United States Department of Agriculture

Weed Risk Assessment for *Chondrilla juncea L.* (Asteraceae) – Rush skeletonweed

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Version 1

Left: Stems and basal leaves of *Chondrilla juncea* (source: Robert Vidéki, Doronicum Szolgáltató Korlátolt Felelősségű Társaság). Top right: Flowers and achenes of *C. juncea* (source: Joseph M. DiTomaso, University of California - Davis). Bottom right: *Chondrilla juncea* infestation in a field (source: Eric Coombs, Oregon Department of Agriculture). All photographs are from Bugwood.com (Bugwood, 2016).

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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.

	***Chondrilla juncea* L. – Rush skeletonweed**
Species Information	Family: Asteraceae Synonyms: None. Common names: Rush skeletonweed (Jacobs and Goodwin, 2009; NRCS, 2016), skeleton weed (Britton and Brown, 1913; McVean, 1966; Pammel, 1911), gum succory (Britton and Brown, 1913; Pammel, 1911), naked weed (Britton and Brown, 1913), devil's grass (Britton and Brown, 1913), hog bite (Britton and Brown, 1913). Botanical description: *Chondrilla juncea* is a perennial herbaceous plant that grows in disturbed areas (Holm et al., 1997; McVean, 1966; Sheley, 1994). It grows 30 to 100 cm tall and has two different types of leaves: rosette leaves, which are glabrous and linear or lobed, and stem leaves, which are few in number and entire or toothed. All plant parts exude a milky latex when broken (Holm et al., 1997). The fruit is a green to brown, dry, indehiscent achene that is 3 to 4 mm in length with barbed, tooth-like projections and a pappus with white bristles (Holm et al., 1997). Several different biotypes exist in Australia and the United States, the most well-studied being biotypes A, B, and C (Gaskin et al., 2013; Sheley and Petroff, 1999).These biotypes vary in inflorescence morphology, fruit characteristics, and rosette leaf shape (Caso, 1985; Hull and Groves, 1973) as well as in resistance to pathogens (Burdon et al., 1981; Supkoff et al., 1988). Botanical descriptions can be found in Caso (1985), Holm et al. (1997), and McVean (1966). Initiation: PPQ received a market access request for wheat seed for planting from the government of Italy (MPAAF, 2010). A commodity import risk assessment determined that *C. juncea* could be associated with this commodity as a seed contaminant. The PERAL Weed Team evaluated 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, and the results are presented here. Foreign distribution and status: *Chondrilla juncea* is native to Europe (Pammel, 1911) from the Mediterranean north to Germany and the Netherlands, as well as to the central Russian steppe (McVean, 1966). It has been introduced to and become invasive in Australia (Parsons, 1973) and Argentina (Caso, 1985). This species was also introduced to and subsequently eradicated from New Zealand (Howell and Sawyer, 2006; Veitch and Clout, 2002). U.S. distribution and status: *Chondrilla juncea* has been present in the United States since 1872 (McVean, 1966). It occurs in 18 states, California, Washington, Oregon, Idaho, Colorado, Montana, Wyoming, Utah, Arizona, Indiana, Michigan, New York, Pennsylvania, New Jersey, Maryland, Virginia, West Virginia, and Georgia (EDDMapS, 2016; Kartesz, 2016; NRCS, 2016). Nine of these states, Arizona, California, Colorado, Idaho,

Montana, Nevada, Oregon, Washington, and Wyoming regulate *C. juncea* as a state noxious weed or weed seed contaminant (Lionakis Meyer and Effenberger, 2010; USDA-AMS, 2014). Many western states are actively working to control *C. juncea*: there are ongoing eradication efforts for *C. juncea* in Montana (Prather, 2016) and Wyoming (Schwarzländer, 2016), Montana and Idaho have task forces specifically for this weed (Schwarzländer, 2016), and biological control agents have been introduced into California to reduce *C. juncea* populations (Supkoff et al., 1988). We found no evidence that *C. juncea* is cultivated in the United States (e.g., Bailey and Bailey, 1976; Brenzel, 1995; Dave's Garden, 2016).

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

1. *Chondrilla juncea* analysis

Establishment/Spread Potential *Chondrilla juncea* has been introduced to Australia, Argentina, and the United States and has rapidly spread over thousands of acres in these countries (Caso, 1985; McVean, 1966; Parsons, 1973; Sheley, 1994). It can spread to new areas as a contaminant of nursery plants (Parsons, 1973) and hay (Groves et al., 1995), and the seeds can adhere to clothing, bags, and animal fur, and spread in mud on vehicles and equipment (McVean, 1966; Parsons, 1973; Sheley, 1994). The seeds are also dispersed by wind (McVean, 1966; Parsons, 1973; Sheley, 1994). *Chondrilla juncea* plants produce long tap roots that grow adventitious root buds after being damaged, and each one of these buds can form a new plant (McVean, 1966). We had a low level of uncertainty for this risk element.

