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Weed Risk Assessment for *Hirschfeldia incana* (L.) Lagr.-Foss (Brassicaceae) – Shortpod mustard

Clockwise from the top left. Habit and basal rosette of *Hirschfeldia incana* (source: Joseph M. DiTomaso, University of California - Davis, Bugwood.org). Fruit pods and habit (source: Anonymous, 2007). Population along a trail of the Santa Monica Mountains National Recreation Area, CA (bottom left, source: Anonymous, 2007).

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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.

	Hirschfeldia incana **(L.) Lagr.-Foss. – Shortpod mustard**
Species Information	Family: Brassicaceae Synonyms: *Brassica adpressa* Boiss., *Erucastrum incanum* (L.) Koch, *Sinapis incana* L. (NGRP, 2016); *B. geniculata* (Desf.) J. Ball, *B. incana* Ten. (NRCS, 2017); *H. adpressa* Moench (Parsons and Cuthbertson, 2001). Common names: Mediterranean mustard, summer mustard, hairy brassica, hoary mustard (NGRP, 2017), shortpod mustard (NRCS, 2017), buchan weed (Parsons and Cuthbertson, 2001), hairy mustard (AOSA, 2014). Botanical description: *Hirschfeldia incana* is an herbaceous, annual mustard (Hanf, 1983) that produces stems from 1 to 1.5 meters tall (Bojňanský and Fargašová, 2007; Hanf, 1983; Stace, 2010). It produces leaves as a rosette at the base of the plant and along the lower portions of the stems (Parsons and Cuthbertson, 2001). Flowers are pale yellow and crowded to the tips of the stems, which become much extended after flowering (Hanf, 1983). Plants produce typical mustard-like fruit pods (i.e., siliques) that are about 1 to 1.5 cm long and appressed to the stems (Hanf, 1983; Parsons and Cuthbertson, 2001). The seeds are globular to ovate-oblong, about 0.7-1.6 by 0.7-0.9 mm in size (Bojňanský and Fargašová, 2007; Hanf, 1983). The numerous stiff, white hairs give plants a gray-green appearance (Parsons and Cuthbertson, 2001). *Hirschfeldia incana* and *Brassica nigra* can be confused with each other, but they are distinguishable on the basis of several characters (Chester and Strong, 2011; Warwick, 1993+). 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 *H. incana* could be associated with this commodity as a seed contaminant. In this assessment, PERAL 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. Foreign distribution and status: *Hirschfeldia incana* is native to Africa (Algeria, Libya, Morocco, Tunisia), temperate Asia (e.g., Armenia, Israel, Saudi Arabia, Turkey), and Europe (Ukraine, Albania, Croatia, Greece, Italy, France, Portugal, Spain) (NGRP, 2017). It is naturalized in Africa (Madeira Islands, Canary Islands, South Africa), temperate Asia (Japan), Australasia (Australia, New Zealand), Europe (Belarus, Belgium, Estonia, Denmark, Germany, Hungary, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Slovakia, Switzerland, Ukraine, the United Kingdom, Russian Federation), South America (Argentina, Chile, Uruguay), and North America (Mexico) (Bojňanský and Fargašová, 2007; DAISIE, 2017; Howell and Sawyer, 2006; NGRP, 2017; Reynolds, 2002; Villaseñor and Espinosa-García, 2004). It was recently collected for the first time in Kyrgyzstan (Lazkov and Sennikov, 2014). It is considered invasive and spreading in the Canary Islands (Stierstorfer and Gaisbergm,

2006), the United Kingdom (Lee et al., 2004), and Chile (Castro et al., 2016). It is a casual in the Czech Republic (Pyšek et al., 2012) and Australia (Parsons and Cuthbertson, 2001). *Hirschfeldia incana* is regulated as a quarantine pest by Brazil, Colombia, and Peru (APHIS, 2017). It is also classified as a Declared Weed in Australia (Randall, 2007). In 2001, it was classified as a "proclaimed plant" in South Australia (Parsons and Cuthbertson, 2001); however, it currently is not regulated by that state (Government of South Australia, 2017).

U.S. distribution and status: *Hirschfeldia incana* was first collected in the United States in 1895 in the San Bernardino region and was already considered a serious agricultural pest by 1936 (cited in Warwick, 1993+). It is naturalized in the United States (Rollins, 1981) throughout most of California, and in one to three counties each in Arizona, Hawaii, Nevada, and Oregon (Calflora, 2017; EDDMapS, 2016; Kartesz, 2017; NRCS, 2017). It is also reported to be in Washington (NPS, 2017). In California, it is continuing to spread and increase in abundance (Anonymous, 2014). *Hirschfeldia incana* is listed as a weed by the Weed Science Society of America (WSSA, 2010). The California Invasive Plant Council ranked it as a moderate invader, which includes species that have substantial and apparent, but generally not severe ecological impacts (Cal-IPC, 2017). Workers are trying to control this species in California (e.g., NPS, 2017). "Few herbicides provide effective control of shortpod mustard. Many herbicides used on annual and biennial mustards are less effective on this perennial" (DiTomaso and Kyser, 2013). *Hirschfeldia incana* is a declared noxious weed in Orange County, CA (OC Public Works, 2017), and it is specifically included in a weed-free certification program in gravel in the state (Anonymous, No Date). Although it may be present in botanical gardens or research collections, we found no evidence that *H. incana* is commercially or privately cultivated in the United States (e.g., Backyard Gardener, 2017; Dave's Garden, 2017; Page and Olds, 2001; Univ. of Minn., 2016).

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

1. *Hirschfeldia incana* analysis

Establishment/Spread Potential

Hirschfeldia incana has already demonstrated its capacity to establish and spread in several countries, including Australia (Parsons and Cuthbertson, 2001), Chile (Castro et al., 2016), the Canary Islands (Stierstorfer and Gaisbergm, 2006), Mexico (CABI, 2017), the United Kingdom (Lee et al., 2004), and the United States (Anonymous, 2014). It reproduces prolifically through seeds (Siemens, 2011; South East Natural Resources Management Board, 2009). Although plants are primarily outcrossing, they can set selfed

[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).

seed to some extent (Darmency and Fleury, 2000) and do not require specialist pollinators. Seeds are easily dispersed by people on machinery and clothing (Ansong and Pickering, 2014; Parsons and Cuthbertson, 2001), by soil movement during road grading (Parsons and Cuthbertson, 2001), and in trade in wool (Stace, 2010), birdseed (Hanson and Mason, 1985), grain (GTA, No Date; Wilson et al., 2016), and seeds for planting (AQAS, 2017; Wilson, 2017). It is also dispersed by wind (Chronopoulos et al., 2005) and animals (Quinn et al., 2008; Stace, 2010). Seeds can persist in the soil for a few years (Chadoeuf et al., 1998). *Hirschfeldia incana* evolved resistance to acetolactate-synthase (ALS) inhibitor herbicides in 2013 in Argentina, where it infests wheat and winter barley crops (Heap, 2017). Overall, we had a low level of uncertainty for this risk element.
Risk score = 20 Uncertainty index = 0.11

Impact Potential *Hirschfeldia incana* is a weed of open, disturbed habitats in natural, anthropogenic, and agricultural systems, and is being controlled by resource managers in all three types of systems. In natural areas in California, it displaces and outcompetes native species (DiTomaso and Kyser, 2013; NPS, 2017). At Pinnacles National Park, the National Park Service is actively trying to control it and two other problematic herbaceous species (NPS, 2017). Although we found no direct evidence of specific impacts in anthropogenic systems, *H. incana* is a well-documented weed of ruderal sites such as roadsides, railways, fence lines, and suburbs across several countries (Auld and Medd, 1987; Cousens et al., 1993; DiTomaso and Healy, 2007; Parsons and Cuthbertson, 2001). It is being controlled in Santiago, Chile, and despite efforts to eradicate it, populations continue to persist (Castro et al., 2016). In an artificial native plant meadow in California, horticulturalists are using solarization to kill it and other herbaceous weed species (Stapleton and Jett, No Date). In agricultural systems, it "can become a serious competitor for space in winter-growing cereal crops, reducing yield…" (Parsons and Cuthbertson, 2001). In pastures, it can lead to tainted meat and dairy products by imparting an off-flavor, limit access to other pasture plants, and interfere with harvest of cereals (Parsons and Cuthbertson, 2001). Deep ploughing effectively controls *Hirschfeldia incana* by burying the taproot of established plants, but further work is needed to destroy new seedling recruits (Parsons and Cuthbertson, 2001). Because we had limited evidence or no evidence for many of our questions, our uncertainty for this risk element was very high.
Risk score = 3.7 Uncertainty index = 0.30

Geographic Potential Based on three climatic variables, we estimate that about 59 percent of the United States is suitable for the establishment of *H. incana* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world. The map for *H. incana* represents the joint distribution of Plant Hardiness Zones 6-12, areas with 0-60 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. *Hirschfeldia incana* occurs in a variety of habitats, such as clearings, roadways, railways, canal embankments, waste places, canyons, pastures, docks, cropland, vineyards, dry washes, coastal scrub, and deserts (Crawley, 2011; DiTomaso and Kyser, 2013; Lee et al., 2004; Rollins, 1981). In Europe, it occurs in sand, clay, and gravel soils that are deficient in humus but rich in nutrients (Hanf, 1983).

