quarantined, destroyed, refused entry, and/or current populations must be controlled (California Department of Food and Agriculture, 2016; Kelch, 2015).

Echium plantagineum is a concern in California, as officials are worried it may affect rare and endangered plant and animal taxa such as *Trifolium amoenum*, *California macrophylla*, *Lasthenia burkei*, *Ambystoma californiense*, and *Cervus canadensis nannodes* (Kelch, 2015; U.S. Fish & Wildlife Service, 2017). While *E. plantagineum* is not currently found in the same areas as the previously mentioned taxa, the concern comes from the ability of *E. plantagineum* to withstand a wide range of environmental conditions. Also, it is currently spreading in Sonoma County, CA after having a stable population for many years (Kelch, 2015). Along with its ability to withstand a wide range of environmental conditions, *E. plantagineum* has recently developed herbicide resistance to ALS inhibitors (B/2) in Australia and Brazil (Heap, 2017). Despite concerns over *E. plantagineum*, many beekeepers find this species extremely useful due to its high pollen production (Berti et al., 2007; Cullen and Delfosse, 1984; Eberle et al., 2014). Experimental studies carried out in western Minnesota have shown *E. plantagineum* to be beneficial to pollinators by extending floral resources for the season (Eberle et al., 2014). Prior experiments in North Dakota yielded similar results demonstrating the usefulness of *E. plantagineum* to pollinators (Berti et al., 2007). While *E. plantagineum* is already present in the United States, its distribution is restricted (NRCS, 2016). However, its recent resistance to herbicides, its ability to survive in various conditions, and its perceived benefit for pollinators may result in it being spread within the United States.

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Appendix A. Weed risk assessment for *Echium plantagineum* L. (Boraginaceae). Below is all of the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file, where this assessment was conducted, is available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - negl	5	It is native in parts of Africa (Algeria, Egypt, Libya, Morocco, Tunisia, Madeira Islands, Canary Islands), temperate Asia (Georgia, Cyprus, Israel, Jordan, Lebanon, Syria, Turkey), and Europe (Ukraine, Germany, United Kingdom, Albania, Bulgaria, Croatia, Greece, Italy, Slovenia, France, Portugal, Spain) (NGRP, 2016). It is naturalized in parts of Africa (Kenya, Tanzania, the Azores, Ethiopia, Eritrea, Zimbabwe, Lesotho, and South Africa), Australia, New Zealand, Canada (Manitoba, Ontario), the United States (Massachusetts, New York, Pennsylvania, Oregon, and California), Argentina, Chile, and Uruguay (NGRP, 2016). It was introduced into central Australia in the 1850s and has since "spread widely and now occurs, often abundantly, throughout the south and east" (Piggin, 1978a). While there is some debate as to the exact dates, it is believed that *E. plantagineum* was introduced into Australia in the mid-1800s and by the mid-1900s had spread to Victoria (1859), New South Wales (1859), Tasmania (1869), Western Australia (1889), Queensland (1916), and the Northern Territory (1956) (Groves et al., 1995). By 1904, it was declared a noxious weed in Australia after being introduced in 1860 (Parsons, 1973). It is now considered to be fully naturalized in Victoria (Ross and Walsh, 2003). *Echium plantagineum* was first recorded in New Zealand in 1879 and was considered to be very rare (Tomson, 1922). By 1919, it was recorded in a higher abundance of localities throughout the North Island (Tomson, 1922). It has been seen spreading in Sonoma County, CA (Kelch, 2015) and Concepción, Chile (Matthei, 1995). The alternate answers for the uncertainty simulation are both "e."