Risk score = 20 Uncertainty index = 0.06

Impact Potential While *C. juncea* is only a minor weed in its native range (Parsons, 1973), it is considered one of the most economically significant weeds in Australia. This is because *C. juncea* reduces the yields of cereal crops by 50 to 80 percent (Heap, 1993; Sheley, 1994). Additionally, the tough, wiry stems of *C. juncea* get tangled in combines, greatly hindering harvesting (McVean, 1966; Parsons, 1973; Sheley, 1994). In Australia, many wheat growers went out of business in the 1930s due to total crop losses caused by *C. juncea* (McVean, 1966). Biological controls have been introduced into Australia and the United States to reduce *C. juncea* populations in agricultural fields (Burdon et al., 1981; Supkoff et al., 1988). *Chondrilla juncea* has invaded natural areas in the Snake River Plain in Idaho and Oregon, and has become the dominant species on the forest floor of the Boise National Forest in Idaho (Pettingill, 2016). An isolated population of *C. juncea* has also been found in the Grand Canyon National Park in Arizona (Forest Service, 2014). *Chondrilla juncea* is

[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).

not considered to be a weed of urban and suburban areas. We had an average level of uncertainty for this risk element.
Risk score = 3.3 Uncertainty index = 0.12

Geographic Potential Based on three climatic variables, we estimate that about 86 percent of the United States is suitable for the establishment of *C. juncea* (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 *C. juncea* represents the joint distribution of Plant Hardiness Zones 4-11, areas with 0-90 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, subarctic, and tundra.

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. *Chondrilla juncea* commonly grows in disturbed areas such as agricultural fields, roadways, waste areas, river banks, dry river beds, and areas weakened by drought or improper grazing (Britton and Brown, 1913; McVean, 1966; Pammel, 1911; Sheley, 1994).

Entry Potential We did not assess the entry potential of *C. juncea* because it is already present in the United States (EDDMapS, 2016; Kartesz, 2016; McVean, 1966; NRCS, 2016).

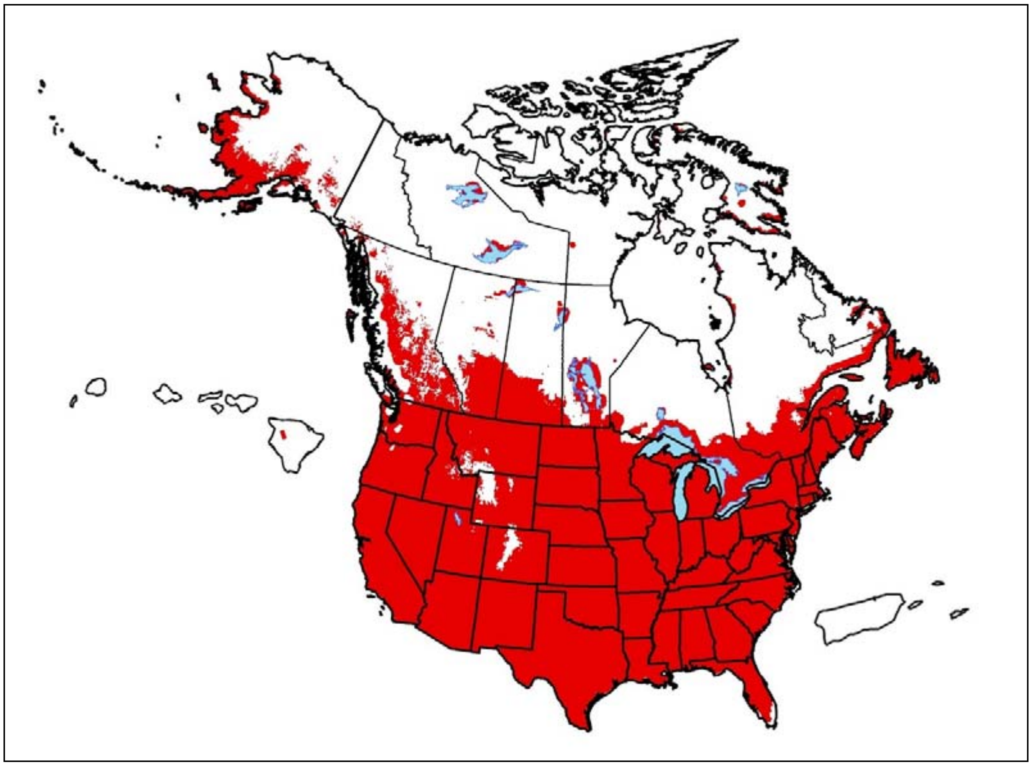

Figure 1. Potential geographic distribution of *Chondrilla juncea* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

<u>2. Results</u>

Model Probabilities: P(Major Invader) = 92.8%
P(Minor Invader) = 6.9%
P(Non-Invader) = 0.2%