Entry Potential Although *H. incana* is already naturalized in the United States, we evaluated its entry potential to determine how likely it is for additional material to be introduced. On a scale of 0 to 1, where 1 represents a maximum likelihood to enter through multiple pathways, *H. incana* scored 0.57. The most likely pathway for its entry would be intentionally for mustard breeding research (Siemens, 2011) or for use in phytoremediation (Auguy et al., 2013; Auguy et al., 2016; Midhat et al., 2017). The second most likely pathway for it to enter would be as a contaminant of either grain (GTA, No Date; Wilson et al., 2016) or seeds for planting (AQAS, 2017; Wilson, 2017). Seeds may also enter through several other pathways, including on clothing (Ansong and Pickering, 2014) and in wool (Stace, 2010), birdseed (Hanson and Mason, 1985), and ore (Verloove, 2006). It also disperses in mud on animal livestock (Parsons and Cuthbertson, 2001), and it may therefore naturally disperse across the U.S./Mexican border. Overall, we had a low level of uncertainty associated with this risk element.

Risk score = 0.57 Uncertainty index = 0.13

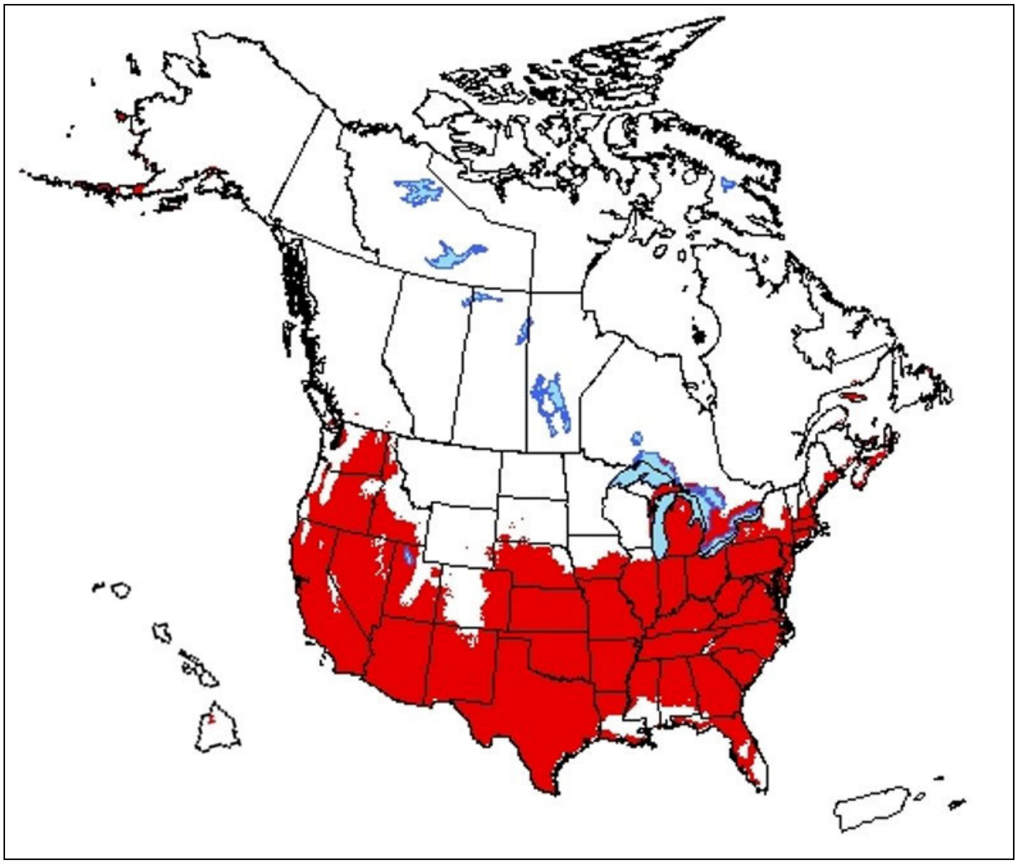

Figure 1. Potential geographic distribution of *H. incana* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 94.3%
P(Minor Invader) = 5.5%
P(Non-Invader) = 0.2%
Risk Result = High Risk
Secondary Screening = Not Applicable

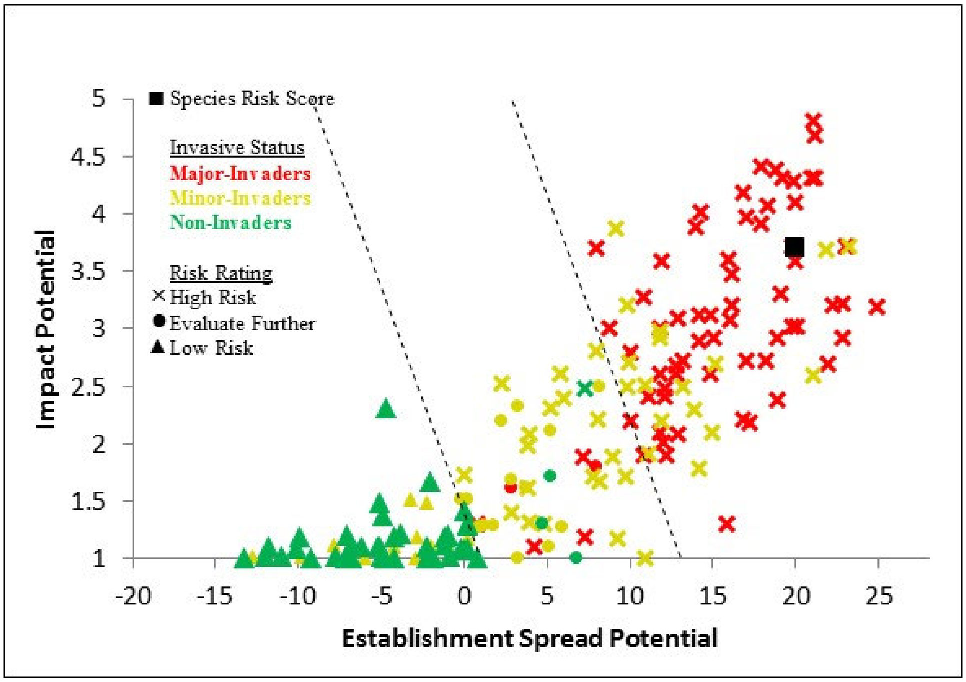

Figure 2. *Hirschfeldia incana* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

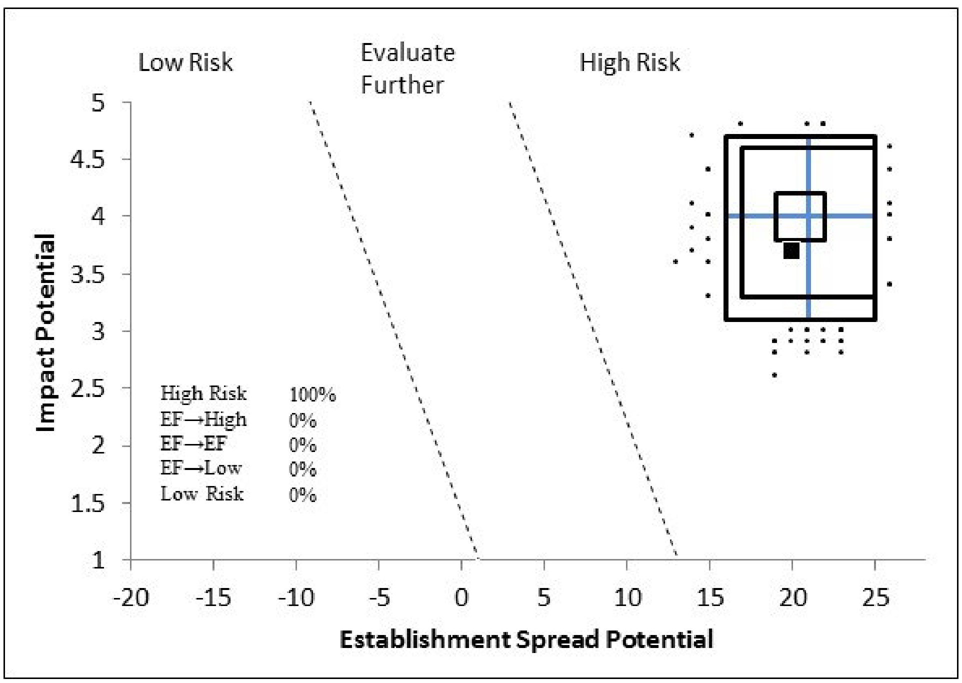

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *H. incana*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Hirschfeldia incana* is High Risk (Fig. 2), and although there was very high uncertainty for its impact potential, our uncertainty analysis indicates that our conclusion is robust, because even if we changed some of the answers randomly, we still obtain the same result (Fig. 3). Relative to the abundance of sources claiming that this species is weedy or invasive, we found relatively few sources with specific or detailed accounts of its impacts. Its impact risk score was driven to a large extent by the evidence of control we found in natural, anthropogenic, and production systems (Appendix A).