ES-2 (Is the species highly domesticated)	n - low	0	While *Echium plantagineum* was previously cultivated in Australia (Randall, 2007), and is currently being cultivated in California (Annie's Annuals & Perennials, 2017) and Chile (Matthei, 1995), we found no evidence that it has been domesticated or bred for traits conferring reduced weed potential.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-3 (Weedy congeners)	y - mod	1	The genus *Echium* consists of approximately 60 species (Retief and van Wyk, 1998). Randall (2012) lists approximately 26 species of *Echium* as weeds ranging from either invasive to being an environmental or agricultural weed. *Echium vulgare* has become naturalized throughout Canada and is not considered to be a competitor to crops (Klemow et al., 2002). However, it can cause severe dermatitis in humans, act as an alternate host for pathogens, and could be toxic to livestock if consumed in large quantities (Klemow et al., 2002). In Australia, *E. vulgare* and *E. italicum* are found along roadsides and neglected areas, but are not considered major weeds (Groves et al., 1995).
ES-4 (Shade tolerant at some stage of its life cycle)	y - low	1	While conducting a study of herbaceous vegetation in Portugal, Hussain et al. (2009) recorded *E. plantagineum* in the understory and outside the tree canopy locations. Germination of *E. plantagineum* occurs more rapidly in dark conditions than in lighter conditions (Groves et al., 1995).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	y - negl	1	*Echium plantagineum* forms "large flat rosettes" (Konarzewski, 2012). The leaves form in a rosette pattern that is either ovate or lanceolate (Groves et al., 1995).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Echium plantagineum* forms dense populations (Government of Western Australia, 2017). *Echium plantagineum* is able to produce up to 10,000 seeds with "seed rains of 30,000 per m²" (Konarzewski, 2012). See pictures of *E. plantagineum* provided at the start of the WRA by The Oregon Department of Agriculture.
ES-7 (Aquatic)	n - negl	0	It is not an aquatic plant. It is a member of the Boraginaceae family (NGRP, 2016).
ES-8 (Grass)	n - negl	0	It is not a grass. It is a member of the Boraginaceae family (NGRP, 2016).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	It is a member of the Boraginaceae family (NGRP, 2016) which is not known to contain nitrogen-fixing species (Martin and Dowd, 1990; Santi et al., 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	It reproduces entirely by seed (Piggin, 1978a). It produces viable seeds, and many remain viable for up to five years in a seed bank (Parsons and Cuthbertson, 2001).
ES-11 (Self-compatible or apomictic)	y - mod	1	Petanidou et al. (2012) found that during studies of native and invasive populations of *E. plantagineum*, native populations were self-incompatible while invasive populations were self-compatible. We answered yes with moderate uncertainty because we found only

Question ID	Answer - Uncertainty	Score	Notes (and references)
			one study looking at whether or not *E. plantagineum* is self-compatible and the study only consisted of eight locations (half native, half invasive).
ES-12 (Requires specialist pollinators)	n - low	0	Insect visitors are encouraged to visit due to *Echium plantagineum's* flower color and abundance of nectar and pollen (Groves et al., 1995). We found no direct evidence that *E. plantagineum* requires specialist pollinators. Because this species has become naturalized in several regions beyond its native range, it seems unlikely to require specialist pollinators.
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	b - negl	1	It is an annual (Piggin, 1978a). It is considered a winter annual or biennial forb in Australia (Konarzewski, 2012). In Australia, *E. plantagineum* can be seen flowering throughout the year due to seedlings emerging in different seasons (Groves et al., 1995). In Australia *E. plantagineum* can be biennial with every growth stage being present throughout the year (Parsons and Cuthbertson, 2001). Alternate answers for the uncertainty simulation were set to "a" because this species can germinate during the summer during heavy rains, and produce small plants that set seed by the autumn, when it generally germinates (Government of Western Australia, 2017). We found no other evidence indicating there can be two generations per year or that those autumn-produced sees can germinate immediately.