Risk Result = High Risk

Secondary Screening = Not Applicable

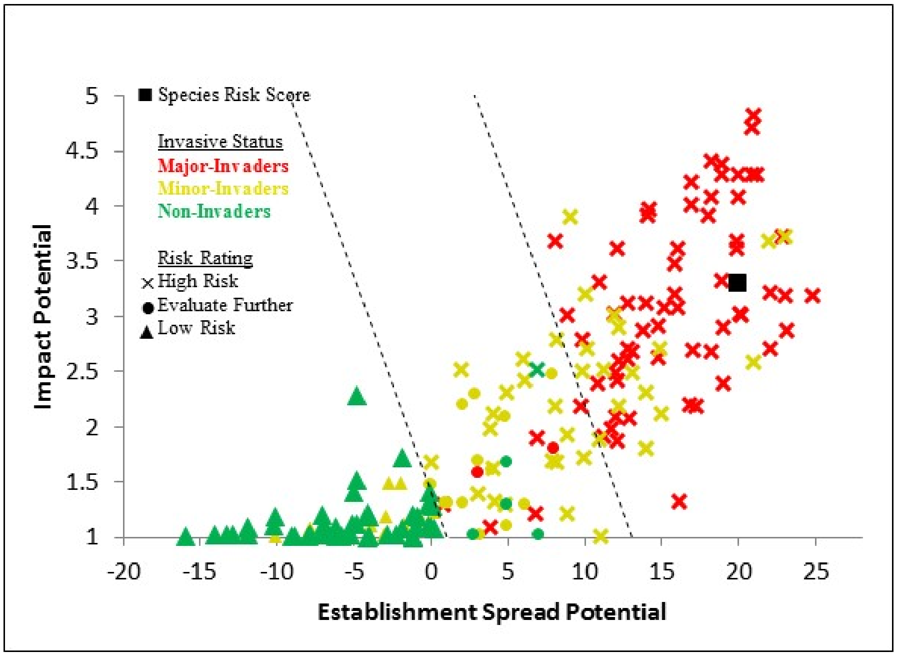

Figure 2. *Chondrilla juncea* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

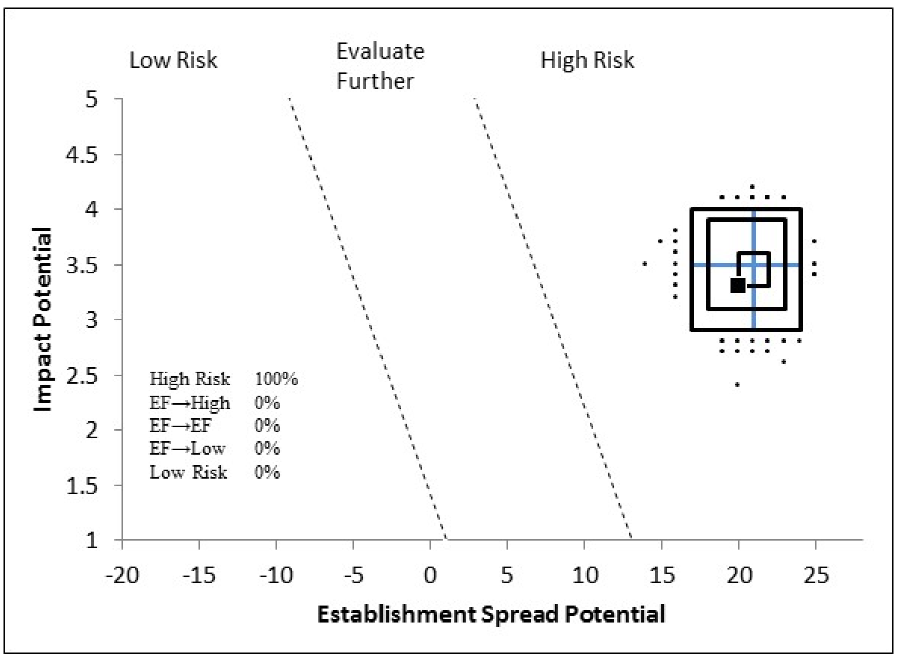

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *C. juncea*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *C. juncea* is High Risk. *Chondrilla juncea* shares traits in common with other major invaders (Figure 2), and 100 percent of our simulated risk scores resulted in outcomes of high risk (Figure 3). *Chondrilla juncea* is difficult to detect (Ferriter, 2016) and difficult to control due to its ability to rapidly grow from adventitious root buds after being damaged (McVean, 1966). It is possible that rodent activity could exacerbate the spread of *C. juncea* (Prather, 2016), similar to the way in which pocket gophers may have contributed to the proliferation of *Falcaria vulgaris* in South Dakota (Korman, 2011). In the United States, over 6.2 million acres are infested with *C. juncea*. However, this may be only a portion of the total area of the United States where *C. juncea* could establish; our map of the potential geographic distribution of *C. juncea* (Figure 1) shows that nearly all of the contiguous United States has a suitable climate for *C. juncea*. An economic analysis reported that *C. juncea* has had an economic impact of almost $1.4 million in Oregon, but if this plant spread to uninfested regions of the state, it would cost Oregon over $228 million (Anonymous, 2014). Biological control agents, including *Puccinia chondrillina* (skeletonweed rust), *Aceria chondrillae* (skeletonweed gall mite), and *Cystiphora schmidti* (skeletonweed gall midge), have been effective at reducing *C. juncea* populations in the United States (Supkoff et al., 1988).

There are multiple biotypes *of C. juncea*, with biotypes A, B, and C being well-studied (Gaskin et al., 2013; Sheley and Petroff, 1999). These biotypes vary in inflorescence morphology, fruit characteristics, and rosette leaf shape (Caso, 1985; Hull and Groves, 1973), as well as in resistance to the pathogens used for biocontrol (Burdon et al., 1981; Supkoff et al., 1988). For example, the rust fungus *P. chondrillina* has reduced the presence of the A biotype in Australia, but the reduced competitive pressure allowed biotypes B and C to spread (Burdon et al., 1981). Biotypes A, B, and C are present in the United States, but many more biotypes exist in Europe (Chaboudez, 1994; Gaskin et al., 2013; Sheley and Petroff, 1999); Gaskin et al. analyzed (2013) *C. juncea* populations and found 682 unique genotypes in Europe, but only seven in North America.