For Australia, Parsons and Cuthbertson (2001) said that *H. incana* is not normally a problem plant. However, this species' behavior may depend on the specific farming practices used, since it is thrives in no-till systems (Dorado and López-Fando, 2006). *Hirschfeldia incana* has been evaluated with three other weed risk assessment tools, which have not produced consistent results. For example, the Australian WRA yielded a result of "reject" that is analogous to our High Risk result (i.e., high risk) (Pheloung, 1995). A South Australia weed risk assessment concluded it represents a low risk for vegetable crops, but a moderate risk for irrigated pasture (South East Natural Resources Management Board, 2009). Finally, the California Invasive Plant Council's assessment resulted in a conclusion of "moderate," which corresponds to species that have substantial and apparent impacts, but generally not severe impacts on ecological processes (Cal-IPC, 2017). The variation among the results of these weed assessment tools is probably due largely to the scope of the various assessment tools. For example, the Cal-IPC assessment focuses exclusively on impacts in natural systems, whereas the South Australia assessment focused on impacts in production systems.

4. Literature Cited

7 U.S.C. § 1581-1610. 1939. The Federal Seed Act, Title 7 United States Code § 1581-1610.

7 U.S.C. § 7701-7786. 2000. Plant Protection Act, Title 7 United States Code § 7701-7786.

Al-Shehbaz, I. A. 1977. Protogyny in the Cruciferae. Systematic Botany 2(4):327-333.

Anonymous. 2007. Wildflowers of the Santa Monica Mountains, National Recreation Area: Mediterranean mustard, *Hirschfeldia incana*. United States Department of the Interior, National Park Service. Last accessed February 10, 2017, http://www.smmflowers.org/mobile/species/Hirschfeldia_incana.htm.

Anonymous. 2014. Invasive plant inventory: Inglewood Oil Field, Bladwin Hills CSD provisions, E.7.b. Cardno ENTRIX and ENVIRON, Los Angeles, CA. 14 pp.

Anonymous. No Date. Weed-free aggregate program: Mojave Desert region. California Invasive Plant Council, California. Last accessed February 9, 2017, http://www.cal-ipc.org/ip/prevention/RegionalPrograms/MojaveDesertRegion.pdf.

Ansong, M., and C. Pickering. 2014. Weed seeds on clothing: A global review. Journal of Environmental Management 144:203-211.

AOSA. 2014. Rules for Testing Seeds: Volume 3. Uniform Classification of Weed and Crop Seeds. Association of Official Seed Analysts (AOSA), Washington D.C. 274 pp.

APHIS. 2017. Phytosanitary Certificate Issuance & Tracking System (PCIT). United States Department of Agriculture, Animal and Plant Health Inspection Service (APHIS). https://pcit.aphis.usda.gov/pcit/. (Archived at PERAL).

AQAS. 2017. Agriculture Quarantine Activity Systems (AQAS) Database. United States Department of Agriculture - Plant Protection and Quarantine. https://mokcs14.aphis.usda.gov/aqas/login.jsp. (Archived at PERAL).

Auguy, F., M. Fahr, P. Moulin, A. Brugel, L. Laplaze, M. E. Mzibri, A. Filali-Maltouf, P. Doumas, and A. Smouni. 2013. Lead tolerance and accumulation in *Hirschfeldia incana*, a Mediterranean Brassicaceae from metalliferous mine spoils [Abstract]. PLoS ONE 8(5).

Auguy, F., M. Fahr, P. Moulin, M. El Mzibri, A. Smouni, A. Filali-Maltouf, G. Béna, and P. Doumas. 2016. Transcriptome changes in *Hirschfeldia incana* in response to lead exposure [Abstract]. Frontiers in Plant Science 6(JAN2016).

Auld, B. A., and R. W. Medd. 1987. Weeds: An Illustrated Botanical Guide to the Weeds of Australia. Inkata Press, Melbourne, Australia. 255 pp.

Backyard Gardener. 2017. Plant Finder [online database]. BackyardGardener.com. http://www.backyardgardener.com. (Archived at PERAL).

Bojňanský, V., and A. Fargašová. 2007. Atlas of Seeds and Fruits of Central and East-European Flora: The Carpathian Mountains Region. Springer, Dordrecht, The Netherlands. 1046 pp.

Bugwood. 2017. Weed Images. Bugwood Images. https://www.weedimages.org/index.cfm. (Archived at PERAL).

CABI. 2017. Invasive Species Compendium, Online Database. CAB International (CABI). http://www.cabi.org/cpc/. (Archived at PERAL).

Cal-IPC. 2017. California Invasive Plant Inventory Database. California Invasive Plant Council. http://cal-ipc.org/paf/. (Archived at PERAL).

Calflora. 2017. California flora database. Calflora. http://www.calflora.org/about-cf.html. (Archived at PERAL).

Castro, S. A., J. A. Figueroa, and V. Escobedo. 2016. Effect of the harvest year and cultivation temperature on the germination of *Hirschfeldia incana* (Brassicaceae): Inferences on its invasiveness in Chile. Revista Brasileira de Botanica 39(1):193-196.

Chadoeuf, R., H. Darmency, J. Maillet, and M. Renard. 1998. Survival of buried seeds of interspecific hybrids between oilseed rape, hoary mustard and wild radish. Field Crops Research 58(3):197-204.

Chester, T., and J. Strong. 2011. Plants of southern California: analysis pages: Mustard (*Brassica nigra* and *Hirschfeldia incana*): How to tell the difference. Tom Chester. Last accessed February 10, 2017, http://tchester.org/plants/analysis/mustard/comparison.html.

Chèvre, A. M., F. Eber, E. Jenczewski, H. Darmency, and M. Renard. 2003. Gene flow from oilseed rape to weedy species. Acta Agriculturae Scandinavica - Section B: Soil and Plant Science 53(SUPPL. 1):22-25.

Chronopoulos, G., M. Theocharopoulos, and D. Christodoulakis. 2005. Phytosociological study of *Hirschfeldia incana* (L.) Lagreze-Fossat (Cruciferae) communities in mainland Greece. Acta Botanica Croatica 64(1):75-114.

Cousens, R., R. Baweja, J. Vaths, and M. Schofield. 1993. Comparative biology of cruciferous weeds: A preliminary study. Pages 376-380 *in* Weed Society of Queensland (ed.). 10th Australian Weeds Conference/14th Asian-Pacific Weed Science Society Conference. Weed Society of Queensland, Brisbane, Australia.

Cox, R. D., and E. B. Allen. 2008. Composition of soil seed banks in southern California coastal sage scrub and adjacent exotic grassland. Plant Ecology 198(1):37-46.

Crawley, M. J. 2011. London. Pages 207-236 *in* J. G. Kelcey and M. Norbert (eds.). Plants and Habitats of European Cities. Springer, New York.

DAISIE. 2017. Delivering Alien Invasive Species Inventories for Europe (DAISIE, Online Database). http://www.europe-aliens.org/index.jsp. (Archived at PERAL).

Darmency, H., and A. Fleury. 2000. Mating system in *Hirschfeldia incana* and hybridization to oilseed rape. Weed Research 40(2):231-238.

Dave's Garden. 2017. Plant files database. Dave's Garden. http://davesgarden.com/guides/pf/go/1764/. (Archived at PERAL).