ES-14 (Prolific seed producer)	y - negl	1	*Echium plantagineum* is a prolific seed producer (Parsons and Cuthbertson, 2001; Weber, 2003). During field experiments in Australian pastures, Piggin (1978b) found *E. plantagineum* was capable of producing 6000 germinable seeds per square meter. *Echium plantagineum* is able to produce up to 10,000 seeds with "seed rains of 30,000 per meter square" (Konarzewski, 2012).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	In South Australia, it was moved in soil that was spread along a railway line (Piggin, 1978a). Large quantities of *E. plantagineum* seed have been moved with soil and vehicles (Groves et al., 1995; Moerkerk, 2006).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	It contaminates harvested grain (Groves et al., 2005; Groves et al., 1995; Piggin, 1978a), and contaminates fodder (Groves et al., 2005; Parsons and Cuthbertson, 2001). It was believed to have been introduced into South Africa through bird seed (Retief and van Wyk, 1998).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17 (Number of natural dispersal vectors)	3	2	Propagule traits for questions ES-17a through ES-17e: The seeds are 2×2.5 mm in size, usually black or brownish-gray in color. They are triquetrous and grouped in fours, with three seeds dropping from the receptacle while one remains attached (Groves et al., 1995). The seed coats are rough and adhesive (Groves et al., 1995).
ES-17a (Wind dispersal)	n - negl		We found no evidence that it is dispersed by wind. Furthermore, it is believed to not be carried far by wind due to its small, non-winged heavy seeds (Groves et al., 1995; Piggin, 1978a).
ES-17b (Water dispersal)	y - negl		We found no evidence that this species is specifically adapted for water dispersal, but the seeds can be spread by water when *E. plantagineum* grows close to rivers and streams (Groves et al., 1995). Run-off has aided in its dispersal (Parsons and Cuthbertson, 2001). It can be dispersed by streams (Weber, 2003).
ES-17c (Bird dispersal)	? - max		During a drought in the late 1960s in New South Wales, two species of birds (*Ocyphaps lophotes* and *Phaps chalcoptera*) consumed a large amount of *E. lycopsis* seeds (synonym of *E. plantagineum*) (Frith et al., 1974). Despite the large consumption of seeds, the authors did not indicate whether or not the seeds survived gut passage and germinated.
ES-17d (Animal external dispersal)	y - negl		Species of ants (*Pheidole megacephale* Fab., *Iridomyrmex discors* Forel., and *Prolasius sp*.) in New South Wales have been observed to carry and store seeds of *E. plantagineum* both aboveground and belowground (Piggin, 1978a). The seeds can stick to livestock (Groves et al., 1995; Piggin, 1978a). The seed coat allows it to adhere to animal fur and wool (Parsons and Cuthbertson, 2001).
ES-17e (Animal internal dispersal)	y - low		Field and laboratory experiments in Australia showed that while sheep can ingest large quantities of *E. plantagineum*, a small percentage of the ingested seeds pass intact after three days of ingestion and are able to germinate (Piggin, 1978a). Seeds of *E. plantagineum* are able to pass intact through grazing animals' digestive tracts (Parsons and Cuthbertson, 2001).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Laboratory studies have shown *Echium plantagineum* seeds to continuously germinate over 6.5 years, while field studies have shown seeds to germinate after two years (Groves et al., 1995). In Australia, *E. plantagineum* can stay dormant in the soil for five years (Parsons

Question ID	Answer - Uncertainty	Score	Notes (and references)
			and Cuthbertson, 2001). It can form a soil seed bank and have seeds remain viable for a few years (Weber, 2003).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	? - max	0	*Echium plantagineum* can be reduced by pre-sowing cultivation and grazing (Groves et al., 1995). We did not find clear evidence that E. plantagineum resprouts vigorously after being exposed to mutilations, cultivation, or fire.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	y - negl	1	*Echium plantagineum* has developed herbicide resistance to acetolactate synthase (ALS) inhibitors (B/2) in Australia (South and West) and Brazil (Heap, 2017).