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Appendix A. Weed risk assessment for *Chondrilla juncea* L. (Asteraceae). 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	This species is native to Europe (Pammel, 1911) from the Mediterranean north to Germany and the Netherlands, as well as to the central Russian steppe (McVean, 1966). However, Parsons (1973) says *C. juncea* is native to southern Russia and Asia Minor and then spread to the Mediterranean and central Europe. In Australia, "*Chondrilla juncea*...was first identified...in New South Wales...It spread at an average rate of more than 15 miles (24 km) per annum throughout...south-eastern Australia over the next 40 years and...has been recorded as isolated colonies in southern Queensland, Western Australia and...in South Australia" (McVean, 1966). By 1973, *C. juncea* was present on millions of acres in Australia (Parsons, 1973). Parsons (1973) remarked, "When it is considered that in less than 60 years skeleton weed has spread from Wagga 600 miles north into Queensland and 2,000 miles west into Western Australia it is a remarkable example of the plant's powers of dispersal and establishment, particularly in view of the efforts expended in trying to prevent this spread" (Parsons, 1973). In Argentina, *C. juncea* was first recorded in Buenos Aires in 1977, and by 1985, had spread to cover over 50,000 hectares (Caso, 1985); by 1997, it had invaded 100,000 hectares there (Holm et al., 1997). *Chondrilla juncea* was first recorded in the United States in 1872 (Parsons, 1973), and has since spread into Virginia, West Virginia, Pennsylvania, Michigan (Britton and Brown, 1913; Kartesz, 2016), Washington, Idaho, California (Parsons, 1973), Oregon (Heap, 1993), and Montana (Sheley, 1994). An "isolated, yet expanding population" has also been found in the Grand Canyon National Park in Arizona (Forest Service, 2014). By 1988, 80,000 hectares of rangeland in California were infested with *C. juncea* (Supkoff et al., 1988). By 2004, 6.2 million acres of rangeland in the Pacific Northwest and California were infested with *C. juncea* (Sheley, 1994). The alternate answers for the uncertainty simulation were both "e."
ES-2 (Is the species highly domesticated)	n - negl	0	We found no evidence that *C. juncea* has been highly domesticated. It is not listed as cultivated by Bailey and Bailey (1976), and we did not find any plants available for sale online.
ES-3 (Weedy congeners)	n - low	0	There are 25 species in the genus *Chondrilla* (Mabberley, 2008; Weakley, 2015). Holm et al. (1979) do not list any of these related species as being significant or principal weeds. We did not find any

Question ID	Answer - Uncertainty	Score	Notes (and references)
			evidence of other *Chondrilla* species being significant weeds anywhere in the world (e.g., Randall [2012]).
ES-4 (Shade tolerant at some stage of its life cycle)	y - high	1	In shading experiments, some *C. juncea* plants were still able to flower and set seed when daylight was reduced by 50 percent, and seedlings were still able to germinate, establish, and grow at levels of 10 percent daylight. Seedling establishment was prevented at levels below 1 percent daylight, however (McVean, 1966). "Germination takes place equally well in light and in darkness" (McVean, 1966). *Chondrilla juncea* has become established in the Boise National Forest in Idaho under dense, shady stands of conifers (Pettingill, 2016). "Rush skeletonweed is somewhat intolerant of shade and is seldom found on closed forest canopy sites" (Jacobs and Goodwin, 2009). Dense stands of legumes can shade out *C. juncea* seedlings and limit their establishment (Sheley and Petroff, 1999). Seedlings are very sensitive to competition for light (Parsons and Cuthbertson, 2001). We answered yes based on McVean's research and the ability of *C. juncea* to become established in the Boise National Forest, but used high uncertainty due to the conflicting information in the literature.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - low	0	*Chondrilla juncea* plants have a basal rosette of leaves up to 8 inches long (Parsons, 1973) and stiff, widely branched stems with a few widely spaced leaves (Britton and Brown, 1913; Pammel, 1911). In photographs, the rosettes do not appear to be tightly appressed or smothering (Auld and Medd, 1987; Parsons, 1973; Parsons and Cuthbertson, 2001).
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	In Australia, *C. juncea* "forms tall and dense thickets on roadsides and is often found in dense stands in native pasture….Dense colonies of strong, bushy plants up to 120 cm tall are formed where there has been repeated disturbance of the soil" (McVean, 1966). It forms dense thickets along roadsides and in pastures weakened by drought or overgrazing (Groves et al., 1995). It grows densely in grazing lands in Virginia and West Virginia (Parsons and Cuthbertson, 2001).
ES-7 (Aquatic)	n - negl	0	*Chondrilla juncea* is not an aquatic plant; it is a terrestrial plant in the family Asteraceae (formerly Compositae) (McVean, 1966; NGRP, 2016).
ES-8 (Grass)	n - negl	0	*Chondrilla juncea* is not a grass; it is a member of the family Asteraceae (formerly Compositae) (McVean, 1966; NGRP, 2016).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Furthermore, *C. juncea* is not a woody plant; it is a herbaceous perennial in the family Asteraceae (Panetta, 1990; Sheley and Petroff, 1999; Shepherd, 1991).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	"The production of seed has been responsible for virtually all of the remarkable distribution of skeleton weed throughout Australia" (Parsons and Cuthbertson, 2001). *Chondrilla juncea* populations produce viable seed in Australia (McVean, 1966). The species