Davis, A. R. 1991. Mixed loading of pollen from *Echium plantagineum* L. (Boraginaceae) and *Hirschfeldia incana* (L.) Lagreze-Foss. (Brassicaceae) by an individual honey bee (*Apis mellifera* L.) [Abstract]. American Bee Journal 131(10):649-655.

Devos, Y., A. de Schrijver, and D. Reheul. 2009. Quantifying the introgressive hybridisation propensity between transgenic oilseed rape and its wild/weedy relatives. Environmental Monitoring and Assessment 149(1-4):303-322.

DiTomaso, J. M., and E. A. Healy. 2007. Weeds of California and Other Western States (vols. 1 & 2). University of California, Oakland, CA, U.S.A. 1808 pp.

DiTomaso, J. M., and G. B. Kyser. 2013. Weed Control in Natural Areas in the Western United States. University of California, Weed Research and Information Center, Davis, California. 544 pp.

Dorado, J., and C. López-Fando. 2006. The effect of tillage system and use of a paraplow on weed flora in a semiarid soil from central Spain. Weed Research 46(5):424-431.

Earlywine, D. T., R. J. Smeda, T. C. Teuton, C. E. Sams, and X. Xiong. 2010. Evaluation of oriental mustard (*Brassica juncea*) seed meal for weed suppression in turf. Weed Technology 24(4):440-445.

EDDMapS. 2016. Early Detection & Distribution Mapping System (EDDMapS) [Online Database]. The University of Georgia - Center for Invasive Species and Ecosystem Health. http://www.eddmaps.org/. (Archived at PERAL).

Farzadfar, S., Y. Tomitaka, M. Ikematsu, A. R. Golnaraghi, R. Pourrahim, and K. Ohshima. 2009. Molecular characterisation of Turnip mosaic virus isolates from Brassicaceae weeds [Abstract]. European Journal of Plant Pathology 124(1):45-55.

GBIF. 2017. GBIF, Online Database. Global Biodiversity Information Facility (GBIF). http://www.gbif.org/. (Archived at PERAL).

Government of South Australia. 2017. Consolidated list of declarations of animals and plants: Natural Resources Management Act 2004. Government of South Australia. Last accessed January 27, 2017, http://www.pir.sa.gov.au/biosecurity/weeds_and_pest_animals/weeds_in_sa#toc0.

Government of Ukraine. 2013. Information required by APHIS for commodity import request requiring change in regulations (7 CFR 319.5) for wheat from Ukraine. Government of Ukraine. 3 pp.

Gresta, F., A. Cristaudo, A. Onofri, A. Restuccia, and G. Avola. 2010. Germination response of four pasture species to temperature, light, and post-harvest period. Plant Biosystems 144(4):849-856.

GTA. No Date. Seed Impurities of Grain...an Identification Kit. Grain Trade Australia (GTA), Royal Exchange, NSW, Australia. 138 pp.

Gulden, R. H., S. I. Warwick, and A. G. Thomas. 2008. The Biology of Canadian Weeds. 137. *Brassica napus* L. and *B. rapa* L. Canadian Journal of Plant Science 88(5):951-996.

Hanf, M. 1983. The Arable Weeds of Europe: With their Seedlings and Seeds. BASF, Ipswich, U.K. 494 pp.

Hanson, C. G., and J. L. Mason. 1985. Bird seed aliens in Britain. Watsonia 15:237-252.

Heap, I. 2017. The international survey of herbicide resistant weeds. Weed Science Society of America. http://weedscience.org/. (Archived at PERAL).

Heide-Jorgensen, H. S. 2008. Parasitic Flowering Plants. Brill, Leiden, The Netherlands. 438 pp.

Holm, L. G., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1991. A Geographical Atlas of World Weeds. Krieger Publishing Company, Malabar, Florida, U.S.A. 391 pp.

Horovitz, A., and J. Galil. 1972. Gynodioecism in East Mediterranean *Hirschfeldia incana*. Cruciferae. Botanical Gazette 133(2):127-131.

Howell, C. J., and J. W. D. Sawyer. 2006. New Zealand Naturalised Vascular Plant Checklist. New Zealand Plant Conservation Network, Wellington, New Zealand. 60 pp.

IPPC. 2012. International Standards for Phytosanitary Measures No. 5: Glossary of Phytosanitary Terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. 38 pp.

IPPC. 2015. International Standards for Phytosanitary Measures No. 2: Framework for Pest Risk Analysis. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. 18 pp.

Kartesz, J. 2017. The Biota of North America Program (BONAP). North American Plant Atlas. http://bonap.net/tdc. (Archived at PERAL).

Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294.

Lazkov, G., and A. Sennikov. 2014. New records in vascular plants alien to Kyrgyzstan. Biodiversity Data Journal 2(e1018):1-23.

Lee, P. L. M., R. M. Patel, R. S. Conlan, S. J. Wainwright, and C. R. Hipkin. 2004. Comparison of genetic diversities in native and alien populations of hoary mustard (*Hirschfeldia incana* [L.] Lagreze-fossat). International Journal of Plant Sciences 165(5):833-843.

Liu, Y., W. Wei, K. Ma, J. Li, Y. Liang, and H. Darmency. 2013. Consequences of gene flow between oilseed rape (*Brassica napus*) and its relatives. Plant Science 211:42-51.

Luu, D.-T., S. Hugues, E. Passelègue, and P. Heizmann. 2001. Evidence for orthologous S-locus-related I genes in several genera of Brassicaceae. Molecular and General Genetics 264(6):735-745.

Mabberley, D. J. 2008. Mabberley's Plant-Book: A Portable Dictionary of Plants, Their Classification and Uses (3rd edition). Cambridge University Press, New York. 1021 pp.

Martin, P. G., and J. M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.

Martin, T. G., S. Campbell, and S. Grounds. 2006. Weeds of Australian rangelands. The Rangeland Journal 28(1):3-26.

Marushia, R. G., M. L. Brooks, and J. S. Holt. 2012. Phenology, growth, and fecundity as determinants of distribution in closely related nonnative taxa. Invasive Plant Science and Management 5(2):217-229.

Matthei, O. J. 1995. Manual de las Malezas que Crecen en Chile. Alfabeta Impresores, Santiago, Chile. 545 pp.

Midhat, L., N. Ouazzani, M. Esshaimi, A. Ouhammou, and L. Mandi. 2017. Assessment of heavy metals accumulation by spontaneous vegetation: Screening for new accumulator plant species grown in Kettara mine-Marrakech, Southern Morocco [Abstract]. International Journal of Phytoremediation 19(2):191-198.

Morales, C. L., and M. A. Aizen. 2002. Does invasion of exotic plants promote invasion of exotic flower visitors? A case study from the temperate forests of the southern Andes. Biological Invasions 4:87-100.

NGRP. 2016. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx?language=en. (Archived at PERAL).

NGRP. 2017. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx?language=en. (Archived at PERAL).

Nickrent, D. 2009. Parasitic plant classification. Southern Illinois University Carbondale, Carbondale, IL. Last accessed June 12, 2009, http://www.parasiticplants.siu.edu/ListParasites.html.

NPB. 2016. Laws and regulations. The National Plant Board (NPB). Last accessed September 28, 2016, http://nationalplantboard.org/laws-and-regulations/.

NPS. 2017. Exotic plants of Pinnacles National Monument. United States Department of Interior, National Park Service (NPS), United States. Last accessed February 13, 2017, https://www.nps.gov/pinn/learn/nature/exoticplants.htm.

NRCS. 2017. The PLANTS Database. United States Department of Agriculture, Natural Resources Conservation Service (NRCS), The National Plant Data Center. http://plants.usda.gov/cgi_bin/. (Archived at PERAL).

OC Public Works. 2017. Noxious weeds and native vegetation. Orange County (OC) Public Works, California. Last accessed February 13, 2017, http://www.ocagcomm.com/abatement/weeds.

Page, S., and M. Olds (eds.). 2001. The Plant Book: The World of Plants in a Single Volume. Mynah, Hong Kong. 1020 pp.

Paolini, J. J., L. H. Quon, and E. J. Questad. 2014. The impact of invasive forbs on fine fuel loads in degraded coastal sage scrub. Crossosoma 40(1).

Pardillo López, L. M., and I. E. La Serna Ramos. 2007. Pollen analysis of some honeys from Tenerife and La Gomera (Canary islands, Spain). Geo-Eco-Trop 31(1):215-232.

Parsons, W. T., and E. G. Cuthbertson. 2001. Noxious weeds of Australia (2nd edition). CSIRO Publishing, Collingwood, Victoria, Australia. 698 pp.