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	9	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high	0	Experimental studies of young and aged root extracts showed *Echium plantagineum* to inhibit the growth of annual ryegrass (Weston et al., 2012). We answered no with high uncertainty, because we found only one study that looked at *E. plantagineum* and allelopathy, and because we found no field-based evidence that indicates it may be allelopathic.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *Echium plantagineum* or its congeners are parasitic; the family Boraginaceae is not known to contain parasitic plants (Nickrent, 2016; Nickrent and Musselman, 2004).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	*Echium plantagineum* is mainly found as a weed of agriculture (Broster et al., 2012; Groves et al., 1995). We found no direct evidence that *E. plantagineum* changes ecosystem processes and parameters.
Imp-N2 (Changes habitat structure)	n - low	0	We found no evidence that it changes habitat structure.
Imp-N3 (Changes species diversity)	n - high	0	*Echium plantagineum* is able to out compete other plants in pastures and rangelands due to its ability to withstand environmental stress and start germination earlier (Parsons and Cuthbertson, 2001). Therefore, it can suppress the growth of subterranean clover and ryegrass, and shade out other species with its rosette leaves (Parsons and Cuthbertson, 2001). In places where it is invasive, *E. plantagineum* is capable of crowding out native species (Weber, 2003). In spite of a

Question ID	Answer - Uncertainty	Score	Notes (and references)
			general statement about *E. plantagineum* crowding out native species, we answered no with high uncertainty, because we only found evidence of this occurring in agricultural systems.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0.1	In California, there is concern that *E. plantagineum* may affect rare taxa such as *Trifolium amoenum*, *California macrophylla*, *Lasthenia burkei*, *Ambystoma californiense*, and *Cervus canadensis nannodes* (Kelch, 2015). *Trifolium amoenum*, *Lasthenia burkei*, and *Ambystoma californiense* are considered endangered in California (U.S. Fish & Wildlife Service, 2017). We answered yes with high uncertainty, because while the species of concern are rare and/or endangered, *E. plantagineum* is currently not affecting them but has been shown to be capable of surviving in a wide range of habitats.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	? - max		Currently *Echium plantagineum* has only been found in agricultural settings, along roadsides, and in disturbed areas where it has been introduced (Broster et al., 2012; Groves et al., 1995; Piggin, 1978b). We found no evidence that it currently affects any U.S. globally outstanding ecoregions, but acknowledge that *E. plantagineum* is capable of establishing in a wide range of habitats. Therefore, we answered unknown with max uncertainty.
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	b - low	0.2	It has been recorded as a weed in natural systems in Australia (Randall, 2007). It became established on reserves throughout southern Australia after escaping cultivation (Groves et al., 1995). It is considered to be a threat to rangeland biodiversity in Australia (Martin et al., 2006). Additionally, we found no evidence that it is being controlled in natural systems or that it is even considered a weed in its native range (Grigulis et al., 2001). Currently, the only evidence of control is in relation to agricultural systems. The alternate answers for the uncertainty simulation were both "a."
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0	We found no evidence that *Echium plantagineum* negatively impacts personal property, human safety, or public infrastructure. Currently, the majority of information about *E. plantagineum* focuses on its presence in agricultural systems. For this reason, we used low uncertainty for this question, and for questions Imp-A2 and Imp-A3.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence that *Echium plantagineum* changes or limits recreational use of an area.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We found no evidence that *Echium plantagineum* affects desirable and ornamental vegetation.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	a - low	0	In Australia, *E. plantagineum* was believed to be originally cultivated as a garden plant, but it escaped and became established on reserves and paddocks throughout the south (Groves et al., 1995). It is often found on roadsides (Groves et al., 1995; Parsons and Cuthbertson, 2001). Despite the presence of *E. plantagineum* along roadsides, there is no direct evidence that it is considered a weed in anthropogenic systems. Therefore, we answered "a" with low uncertainty. The alternate answers for the uncertainty simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	Young plants of *Echium plantagineum* can hinder the growth of other pasture legumes by aggressively competing for moisture and light (Cullen and Delfosse, 1984). Field experiments in Australia showed that grazing sheep were lighter and grew less wool when their diet consisted mainly of *E. plantagineum* (Seaman et al., 1989). It is estimated that *E. plantagineum* costs Australian agriculture $30 million per year (Groves et al., 2005). However, the exact breakdown of the $30 million is unclear.