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
			reproduces by seed in the United States (Sheley and Petroff, 1999).
ES-11 (Self-compatible or apomictic)	y - negl	1	*Chondrilla juncea* plants can reproduce by apomixis; research studies have demonstrated that the plants are still able to produce normal seed after floral structures are removed (McVean, 1966). *Chondrilla juncea* is an obligate apomict, which means it can form seeds without sexual reproduction (Caso, 1985; Chaboudez, 1994; Hull and Groves, 1973). *Chondrilla juncea* will also occasionally reproduce sexually (Shepherd, 1991).
ES-12 (Requires specialist pollinators)	n - negl	0	We found no evidence that *C. juncea* requires specialist pollinators. *Chondrilla juncea* is an obligate apomict that does not require pollination to set seed (Caso, 1985; Chaboudez, 1994; Hull and Groves, 1973). Additionally, its flowers are "visited by a wide variety of insects and bees" (McVean, 1966). "Major source of pollen for honey bees" (Sheley, 1994).
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 - low	1	In Australia, seeds germinate in the fall and the plants grow during the winter and spring months. The plants then flower during the summer and produce seeds during the summer and fall (McVean, 1966; Parsons, 1973). In the United States, *C. juncea* seeds germinate in the fall and then overwinter as a rosette of leaves. In the spring, the plants grow rapidly and then produce seeds in the summer and fall (Sheley and Petroff, 1999). Panetta (1989b) determined that *C. juncea* plants could produce seed in their first year of growth under favorable soil and moisture conditions. Perennial (Britton and Brown, 1913; Pammel, 1911). *Chondrilla juncea* has been described as a biennial in the literature, but this is a misclassification (Holm et al., 1997). It grows as a long-lived perennial in disturbed areas (McVean, 1966). Based on this evidence, we chose "b." The alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - low	1	"The seed production on skeleton weed is prolific, as a single plant can produce over 15,000 seeds in one season, although the average is much less. A 90% seed germination can occur, but this varies considerably depending on environmental conditions" (Parsons, 1973). Greater than 90 percent of seeds may be viable when produced from well-watered plants (Groves et al., 1995). In greenhouses, the plants produce 500-1,500 seeds per plant. Older, multiple-stemmed plants may produce ten times that much seed. Drought conditions can greatly reduce seed viability though (McVean, 1966). A mature plant can produce 10,000 to 20,000 seeds per season in Western Australia (Panetta, 1988). *Chondrilla juncea* plants can produce over 20,000 seeds, but in the first year plants will more commonly produce 250 to 300 seeds (Sheley, 1994). Panetta (1989a) determined that 65 to75 percent of *C. juncea* seeds will not germinate, even under ideal conditions, because a large number of the seed embryos produced are abnormal or aborted (Kościńska-Pająk, 1996). Plants produce 6 to 15 flowers (Britton and

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Brown, 1913). *Chondrilla juncea* plants are 30 to 100 cm tall with a basal rosette up to 15 cm in diameter (Holm et al., 1997), which means a large number of plants can be present over one square meter. Based on this evidence, we answered yes, but used low uncertainty because germination rates can vary depending on environmental conditions.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	In Australia, "primary spread appears to have been by road and rail, following stock movements and the transport of hay and seeds; in other districts infestation appears to have been solely from paddock to paddock" (McVean, 1966). It is spread by railway lines and freight terminals (Dodd, 1987). It is spread to new areas by agricultural (Parsons, 1973) and logging equipment (Jacobs and Goodwin, 2009). Scales and tooth-like projections allow seeds to adhere to clothing, bags, and agricultural machinery. The seeds are also spread to new areas in mud on vehicles (Parsons, 1973; Sheley, 1994). Cultivation can spread root pieces and contribute to the spread of this species (Callihan et al., 2016). "The rapid northward spread of *C. juncea* in New South Wales during 1957-67 was attributed...to the rise of road transport conveying seeds in much the same ways as did the railways in the 1930s" (Groves et al., 1995).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	*Chondrilla juncea* seeds have been found in shipments of table grapes being imported into New Zealand from Australia (Panetta, 1990), and *C. juncea* is thought to have been introduced into Australia in imported vine stocks from Europe (Parsons, 1973) or as a contaminant of animal fodder or bedding (Groves et al., 1995). In Australia, "the bulk of the wheat crop is harvested before [*C. juncea*] seed has been formed so that the [wheat] grain itself is seldom contaminated" (McVean, 1966); however, if harvesting is delayed for a few weeks the grain can become contaminated (Parsons, 1973). It is listed as a crop contaminant by the Association of Official Seed Analysts (AOSA, 2014).
ES-17 (Number of natural dispersal vectors)	3	2	Seed description used to answer ES-17a through ES-17e: "achenes terete with an abrupt, slender beak, several ribbed, smooth below" (Pammel, 1911). Seed has a "stalked pappus of toothed bristles" (Parsons, 1973). Members of the genus *Chondrilla* have a "pappus of copious soft white simple bristles" (Britton and Brown, 1913).
ES-17a (Wind dispersal)	y - negl		Seeds are dispersed by wind (McVean, 1966; Parsons, 1973; Sheley, 1994). Seeds have been carried over 60 miles away by the updraft caused by wild fires (Pettingill, 2016).
ES-17b (Water dispersal)	y - low		Seeds are dispersed by water (Groves et al., 1995; Sheley, 1994). Seeds float in water currents (Jacobs and Goodwin, 2009). Water dispersal of seeds is possible, but thought to be of minor importance in Australia (Parsons, 1973).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17c (Bird dispersal)	? - max		Unknown. We did not find any evidence of dispersal by birds, but this may be possible due to the tooth-like projections the seeds have, which allow them to adhere to animals.
ES-17d (Animal external dispersal)	y - negl		In Australia, *C. juncea* has been transported to paddocks through the movement of livestock and this species is common along sheep tracks (McVean, 1966). The scales and tooth-like projections allow seeds to be dispersed on the wool of sheep. "Probably contamination of wool has been the most important single factor in the wide distribution of the weed...skeleton weed often first shows up in a paddock where a sheep has died" (Parsons, 1973). Sheley (1994) advises to keep livestock in a holding area for 10 to 14 days after they have grazed in areas where *C. juncea* is present. Seed-harvesting ants collect and carry *C. juncea* seed in Australia (Panetta, 1988).
ES-17e (Animal internal dispersal)	n - mod		We found no evidence that *C. juncea* seeds are spread to new areas after being consumed by animals.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - low	-1	*Chondrilla juncea* seeds do not exhibit long-term dormancy. They tend to be short-lived in the field and generally do not survive longer than six months. Research on stored seeds determined that seed viability decreased to less than 10 percent within 40 days of dry storage (Panetta, 1988). "Seeds germinate within 24 hours under optimal conditions" (Sheley, 1994). Seeds lose viability within a year (Caso, 1985). "Even under ideal germination conditions up to 20% of the ripe embryos may remain dormant or die….[seed dormancy] may be connected with moisture stress in the plant" (McVean, 1966). Seeds from biotype A plants may be able to survive longer than seed from B and C biotypes (Panetta, 1989a).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	*Chondrilla juncea* is long-lived in areas "subjected to repeated disturbance and damage" (McVean, 1966). This species produces a long tap root that is "easily broken and readily produces adventitious buds following an injury" (McVean, 1966). *Chondrilla juncea* often appears in paddocks after cultivation and soil disturbance. Seedlings do not germinate well on compact soil. "[S]oil disturbance is extremely favourable to seedling establishment and must be a factor of considerable importance in the field" (McVean, 1966). "After establishment, cutting and grazing, or any severe damage to rosette and tap root, leads to the production of adventitious root buds which give rise to vertical underground stems and new rosettes...Once established the plant will thus survive any amount of cutting or excavation....Decapitation of the plants close to the surface gives large multiple-stemmed plants without much increase in rosette numbers. Severing the roots at greater depth without soil mixing leads to some increase in rosette numbers through the appearance of fresh growth from lateral roots as well as the tap root. Ploughing or other complete soil disturbance gives the