Pheloung, P. 1995. Determining the weed potential of new plant introductions to Australia. Agriculture Protection Board, Western Australia. 36 pp.

PPQ. 2015. Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process. United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ). 125 pp.

Pyšek, P., J. Danihelka, J. Sádlo, J. Chrtek, Jr., M. Chytrý, V. Jarošík, Z. Kaplan, F. Krahulec, L. Moravcová, J. Pergl, K. Štajerová, and L. Tichý. 2012. Catalogue of alien plants of the Czech Republic (2nd edition): Checklist update, taxonomic diversity and invasion patterns. Preslia 84:155-255.

Quinn, L. D., M. Kolipinski, V. R. Coelho, B. Davis, J. M. Vianney, O. Batjargal, M. Alas, and S. Ghosh. 2008. Germination of invasive plant seeds after digestion by horses in California. Natural Areas Journal 28(4):356-362.

Randall, J. M. 2007. The Introduced Flora of Australia and its Weed Status. CRC for Australian Weed Management, Department of Agriculture and Food, Western Australia, Australia. 528 pp.

Randall, R. P. 2012. A Global Compendium of Weeds, 2nd edition. Department of Agriculture and Food, Western Australia, Perth, Australia. 1107 pp.

Reed, C. F. 1977. Economically Important Foreign Weeds. Agricultural Research Service, United States Department of Agriculture, Washington, D.C. 746 pp.

Reynolds, S. C. P. 2002. A Catalogue of Alien Plants in Ireland. National Botanic Gardens, Glasnevin, Ireland. 315 pp.

Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Elchbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. T. Hurley, K. M. Carney, R. Abell, and S. Walters. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press, Washington D.C. 485 pp.

Robson, T. O., P. J. Americanos, and B. E. Abu-Irmaileh. 1991. Major Weeds of the Near East. Food and Agriculture Organization of the United Nations, Rome. 236 pp.

Rollins, R. C. 1981. Weeds of the Cruciferae (Brassicaceae) in North America. Journal of the Arnold Arboretum 62:517-540.

Salvatore, S., N. Pellegrini, O. V. Brenna, D. Del Rio, G. Frasca, F. Brighenti, and R. Tumino. 2005. Antioxidant characterization of some sicilian edible wild greens [Abstract]. Journal of Agricultural and Food Chemistry 53(24):9465-9471.

Santi, C., D. Bogusz, and C. Franche. 2013. Biological nitrogen fixation in non-legume plants. Annals of Botany 111(5):743-767.

Siemens, J. 2011. *Hirschfeldia*. Pages 171-176 *in* C. Kole (ed.). Wild Crop Relatives: Genomic and Breeding Resources: Oilseeds. Springer, Dordrecht.

Simmonds, H., P. Holst, and C. Bourke. 2000. The palatability, and potential toxicity of Australian weeds to goats. Rural Industries Research and Development Corporation, Australia. 156 pp.

South East Natural Resources Management Board. 2009. South East Pest Management Strategy, Part 2: Pest Management Plan: Buchan weed (*Hirschfeldia incana*). Government of South Australia. Last accessed February 10, 2017, http://pir.sa.gov.au/__data/assets/pdf_file/0013/223231/buchan_weed_policy.pdf.

Stace, C. 2010. New Flora of the British Isles (3rd ed.). Cambridge University Press, Cambridge, UK. 1130 pp.

Stapleton, J. J., and S. Jett. No Date. A large-scale demonstration of solar inactivation of invasive weed propagules for revegetation with California native wildflower communities. University of California, Parlier, CA. Last accessed February 9, 2017, http://ucanr.edu/sites/Solarization/files/114659.pdf.

Stierstorfer, C., and M. v. Gaisbergm. 2006. Annotated Checklist and Distribution of the Vascular Plants of El Hierro, Canary Islands, Spain. Englera (27):3-221.

Swearingen, J. 2011. Invasive plant atlas of the United States. National Park Service. Last accessed June 27, 2011, http://www.invasiveplantatlas.org/index.html.

Taleb, A., M. Bouhache, and S. B. Rzozi. 1998. Flore adventice des céréales d'automne au Maroc. Actes Inst. Agron. Vet (Maroc) 18(2):121-130.

Univ. of Minn. 2016. Plant Information Online Database. University of Minnesota. https://plantinfo.umn.edu/default.asp. (Archived at PERAL).

USDA-AMS. 2016. State noxious-weed seed requirements recognized in the administration of the Federal Seed Act. United States Department of Agriculture (USDA), Agricultural Marketing Service (AMS), Washington D.C. 121 pp.

Verloove, F. 2006. Catalogue of neophytes in Belgium (1800-2005). National Botanic Garden of Belgium, Meise, Belgium. 89 pp.

Villaseñor, J. L., and F. J. Espinosa-García. 2004. The alien flowering plants of Mexico. Diversity and Distributions 10:113-123.

Wall, D. A. 1997. Dog mustard (*Erucastrum gallicum*) response to crop competition. Weed Science 45(3):397-403.

Warwick, S. I. 1993+. Flora of North America: *Hirschfeldia* (Online Database): . eFloras. (Archived at PERAL).

Wilson, C. 2017. Quick question. Personal communication to A. L. Koop on February 9, 2017, from Claire Wilson, Risk Analyst, Canadian Food Inspection Agency.

Wilson, C., K. Castro, G. Thurston, and A. Sissons. 2016. Pathway risk analysis of weed seeds in imported grain: A Canadian perspective. In: Daehler C. C, van Kleunen M., Pyšek P., Richardson D. M. (Eds) Proceedings of 13th International EMAPi conference, Waikoloa, Hawaii. NeoBiota 30:49-74.

WSSA. 2010. Composite list of weeds. Weed Science Society of America (WSSA). Last accessed March 12, 2014, http://wssa.net/weed/composite-list-of-weeds/.

Wurzell, B. 1988. *Conyza sumatrensis* (Retz.) E. Walker established in England. Watsonia 17(145-148):145-148.