Imp-P2 (Lowers commodity value)	y - low	0.2	High rates of pollen production by *E. plantagineum* can contaminate French lavender (*Lavandula stoechas* L.) honey; this has led to limits being placed on the amount of *E. plantagineum* pollen allowed in the honey (Bonvehi and Coll, 1993).
Imp-P3 (Is it likely to impact trade?)	y - negl	0.2	*Echium plantagineum* is currently prohibited from being sold in a few Australian states/territories (Northern Territory, South Australia, Western Australia, and Victoria) (Groves et al., 2005). It can be a contaminant of *Chenopodium quinoa* crops (Stace, 2010) and other commodities (see evidence under ES-16). In South Africa, *E. plantagineum* is a prohibited weed that should always be controlled based on the 1983 Conservation of Agriculture Resources Act (Nel et al., 2004). It is regulated by Colombia, Ecuador, Peru, Taiwan, the Republic of Korea, and the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Democratic People's Republic of Korea, (APHIS, 2017). In Canada it is regulated under the Plant Protection Act and listed as a prohibited noxious weed in the Weed Seeds Order 2016 under the Seeds Act (Canadian Food Inspection Agency, 2016).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	We found no direct evidence that *Echium plantagineum* affects irrigation or strongly competes with plants for water.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	y - negl	0.1	*Echium plantagineum* contains pyrrolizidine alkaloids that can cause liver damage and may lead to death in horses and pigs (Parsons and Cuthbertson, 2001). Sheep, cattle, and goats are less susceptible to *E. plantagineum* poisoning, but continual yearly grazing can lead to liver damage (Parsons and Cuthbertson, 2001). In Brazil, two outbreaks of photosensitivity, anorexia, and gastrointestinal distress occurred in cattle that grazed on *E. plantagineum* (Acamovic et al., 2004). It can cause chronic weight loss, acute jaundice, liver damage, and/or death in grazing goats (Simmonds et al., 2000). In Brazil, 28 Holstein calves died after *E. plantagineum* poisoning while other calves experienced photosensitization (Mendez et al., 1985).
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c - negl	0.6	It is considered a weed in pastures and can be found in cereal crops (Broster et al., 2012; Groves et al., 1995). It is considered to be a threat to rangeland biodiversity in Australia (Martin et al., 2006). Herbicides containing 2, 4-D or bromoxynil have shown to be effective in controlling young plants as well as 2, 4-DB, MCPB, dicamba, and pocloram (Parsons and Cuthbertson, 2001). Other herbicides showing good selective control and potential season-long control are metribuzin, methabenzthiazuron, chlorthal dimethyl, and linuron (Parsons and Cuthbertson, 2001). The alternate answers for the uncertainty simulation were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2016).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z4 (Zone 4)	n - low	N/A	Norway (1 point). We answered no with low uncertainty because while *E. plantagineum* has been found growing in various conditions, only one record has been recorded in this plant hardiness zone.
Geo-Z5 (Zone 5)	y - low	N/A	Norway, New Zealand.
Geo-Z6 (Zone 6)	y - negl	N/A	Nova Scotia (1 point), United States (Massachusetts), Germany, Sweden, Norway, and New Zealand.
Geo-Z7 (Zone 7)	y - negl	N/A	The United States (New Jersey), Spain, Germany, Sweden, Norway, Greece, Turkey, New Zealand, and Australia.
Geo-Z8 (Zone 8)	y - negl	N/A	The United States (Oregon), Argentina, South Africa, Morocco, Spain, France, Great Britain, Belgium, Germany, Sweden, Denmark, Norway, Italy, Greece, Albania, Bulgaria, New Zealand, Australia, Tasmania, and Portugal.