Question ID	Answer - Uncertainty	Score	Notes (and references)
			greatest increase in rosette density since the roots become fragmented and each tiny fragment may give rise to a new plant" (McVean, 1966). Root pieces as small as 1 cm long x 3 mm in diameter can produce new plants if enough moisture is present in the soil (Groves et al., 1995).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - mod	0	This species is not listed by Heap (2016) in the International Survey of Herbicide Resistant Weeds. *Chondrilla juncea* "is extremely resistant to herbicides on account of the difficulty of translocation into the extensive underground systems….[In Australia,] none of the selective herbicides used at present has proved to be completely satisfactory in controlling its vigour for more than a few months or the density of the rosette population in the long term" (McVean, 1966). *Chondrilla juncea* is difficult to control using herbicides because *C. juncea* can regenerate from buds and live roots after part of its root system is killed (Groves et al., 1995). Herbicides can be effective at reducing *C. juncea* populations when applied annually, however (Sheley and Petroff, 1999). While *C. juncea* seems to be tolerant to some herbicide applications, we found no evidence that *C. juncea* has developed herbicide resistance. Thus, we answered no with moderate uncertainty.
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)	9	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that *C. juncea* is allelopathic. "*C*[*hondrilla*] *juncea* is not known to be allelopathic" (Holm et al., 1997).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *C. juncea* is a parasitic plant. It is in the family Asteraceae, a family not known to include parasitic plants (Heide-Jørgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - mod	0	We found no evidence that *C. juncea* has this impact.
Imp-N2 (Changes habitat structure)	? - max		The California Invasive Plant Council (Cal-IPC, 2006) lists *C. juncea* as an invader of grasslands with a moderate impact, which is described as having "substantial and apparent—but generally not severe—ecological impacts on...vegetation structure." In Idaho, *C. juncea* has become the dominant species of the forest floor of the Boise National Forest (Pettingill, 2016). Because we did not have specific information about how *C. juncea* may be changing habitat structure, we answered unknown.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N3 (Changes species diversity)	y - low	0.2	In Idaho, *C. juncea* has become established in the Boise National Forest and become the dominant species of the forest floor (Pettingill, 2016). *Chondrilla juncea* "displaces indigenous plants" (Sheley, 1994). In Australia, *C. juncea* has been able to invade native vegetation in areas weakened by drought or overgrazing (McVean, 1966).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0.1	Adair and Groves (1998) list *C. juncea* as a potential threat to the species *Diuris cuneata* in Australia. In Idaho, *C. juncea* has become the dominant species of the forest floor of the Boise National Forest (Pettingill, 2016). Based on these impacts, we answered yes with high uncertainty.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - high	0	We did not find any information about *C. juncea* causing impacts that would alter a natural ecosystem. Thus, we answered no, but with high uncertainty based on the other impacts this species has in natural environments.
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]	c - low	0.6	*Chondrilla juncea* is under eradication in natural areas in eastern Idaho, where it is considered the highest priority weed for weed managers (Pettingill, 2016) and the United States Forest Service has created guidelines for *C. juncea* control in natural areas in the southwestern United States (Forest Service, 2014). The California Invasive Plant Council (Cal-IPC, 2006) lists *C. juncea* as an invader of grasslands with a moderate impact, which is described as having "substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure." Amy Ferriter of Boise State University has seen this plant spread into undisturbed areas (Ferriter, 2016). *Chondrilla juncea* is able to invade natural systems (Schwarzländer, 2016). Kinter et al. (2007) reported that *C. juncea* has also invaded portions of the Snake River Plain in Idaho and Oregon. In Australia, "very few areas of natural vegetation have been invaded by skeleton weed" (Parsons, 1973). Based on this evidence, we answered "c." The alternate answers for the uncertainty simulation were both "b."
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - mod	0	We found no evidence that *C. juncea* has this impact. Lisci and Pacini (1993) recorded *C. juncea* as one of the plants found growing on the walls of Italian towns, but the authors did not say that *C. juncea* was causing any negative impacts in this environment.
Imp-A2 (Changes or limits recreational use of an area)	n - mod	0	We found no evidence that *C. juncea* has this impact.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence that *C. juncea* has this impact. *Chondrilla juncea* seedlings are sensitive to competition from other plants (Parsons, 1973); research has demonstrated that competition from *Trifolium subterraneum* (subterranean clover) reduces the number of *C. juncea* rosettes (McVean, 1966).