Appendix A. Weed risk assessment for *Hirschfeldia incana* (L.) Lagr.-Foss. (Brassicaceae). 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	*Hirschfeldia incana* is native to northern Africa, temperate Asia, and southern Europe (NGRP, 2017). It is naturalized in Africa (Madeira Islands, Canary Islands, South Africa), temperate Asia (Japan), Australasia (Australia, New Zealand), Europe (Belarus, Belgium, Estonia, Denmark, Germany, Hungary, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Slovakia, Switzerland, Ukraine, the United Kingdom, Russian Federation), South America (Argentina, Chile, Uruguay), and North America (Mexico, United States) (Bojňanský and Fargašová, 2007; DAISIE, 2017; Howell and Sawyer, 2006; NGRP, 2017; Reynolds, 2002; Villaseñor and Espinosa-García, 2004). In London, "*Hirschfeldia incana* was relatively local and scarce in the 1970s but is now widespread and abundant" (Crawley, 2011). It is becoming increasingly naturalized in the United Kingdom (Stace, 2010) and undergoing range expansion (Lee et al., 2004). It underwent a notable range expansion in the United Kingdom between 1974 and 1984 when conditions became drier during the summer (Wurzell, 1988). *Hirschfeldia incana* was first recorded in Australia in the early 1900s and then spread throughout the southeastern portion of the continent (Parsons and Cuthbertson, 2001). For Australia, Randall (2007) classifies *H. incana* as an invasive species, which includes species that spread quickly. In Chile, it is a relatively recent alien that is spreading quickly and is expected to continue to spread (Castro et al., 2016). *Hirschfeldia incana* is considered invasive in the Canary Islands (Stierstorfer and Gaisbergm, 2006). It is reported to be invasive in U.S. natural areas (Anonymous, 2014; Swearingen, 2011). In Mexico, it is strongly associated with railways, but has been spreading to other types of habitats (CABI, 2017). Based on this evidence, it is clear that this species is spreading where it has become naturalized. We answered "f" with negligible uncertainty, and set both alternate answers as "e."
ES-2 (Is the species highly domesticated)	n - negl	0	*Hirschfeldia incana* is sometimes used as a wild herb in the Mediterranean, but it is of no economic importance (Salvatore et al., 2005; Siemens, 2011). We found no evidence that *H. incana* is commercially or privately cultivated in the United States (e.g., Backyard Gardener, 2017; Dave's Garden, 2017; Page and Olds, 2001; Univ. of Minn., 2016). Thus, it has likely not been domesticated and is very unlikely to have been bred for reduced weediness traits.
ES-3 (Weedy congeners)	n - mod	0	The genus *Hirschfeldia* includes three species that are taxonomically closely related to *Erucastrum* (Mabberley, 2008; Siemens, 2011). *Hirschfeldia incana* is the only species in the genus that has been reported as weedy (Randall, 2012).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Because this genus includes only three species, and because *H. incana* was once placed in the genus *Erucastrum*, we expanded the scope of this question to include that genus as well. *Erucastrum* includes about 20 species (Mabberley, 2008), several of which have been reported to be weedy (Randall, 2012). One species in this genus (*E. gallicum*) is distinctive in that there are more than 40 references reporting it is weedy (Randall, 2012), suggesting it may be a significant weed. However, we found no evidence that it is a significant weed (e.g., Holm et al., 1991). In fact, Canadian researchers found that relative to flax and wheat, *E. gallicum* is a poor competitor for light, nutrients, and moisture (Wall, 1997). Consequently, we answered no with moderate uncertainty.
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	We found no evidence that *H. incana* is shade tolerant. This species occurs in clearings, motorways, railways, and canal embankments in London (Crawley, 2011), all of which are areas that receive lots of light. In California, this species occurs in full sunlight in coastal scrub communities (Paolini et al., 2014). Although seeds are able to germinate in darkness, germination is greatly enhanced by light (Cousens et al., 1993; Gresta et al., 2010).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - high	0	This species is not a vine, but it usually produces a rosette of leaves (DiTomaso and Kyser, 2013; Marushia et al., 2012; Parsons and Cuthbertson, 2001). Examination of several online images (e.g., Bugwood, 2017) of the rosettes shows that overall, while individual plants produce somewhat flat rosettes of leaves, they are somewhat open. Consequently, we answered no with high uncertainty.
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	*Hirschfeldia incana* forms dense patches in disturbed areas (Parsons and Cuthbertson, 2001). In one California coastal scrub community, it occurred at an average density of about 11 plants per square meter (Paolini et al., 2014). It forms dense populations in South Australia (South East Natural Resources Management Board, 2009).
ES-7 (Aquatic)	n - negl	0	*Hirschfeldia incana* is not an aquatic plant; rather, it is a terrestrial herb (Parsons and Cuthbertson, 2001) that is well-adapted to dry-summer climates (Gresta et al., 2010).
ES-8 (Grass)	n - negl	0	This species is not a grass; rather, it is a mustard in the Brassicaceae family (NGRP, 2017).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. It is not a member of a plant family known to fix nitrogen (Martin and Dowd, 1990; Santi et al., 2013), nor is it a woody plant (Hanf, 1983; Warwick, 1993+).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	It reproduces only by seed (Parsons and Cuthbertson, 2001). Seed viability is high (Darmency and Fleury, 2000; Marushia et al., 2012).
ES-11 (Self-compatible or apomictic)	y - high	1	It is self-incompatible due not only to protogyny, where the female parts of the flowers mature before the male parts (Al-Shehbaz, 1977), but also because S-locus-related genes control late pollen adhesion (Luu et al., 2001). In a pollination experiment, researchers found that while most plants were primarily self-incompatible, there were a few plants that could set selfed seed, albeit at a lower rate compared to outcrossed

Question ID	Answer - Uncertainty	Score	Notes (and references)
			seed set (Darmency and Fleury, 2000). Plants that are male-sterile have been reported from Israel (Horovitz and Galil, 1972). Although the taxon is primarily an outcrossing species, because it can set selfed seed and has been observed to self in South Wales (Lee et al., 2004), we answered yes, but with high uncertainty.
ES-12 (Requires specialist pollinators)	n - negl	0	In a study examining the floral composition of honey on the Canary Islands, many of the samples contained pollen grains from *H. incana*, and one of them was dominated by it, indicating that European honeybees (*Apis mellifera*) are visiting and collecting pollen from these plants (Pardillo López and La Serna Ramos, 2007). In an Israeli study, the authors reported seeing honeybees and solitary bees foraging on the flowers for nectar and pollen (Horovitz and Galil, 1972). Another study reported finding pollen from *H. incana* on a honeybee (Davis, 1991). In Argentina, European honeybees accounted for 75 percent of all insect visits to flowers of *H. incana* (Morales and Aizen, 2002). While these studies do not directly prove that honeybees pollinate *H. incana*, the evidence suggests that they do. Furthermore, because *H. incana* has been able to establish in several continents beyond its native range, we answered no with negligible uncertainty.
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	This species appears to have a flexible life history based on how it has been described: annual or over-wintering annual (Hanf, 1983; Matthei, 1995), biennial or perennial herb (Parsons and Cuthbertson, 2001), annual to biennial (Bojňanský and Fargašová, 2007), and facultative biennial (Marushia et al., 2012). Regardless of this variation, its minimum generation time appears to be one year. Alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - low	1	*Hirschfeldia incana* produces fruit pods that have two cells, each with 3 to 9 seeds each (CABI, 2017; Matthei, 1995; Parsons and Cuthbertson, 2001), though one source reported one seed per cell (Auld and Medd, 1987). In nursery pots exposed to ambient conditions, *H. incana* produced on average 2000 siliques (fruit) and about 6000 seeds per plant (Marushia et al., 2012). These numbers seem reasonable given various online pictures of flowering and fruiting plants (Anonymous, 2007; Bugwood, 2017; Parsons and Cuthbertson, 2001). Seeds germinate readily in autumn (Parsons and Cuthbertson, 2001). One study that examined seed germination found variation in germination rates among different cohorts of seeds, ranging between 43 percent to greater than 80 percent (Castro et al., 2016). Another study found that 45 to 60 percent of seed germinated (Darmency and Fleury, 2000), but did not account for dormant seeds. Another study found seed viability to be near 100 percent (Marushia et al., 2012). In one California coastal scrub community, *H. incana* occurred at an average density of about 11 plants per square meter (Paolini et al., 2014), but it is unknown if these represent reproductive adults or younger plants. Conservatively assuming that plants produce 5000 seeds per plant, that there are 2 plants per square meter, and that only half of these seeds are viable, then

Question ID	Answer - Uncertainty	Score	Notes (and references)
			populations would be producing 5000 viable seeds per square meter, which meets our threshold for a prolific plant. This estimate is consistent with anecdotal comments that *H. incana* has high seed production (Siemens, 2011; South East Natural Resources Management Board, 2009). Consequently, we answered yes with low uncertainty.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Seed is spread in mud adhering to machinery and clothing (Ansong and Pickering, 2014; Parsons and Cuthbertson, 2001), and by road grading (Parsons and Cuthbertson, 2001).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	*Hirschfeldia incana* has been intercepted three times in cereals by the Canadian Food Inspection Agency (Wilson et al., 2016). In heavy infestations in South Australia, it readily spreads as a grain contaminant of cereals (Parsons and Cuthbertson, 2001). It also disperses in mud on animal stock (Parsons and Cuthbertson, 2001). It is classified as a weed seed contaminant by the Association of Official Seed Analysts (AOSA, 2014). This species is a contaminant of wool (Stace, 2010), birdseed (Hanson and Mason, 1985), grain (GTA, No Date), and ore (Verloove, 2006).
ES-17 (Number of natural dispersal vectors)	3	2	Seed properties for questions ES-17a through ES-17e: Plants produce typical mustard-like fruit pods (i.e., siliques) that are about 1 to 1.5 cm long (Hanf, 1983; Parsons and Cuthbertson, 2001). The seeds are globular to ovate-oblong, about 0.7-1.6 by 0.7-0.9 mm in size (Bojňanský and Fargašová, 2007; Hanf, 1983).
ES-17a (Wind dispersal)	y - low		It has the "potential to turn, in the mature state, to a tumble-weed with high individual seed production" (Chronopoulos et al., 2005). Dead plants disperse seed as they are scattered by wind (CABI, 2017).
ES-17b (Water dispersal)	n - high		Seed have been reported to disperse on water moving across the soil surface (Parsons and Cuthbertson, 2001). However, because this species is primarily adapted to dry regions and is not restricted to flood plains or other areas near aquatic habitats, we answered no with high uncertainty (CABI, 2017; Gresta et al., 2010).
ES-17c (Bird dispersal)	n - mod		We found no evidence.
ES-17d (Animal external dispersal)	y - low		It is a frequent wool alien in the United Kingdom (Stace, 2010). It disperses in mud on animal livestock (Parsons and Cuthbertson, 2001).
ES-17e (Animal internal dispersal)	y - low		Based on horse fecal samples collected from wildlands in California, researchers have shown that seeds of *H. incana* are able to germinate after digestion (Quinn et al., 2008).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Seeds exhibit some primary dormancy imposed by the maturing seed coat, but after a month they can germinate (Parsons and Cuthbertson, 2001). In a study examining the germination behavior of seeds stored 30, 150, and 270 days after harvest, seeds stored for just 30 days had the highest cumulative germination rates (Gresta et al., 2010). A seed burial experiment where seeds were periodically exhumed showed that after 41 months, about 50 percent of the seeds remained viable (Chadoeuf et al., 1998). Furthermore, in another experiment by the same authors where seeds were buried (without bags) in fields cultivated with crops, 6 to 21