Geo-Z9 (Zone 9)	y - negl	N/A	Brazil, Argentina, Chile, South Africa, Morocco, Spain, France, Great Britain, Denmark, Sweden, Italy, Greece, New Zealand, Australia, Tasmania, and Portugal.
Geo-Z10 (Zone 10)	y - negl	N/A	The United States (California), Brazil, Argentina, Chile, South Africa, Algeria, Tunisia, Morocco, Spain, France, Great Britain, Italy, Greece, Serbia and Montenegro (1 point), Turkey (1 point), Lebanon (1 point), Israel, Syria, Japan (1 point), New Zealand, Australia, Tasmania, and Portugal.
Geo-Z11 (Zone 11)	y - negl	N/A	The United States (California), Chile, Ethiopia (1 point), South Africa, Republic of Mali, Morocco, Spain, Italy, Greece, Turkey (1 point), Israel, West Bank (1 point), New Zealand, Australia, Tasmania, and Portugal.
Geo-Z12 (Zone 12)	y - negl	N/A	Nicaragua (1 point), Brazil (1 point), South Africa, and Australia.
Geo-Z13 (Zone 13)	n - low	N/A	New Caledonia (1 point).
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C2 (Tropical savanna)	y - mod	N/A	Nicaragua (1 point), Brazil, and New Caledonia (1 point).
Geo-C3 (Steppe)	y - negl	N/A	The United States (California), Argentina, South Africa, Morocco, Tunisia, Spain, Greece, and Australia.
Geo-C4 (Desert)	y - negl	N/A	South Africa, the Republic of Mali, Algeria, Morocco, Tunisia, Spain, and Australia.
Geo-C5 (Mediterranean)	y - negl	N/A	The United States (California, Oregon), Chile, South Africa, Algeria, Morocco, Tunisia, Spain, Portugal, France, Italy, Albania, Greece, Serbia and Montenegro, Turkey, Syria, Lebanon, Israel, West Bank, and Australia.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C6 (Humid subtropical)	y - negl	N/A	Brazil, Argentina, South Africa, Italy, Greece, Turkey, Japan (1 point), and Australia.
Geo-C7 (Marine west coast)	y - negl	N/A	Brazil, Argentina, South Africa, Spain, France, Great Britain, Norway, Denmark, Germany, Belgium, New Zealand, Australia, and Tasmania.
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	The United States (New Jersey). Despite GBIF listing *E. plantagineum* in New Jersey no other evidence was found to support this claim. We answered yes with high uncertainty, because *E. plantagineum* is found in surrounding climate classes.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Nova Scotia (1 point), the United States (Massachusetts), Spain, Norway, Sweden, Denmark, Germany, and Greece.
Geo-C10 (Subarctic)	y - negl	N/A	Spain, France, Norway, Sweden, Germany, and Greece.
Geo-C11 (Tundra)	n - low	N/A	France (1 point).
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that it occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	The United States (California), South Africa, Republic of Mali, Algeria, Tunisia, Spain, and Australia.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	The United States (California), Argentina, South Africa, Tunisia, Morocco, Spain, France, Italy, Greece, Syria, Israel, and Australia.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Argentina, South Africa, Algeria, Tunisia, Morocco, Spain, Portugal, France, Great Britain, Belgium, Germany, Sweden, Italy, Greece, Turkey, Lebanon, West Bank, Israel, Syria, New Zealand, Australia, and Tasmania.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Argentina, Chile, South Africa, Morocco, Spain, Portugal, France, Great Britain, Belgium, Germany, Denmark, Norway, Italy, Greece, Bulgaria, Turkey, New Caledonia, New Zealand, Australia, and Tasmania.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	The United States (Massachusetts, New Jersey), Chile, South Africa, Spain, Portugal, France, Great Britain, Belgium, Germany, Denmark, Sweden, Norway, Italy, Greece, New Zealand, Australia, and Tasmania.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	The United States (Oregon), Nova Scotia, Brazil, Chile, South Africa, Spain, Portugal, France, Germany, Norway, Serbia and Montenegro, New Zealand, Australia, and Tasmania.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	The United States (Oregon), Nicaragua, Brazil, Spain, Norway, Japan (1 point), and New Zealand.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	The United States (Oregon), Brazil, Spain, and Great Britain (1 point).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R9 (80-90 inches; 203-229 cm)	n - negl	N/A	We found no evidence that it occurs in this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	n - negl	N/A	New Zealand (1 point).