Question ID	Answer - Uncertainty	Score	Notes (and references)
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, *C. juncea* does not commonly occur on roadsides (Parsons, 1973). Because we did not find any evidence of *C. juncea* behaving as a weed in urban and suburban areas, we answered "a." 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	Heap (1993) determined that controlling *C. juncea* in barley fields increased barley yields by up to 195 to 199 percent over untreated plots. *Chondrilla juncea* can reduce the yield of cereal crops by 50 to 80 percent (Heap, 1993; Sheley, 1994). In Australia, "wheat yields from paddocks infested with skeleton weed are greatly reduced" (McVean, 1966). *Chondrilla juncea* "dramatically reduces rangeland forage production" (Sheley, 1994). Wheat plants competing with heavy infestations of *C. juncea* do not reach maturity (Parsons and Cuthbertson, 2001).
Imp-P2 (Lowers commodity value)	y - negl	0.2	The tough, wiry stems of *C. juncea* get tangled in harvesting machinery, greatly hindering harvesting (McVean, 1966; Parsons, 1973; Sheley, 1994). Particularly dense infestations can prevent harvesting altogether (Groves et al., 1995). "Many wheat growers [in Australia] went out of business in the mid-1930s as a result of the total crop losses that occurred then and coincided with a period of acute economic depression" (McVean, 1966). Herbicide control of *C. juncea* infestations in wheat is often uneconomical (McVean, 1966). Growers in Australia had to change their cropping systems and move to rotations with legumes and grazing animals in order to grow wheat on land infested with *C. juncea* (Parsons, 1973). *Chondrilla juncea* plants are a sink for nitrogen and can tie up this nutrient and interfere with the growth of other fodder plants in pastures (Groves et al., 1995).
Imp-P3 (Is it likely to impact trade?)	y - low	0.2	*Chondrilla juncea* is a regulated weed in Australia (Groves et al., 1995; Parsons and Cuthbertson, 2001) and British Columbia in Canada (Darbyshire, 2003) and has been eradicated from New Zealand (Howell and Sawyer, 2006; Veitch and Clout, 2002). It is also listed as a harmful organism by Brazil, Chile, Colombia, the Cook Islands, Honduras, Nauru, New Zealand, Niue, and Taiwan (APHIS, 2016). In California, *C. juncea* is an A-rated pest, which is defined as "a pest of known economic or environmental detriment and is either not known to be established in California or it is present in a limited distribution that allows for the possibility of eradication or successful containment. A-rated pests are prohibited from entering the state...If found entering or established in the state, A-rated pests are subject to state (or commissioner when acting as a state agent) enforced action involving eradication, quarantine regulation, containment, rejection, or other holding action" (Lionakis