Question ID	Answer - Uncertainty	Score	Notes (and references)
			percent of the seeds remained viable after three years (Chadoeuf et al., 1998).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	? - max	0	Plants can resprout from the base when damaged (DiTomaso and Kyser, 2013). However, because it is not clear whether plants benefit from this or whether resprouts are particularly more aggressive, we answered unknown.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	y - low	1	This species evolved resistance to acetolactate-synthase (ALS) inhibitor herbicides in 2013 in Argentina, where it infests wheat and winter barley crops (Heap, 2017). Based on this evidence alone, we answered yes with low uncertainty. There has been some concern among scientists that *H. incana* may be able to acquire genetically engineered traits, including herbicide resistance, through hybridization and introgression with crop relatives that have been engineered (e.g., Chèvre et al., 2003). *Hirschfeldia incana* is a close relative of several mustard crops and has been used in breeding programs of *Brassica napus* (Siemens, 2011). In one experiment where herbicide-resistant *B. napus* and *H. incana* were grown in alternating rows, the researchers found that fertile hybrids were produced (Darmency and Fleury, 2000). However, when these were allowed to backcross naturally with *H. incana*, those progeny expressed lower fitness, and none survived past the fifth generation (Darmency and Fleury, 2000). Another study that evaluated the likelihood of gene introgression from *B. napus* to *H. incana* did not find any evidence of gene flow under field conditions (Devos et al., 2009). Thus, introgression of herbicide resistance genes from *B. napus* seems unlikely (Liu et al., 2013).
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	9	2	
ES-23 (Number of precipitation bands suitable for its survival)	6	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max		We found no evidence that this species is allelopathic. However, because *Brassica* species (close relatives of *H. incana*) produce allelopathic compounds that have detrimental effects on crop yield, and seed germination of crops and other weeds (Earlywine et al., 2010; Gulden et al., 2008), we answered unknown.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, it is not a member of a plant family that is known to contain parasitic plant species (Heide-Jorgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	? - max		In California, it contributes significantly to the fine-fuel load of the community (NPS, 2017; Paolini et al., 2014); however, it is unknown whether it affects fire regime.
Imp-N2 (Changes habitat structure)	? - max		*Hirschfeldia incana* is classified as invasive in Australia, which includes species that form monocultures (Randall,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2007), but it is not clear if this particular species forms monocultures. In a California coastal scrub community, it has an average density of 11 individuals per square meter (Paolini et al., 2014). Plants that form monocultures are likely to change habitat structure. However, without more specific evidence for this species, we answered unknown.
Imp-N3 (Changes species diversity)	y - low	0.2	In California, this species spreads in natural areas, displacing native species (DiTomaso and Kyser, 2013). It is outcompeting native species in Pinnacles National Park in California (NPS, 2017). In a California coastal scrub site, it had the third highest cover of all species (Paolini et al., 2014). At another scrub site, researchers found an average density of 9.5 seedlings emerging per square meter (Cox and Allen, 2008). These last two pieces of evidence also indicate it is changing species diversity.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0.1	Species that exclude natives (DiTomaso and Kyser, 2013) or form dense populations (Paolini et al., 2014; Parsons and Cuthbertson, 2001; South East Natural Resources Management Board, 2009) have the potential to affect threatened and endangered species. Consequently we answered yes, but with high uncertainty due to a lack of more specific information.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - mod	0	While this species does invade regions that have been classified as globally outstanding ecoregions (Ricketts et al., 1999), we found no evidence that it has widespread impacts on entire ecosystems.
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	This species is a weed of Australian rangelands, but is not reported to represent a biodiversity threat (Martin et al., 2006). It is a weed of natural areas in Australia (Randall, 2007), and it is invasive in U.S. natural areas (Swearingen, 2011). *Hirschfeldia incana* is one of the species invading Pinnacles National Park in California (NPS, 2017). Invasive plant control efforts in the park are focusing on this and two other species because of their potential for destroying native habitat. In December 1998, the park received an anonymous donation for the removal of invasive mustards (NPS, 2017). 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 - low	0	We found no evidence of this impact. Because it seems unlikely that this herbaceous plant would have this type of impact, we answered no with low uncertainty.
Imp-A2 (Changes or limits recreational use of an area)	? - max		This species is reported to be encroaching on trails in Pinnacles National Park in California (NPS, 2017). We found no direct evidence, but based on some online images (Anonymous, 2007; Bugwood, 2017; Parsons and Cuthbertson, 2001), dense patches may limit how an area is used. Consequently, we answered this question as unknown.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed;	c - negl	0.4	*Hirschfeldia incana* is a weed of ruderal sites in Europe (Bojňanský and Fargašová, 2007; Hanf, 1983; Reynolds, 2002), Chile (Matthei, 1995), Australia (Cousens et al., 1993),

Question ID	Answer - Uncertainty	Score	Notes (and references)
(b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]			and the United States (DiTomaso and Healy, 2007). It is common in wastelands in its native range (Gresta et al., 2010; Horovitz and Galil, 1972). It is a weed of roadsides, railways, and fence lines in Australia (Auld and Medd, 1987; Cousens et al., 1993; Parsons and Cuthbertson, 2001). One of the 50 most common plants in urbanized London, *H. incana* is frequently found throughout the city and is often a dominant component of the vegetation (Crawley, 2011). This species is being controlled in Santiago, Chile, and despite efforts to control/eradicate it, its populations continue to persist (Castro et al., 2016). One study showed that soil solarization can be an effective control strategy for weeds, including *Hirschfeldia incana*, growing in an artificial California native wildflower meadow (Stapleton and Jett, No Date). This species is specifically included in a weed-free certification program in gravel in California (Anonymous, No Date). "Few herbicides provide effective control of shortpod mustard. Many herbicides used on annual and biennial mustards are less effective on this perennial" (DiTomaso and Kyser, 2013). 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 – high	0.4	In some circumstances in Australia, *H. incana* "can become a serious competitor for space in winter-growing cereal crops, reducing yield…" (Parsons and Cuthbertson, 2001). In South Australia, cereal crops are often heavily infested (Parsons and Cuthbertson, 2001). *Hirschfeldia incana* was classified by Holm et al. (1991) as a principal weed in Australia, which indicates it is having some kind of significant impact. A South Australia plant policy document reports it competes with broad-acre crops and pastures in some situations, and it "increases" in broadleaf crops and vegetable seed (South East Natural Resources Management Board, 2009).
Imp-P2 (Lowers commodity value)	y - low	0.2	In Australia, it invades run-down pastures, where, because it is edible in the early stages, it taints meat and dairy products (Parsons and Cuthbertson, 2001). "Becoming tall and coarse as it matures, Buchan weed loses its palatability and, in dense patches, limits access to other pasture plants" (Parsons and Cuthbertson, 2001). It interferes with harvest of cereals and contaminates grain (Parsons and Cuthbertson, 2001). In some regions of Iran, it was found as a wild weed host of turnip mosaic virus (Farzadfar et al., 2009).
Imp-P3 (Is it likely to impact trade?)	y - low	0.2	*Hirschfeldia incana* is regulated in Brazil, Colombia, and Peru (APHIS, 2017). It is also classified as a Declared Weed in Australia (Randall, 2007). In 2001, it was listed as a noxious weed for South Australia (Parsons and Cuthbertson, 2001); however, it is not currently regulated by that state (Government of South Australia, 2017). We did not find any evidence that it is regulated as a noxious weed in the United States (e.g., Kartesz, 2017; NPB, 2016; NRCS, 2017; USDA-AMS, 2016) except in Orange County, CA, where it is a declared noxious weed (OC Public Works, 2017). It is included in a weed-free certification program in gravel in