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	We found no evidence that it occurs in this precipitation band.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - negl	0	Although this species is already is found in the United States (i.e., California, Oregon, Pennsylvania, New York, and Massachusetts), we set this answer to no, to be able to estimate the likelihood of additional plant material entering the United States (Kartesz, 2015; NRCS, 2016).
Ent-2 (Plant proposed for entry, or entry is imminent)	n - negl	0	We found no evidence that its entry is imminent.
Ent-3 (Human value & cultivation/trade status)	d - negl	0.05	In Australia, *E. plantagineum* was believed to be originally cultivated as a garden plant, but it escaped and became established on reserves and paddocks through the south (Groves et al., 1995). *Echium plantagineum* is valued for providing an early source of nectar for bees and for producing a light, premium grade honey that can add a stronger flavor to *Eucalyptus* honeys (Cullen and Delfosse, 1984). It is cultivated at a botanical garden at the University of Concepción in Chile (Matthei, 1995) and at a nursery in California (Annie's Annuals & Perennials, 2017). It is sold online through retailers such as Amazon and eBay Amazon, 2017; eBay, 2017).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	? - max		It has been introduced into Canada, but has yet to persist (Canadian Food Inspection Agency, 2016). It is listed as occurring in Nicaragua (GBIF, 2016), but no other references can verify this occurrence. We answered unknown with maximum uncertainty, because while it has been introduced to Canada and Nicaragua, we are unable to find any supporting evidence that *E. plantagineum* is currently present in these countries or in China, Mexico, the rest of Central America, and the Caribbean.
Ent-4b (Contaminant of plant propagative material (except seeds))	n - low	0	We found no evidence that *E. plantagineum* is a contaminant of propagative plant material.
Ent-4c (Contaminant of seeds for planting)	y - low	0.04	It was introduced to Oregon as part of a wildflower seed mix (Hulting et al., 2007). It was believed to have entered South Africa through sown mixed bird seed (Retief and van Wyk, 1998).
Ent-4d (Contaminant of ballast water)	n - low	0	We found no evidence that *E. plantagineum* is a contaminant of ballast water.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - low	0	We found no evidence that *E. plantagineum* is a contaminant of aquarium plants or other aquarium products.
Ent-4f (Contaminant of landscape products)	y - low	0.02	It was believed to have been a contaminant of soil that was spread along an Australian railway line (Groves et al., 1995).
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	y - negl	0.02	It can be a contaminant of farming equipment and other vehicles (Groves et al., 1995; Hulting et al., 2007; Moerkerk, 2006).
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	y - negl	0.01	It can be a contaminant of harvested grain (Groves et al., 2005; Groves et al., 1995; Piggin, 1978a). Interceptions at major ports in India showed *E. plantagineum* to be a contaminant of wheat grain consignments (Singh, 2001).
Ent-4i (Contaminant of some other pathway)	e - negl	0.04	It can be a contaminant of hay (Hulting et al., 2007). It can contaminate fodder (Groves et al., 2005; Parsons and Cuthbertson, 2001).
Ent-5 (Likely to enter through natural dispersal)	n - low	0	*Echium plantagineum* does not seem likely to enter the United States through natural dispersal because it is not present in a bordering country.