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Meyer and Effenberger, 2010). In the state of Washington, *C. juncea* is a Class B Noxious weed, which is defined as a weed limited in distribution. Containment and preventing existing infestations from spreading is the primary goal for these weeds (NWCB, 2010). Arizona, Colorado, Idaho, Montana, Nevada, Oregon, Washington, and Wyoming regulate *C. juncea* as a state noxious weed (USDA-AMS, 2014). Because *C. juncea* is also a commodity contaminant (see evidence under ES-16), we answered yes with low uncertainty.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence that *C. juncea* competes for water in an extreme way. *Chondrilla juncea* plants grown in pots "transpire less than potted wheat plants and are more sensitive to moisture stress than fibrous rooted species in general" (McVean, 1966). This species is sensitive to moisture stress, even though *C. juncea* has a tap root that can grow to 250 cm or longer to reach moisture. *Chondrilla juncea* primarily competes with wheat crops for nitrogen, but may compete for moisture during dry seasons (McVean, 1966).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	*Chondrilla juncea* is consumed by sheep, goats, and wild herbivores (McVean, 1966) and is considered a valuable food for sheep and lambs (Parsons, 1973). "It is palatable and nutritious for sheep" (Sheley, 1994). "Rapid spread of skeleton weed occurred in Victoria in the 1950s, coinciding with a drastic reduction in rabbits due to myxomatosis. It is quite likely that rabbits played an important part in preventing the spread and establishment of the weed in earlier years by eating any young plants which appeared" (Parsons, 1973). Simmonds et al. (2000) report *C. juncea* is moderately palatable and poses no known risks to grazing goats. The fibrous flowering stems can cause choking when consumed by cattle (Groves et al., 1995).
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	Herbicides are used to control *C. juncea* in grain crops (Parsons, 1973), and insects, mites, and fungi have been introduced into Australia for biological control (Burdon et al., 1981). Biological control agents were also released in California through a partnership with USDA and the California Department of Food and Agriculture (Supkoff et al., 1988). Proper livestock grazing is advised to control *C. juncea* populations in the United States. Mechanical control can also be used (Sheley, 1994). Australia has spent significant time and money trying to eradicate *C. juncea* (Dodd, 1987; Parsons, 1973). In 1935, the government of New South Wales offered a cash prize for anyone able to develop an eradication method for *C. juncea* (Parsons, 1973). The species is listed as a common weed in Pammel's Weeds of the Farm and Garden (Pammel, 1911). It is considered a "troublesome weed" in wheat fields in Washington state (McVean, 1966) and listed as a noxious weed in Australia (Parsons, 1973). It is a weed of cereal crops in Argentina and of vineyards and citrus groves in Australia

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Groves et al., 1995). In Mediterranean countries, this plant is not considered an important weed because livestock feed on it and keep it under control (McVean, 1966). "In its native environment skeleton weed is of no importance as a weed, with the possible exception of some vine-growing areas in Spain and Portugal" (Parsons, 1973). The alternate answers for the uncertainty simulation are 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 did not find any evidence that *C. juncea* occurs in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We did not find any evidence that *C. juncea* occurs in this zone.
Geo-Z3 (Zone 3)	n - mod	N/A	We did not find any evidence that *C. juncea* occurs in this zone.
Geo-Z4 (Zone 4)	y - low	N/A	A few points in Canada (Vernon, British Columbia) and France.
Geo-Z5 (Zone 5)	y - low	N/A	Multiple points in France.
Geo-Z6 (Zone 6)	y - negl	N/A	Many points in Germany.
Geo-Z7 (Zone 7)	y - negl	N/A	Many points in Germany.
Geo-Z8 (Zone 8)	y - negl	N/A	Many points in France, Spain, Germany, and the Netherlands.
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in Portugal, France, Spain, Australia, and the United States (California).
Geo-Z10 (Zone 10)	y - negl	N/A	Multiple points in Australia.
Geo-Z11 (Zone 11)	y - negl	N/A	Multiple points in Australia.
Geo-Z12 (Zone 12)	n - high	N/A	We did not find any evidence that *C. juncea* occurs in this zone.
Geo-Z13 (Zone 13)	n - mod	N/A	We did not find any evidence that *C. juncea* occurs in this zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - mod	N/A	We found no evidence that *C. juncea* occurs in this climate class.
Geo-C2 (Tropical savanna)	n - mod	N/A	We found no evidence that *C. juncea* occurs in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Many points in Spain and Australia.
Geo-C4 (Desert)	y - negl	N/A	Many points in Spain and Australia.
Geo-C5 (Mediterranean)	y - negl	N/A	Many points in Portugal, Spain, France, and Greece.
Geo-C6 (Humid subtropical)	y - negl	N/A	Multiple points in the United States (Virginia and Maryland) and one point in Argentina.
Geo-C7 (Marine west coast)	y - negl	N/A	Many points in Spain, France, and Germany.
Geo-C8 (Humid cont. warm sum.)	y - mod	N/A	A few points in the United States (Michigan and New Jersey), and one point each in the countries of Georgia and Armenia.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Many points in France and Spain.
Geo-C10 (Subarctic)	y - negl	N/A	Many points in France.
Geo-C11 (Tundra)	y - negl	N/A	Many points in France.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C12 (Icecap)	n - mod	N/A	We found no evidence that *C. juncea* occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - mod	N/A	One point in Algeria and one point in Armenia in this precipitation band. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Many points in Spain and Australia. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Many points in Spain and Portugal. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Many points in France and Greece. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Multiple points in France and Germany. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Multiple points in France and Germany. "In Australia it has been recorded from districts with mean annual rainfalls of from 9 to 60 in. (230-1520 mm)" (McVean, 1966).
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	A few points in the United States (Oregon).
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	A few points in France.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	A few points in Germany.
Geo-R10 (90-100 inches; 229-254 cm)	n - high	N/A	One point in Italy in this precipitation band. Because this one point was the only evidence we found for this precipitation band, we answered no, but used high uncertainty.
Geo-R11 (100+ inches; 254+ cm)	n - high	N/A	We found no evidence that *C. juncea* grows in this precipitation band.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	This species has been present in the United States since 1872 (McVean, 1966). *Chondrilla juncea* occurs in California, Washington, Oregon, Idaho, Colorado, Montana, Wyoming, Utah, Arizona, Indiana, Michigan, New York, Pennsylvania, New Jersey, Maryland, Virginia, West Virginia, and Georgia (EDDMapS, 2016; Kartesz, 2016; NRCS, 2016).
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	

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