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			California (Anonymous, No Date). Because this species has been documented as a contaminant or hitchhiker in trade (see evidence under ES-16), it may potentially impact exports.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	? - max		Matthei (1995), citing another source, reports that *H. incana* seed is toxic to birds, affecting their development and increasing mortality. However, at least while it is in its vegetative state, *H. incana* is moderately palatable to goats (Simmonds et al., 2000) and other livestock (Parsons and Cuthbertson, 2001). Without additional evidence, we answered this question as unknown.
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 - low	0.6	*Hirschfeldia incana* is an agricultural weed in Europe (Bojňanský and Fargašová, 2007; Gresta et al., 2010; Hanf, 1983), where it is native. It is a weed of abandoned pastures in the Canary Islands (Stace, 2010) and cereals in Morocco (Taleb et al., 1998). In Australia, it is a weed of arable land and extends into pastures, vineyards, and orchards (Cousens et al., 1993; Parsons and Cuthbertson, 2001). It is a "[s]erious weed of rainfed cereals and vegetables and occasional in most other crops" (Robson et al., 1991). In the United States, it is a weed of vineyards, orchards, and agronomic crops (DiTomaso and Kyser, 2013). A few decades ago, the USDA classified it as an economically important foreign weed (Reed, 1977). The species can be controlled with deep ploughing, but further work is needed to destroy seedlings (Parsons and Cuthbertson, 2001). Plants can also be treated with herbicides (Parsons and Cuthbertson, 2001). Based on this evidence, we answered "c" with moderate uncertainty. 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, 2017).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that this species occurs in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that this species occurs in this hardiness zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence that this species occurs in this hardiness zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence that this species occurs in this hardiness zone.
Geo-Z5 (Zone 5)	n - high	N/A	One point in Norway. Because this one point may not represent an established population, we answered no.
Geo-Z6 (Zone 6)	y - low	N/A	Many points in Germany. A few in Argentina. One point in the United States (Nevada).
Geo-Z7 (Zone 7)	y - negl	N/A	France, Germany, Greece, and Spain.
Geo-Z8 (Zone 8)	y - negl	N/A	Australia, France, Spain, and the United Kingdom.
Geo-Z9 (Zone 9)	y - negl	N/A	Australia, France, Portugal, and Spain.
Geo-Z10 (Zone 10)	y - negl	N/A	Australia, Portugal, Spain, and the United States (California).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z11 (Zone 11)	y - negl	N/A	Australia, Portugal, Spain, and the United States (California).
Geo-Z12 (Zone 12)	y - negl	N/A	Many points in extreme southwestern United States (California) and Israel. A few points in Mexico.
Geo-Z13 (Zone 13)	n - high	N/A	We found no evidence that this species occurs in this hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that this species occurs in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	We found no evidence that this species occurs in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Spain. A few points in Greece.
Geo-C4 (Desert)	y - low	N/A	Some points in Australia and Greece. A few points in Argentina, Spain, and the United States (California). One point in Chile and Saudi Arabia each. Not particularly abundant in U.S. southwestern deserts (Marushia et al., 2012).
Geo-C5 (Mediterranean)	y - negl	N/A	Australia, France, Greece, Israel, Portugal, Spain, and the United States (California).
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia. A few points in Argentina.
Geo-C7 (Marine west coast)	y - negl	N/A	Australia, Belgium, France, Germany, and the United Kingdom.
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	One point in Kyrgyzstan. We answered yes with high uncertainty because this species grows in warmer and cooler areas.
Geo-C9 (Humid cont. cool sum.)	y - low	N/A	Many points in Germany. Some points in Greece and Spain.
Geo-C10 (Subarctic)	y - mod	N/A	Some points in France and Greece. A few points in Germany. A couple of points in Chile.
Geo-C11 (Tundra)	y - high	N/A	A few points in France.
Geo-C12 (Icecap)	n - mod	N/A	We found no evidence that this species occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - low	N/A	Some points in Israel and Spain. One point each in Chile, Argentina, and Saudi Arabia. A few points in the United States.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Israel and Spain. Some points in France.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	France, Portugal, and Spain. Seeds were collected from a region of Italy receiving a mean of 730 mm of annual precipitation (Gresta et al., 2010).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	France, Portugal, and Spain.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	France, Germany, and Spain. Some points in Portugal.
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	Some points in Spain. A few points in Germany and Greece. One point each in Argentina and Brazil.
Geo-R7 (60-70 inches; 152-178 cm)	n - high	N/A	One point in the United States. We answered no because this record may not represent an established (naturalized) population.
Geo-R8 (70-80 inches; 178-203 cm)	n - high	N/A	Two points in Germany, and one in Australia. We answered no because these records may not represent established (naturalized) populations.
Geo-R9 (80-90 inches; 203-229 cm)	n - high	N/A	One point in Mexico. We answered no because this record may not represent an established (naturalized) population.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R10 (90-100 inches; 229-254 cm)	n - high	N/A	One point in Mexico. We answered no because this record may not represent an established (naturalized) population.
Geo-R11 (100+ inches; 254+ cm)	n - high	N/A	One point in Mexico. We answered no because this record may not represent an established (naturalized) population.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - negl	0	This species is already naturalized in the United States (Calflora, 2017; EDDMapS, 2016; Kartesz, 2017; NRCS, 2017); however, to evaluate the likelihood of further introductions, we set this answer to no and evaluated the other questions in this risk element.
Ent-2 (Plant proposed for entry, or entry is imminent)	n - mod	0	We found no evidence that its entry is imminent.
Ent-3 (Human value & cultivation/trade status)	c - mod	0.25	We found some evidence that *Hirschfeldia incana* is a somewhat desirable species, suggesting it may be intentionally imported at some point. For example, this species is able to tolerate and accumulate heavy metals in its tissues without showing any adverse impacts, suggesting it may be a good species for phytoremediation (Auguy et al., 2013; Auguy et al., 2016; Midhat et al., 2017). It is occasionally collected from the wild in Europe as an herb (Salvatore et al., 2005; Siemens, 2011). It has also been used in breeding program studies of the genus *Brassica* (Siemens, 2011). Because it tends to be a weedy species, there are no large collections to conserve its germplasm; however, "all germplasm banks have some specimens, and several specimens are also stored in the botanic gardens, especially in the Mediterranean region" (Siemens, 2011). Without specific evidence that this species is commercially cultivated and traded, we answered “c” with moderate uncertainty.
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	y - negl		Naturalized in Mexico (Villaseñor and Espinosa-García, 2004).
Ent-4b (Contaminant of plant propagative material (except seeds))	n - mod	0	We found no evidence.
Ent-4c (Contaminant of seeds for planting)	y - low	0.08	U.S. inspectors have intercepted *H. incana* on *Lolium perenne* seed for planting from New Zealand (AQAS, 2017). The Canadian Food Inspection Agency has intercepted it in birds-foot trefoil seed for planting (Wilson, 2017). Because there is ample evidence that *H. incana* contaminates grain imports (see evidence under Ent-4h), it is likely a contaminant of other seeds-for-planting pathways.
Ent-4d (Contaminant of ballast water)	n - low	0	We found no evidence. Because this pathway seems unlikely, we used low uncertainty.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - low	0	We found no evidence. Because this pathway seems unlikely for a species adapted to dry climates and habitats, we used low uncertainty.
Ent-4f (Contaminant of landscape products)	y - low	0.04	*Hirschfeldia incana* is spread by road grading (Parsons and Cuthbertson, 2001), and is one of the weeds included in a weed-free gravel certification program in California

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Anonymous, No Date). Because gravel is a landscape product, we answered yes with low uncertainty.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	y - mod	0.04	Seed is spread on machinery (Parsons and Cuthbertson, 2001).
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	y - negl	0.02	*Hirschfeldia incana* has been intercepted three times in cereals by the Canadian Food Inspection Agency (Wilson et al., 2016). In heavy infestations in South Australia, it readily spreads as a grain contaminant of cereals (GTA, No Date; Parsons and Cuthbertson, 2001).
Ent-4i (Contaminant of some other pathway)	e - low	0.08	Seeds are dispersed on clothing (Ansong and Pickering, 2014), and in wool (Stace, 2010), birdseed (Hanson and Mason, 1985), and ore (Verloove, 2006). It also disperses in mud on animal stock (Parsons and Cuthbertson, 2001). Due to evidence for several pathways, we answered with the maximum score possible, "e".
Ent-5 (Likely to enter through natural dispersal)	y - mod	0.06	*Hirschfeldia incana* is naturalized in Mexico (Villaseñor and Espinosa-García, 2004). Because it disperses in mud on animal livestock (Parsons and Cuthbertson, 2001), gets caught in animal hair (e.g., wool; Stace, 2010), and passes through animals in a viable form (Quinn et al., 2008), it may enter the United States through natural dispersal on or in wild animals from Mexico.