Skeleton Weed – Review of the management and impact of skeleton weed in Eastern Australia

A Report prepared for the Grains Seeds and Hay IFS

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Introduction

In May 2019 the Grains Seeds and Hay Industry Funding Scheme Management Committee of Western Australia engaged Dr David Bowran to document the skeleton weed management practices and impact of skeleton weed on grain/seed/ hay production in Eastern Australia.

The Terms of Reference from the project brief are set out below.

The scope of the review has a focus on:

- Eastern Australia:

o As South Australia is the most recent State to disband its state-wide approach to managing skeleton weed, the South Australian situation should be highlighted.
o Documenting or analysis of the WA situation is not required, unless necessary to highlight differences between the situation in the Eastern States and WA or other key points.

- Skeleton weed
- Grain/seed/hay production

The objectives of the review are as follows

1. To document the extent of skeleton weed in Eastern Australia.
2. To document the impact of skeleton weed on grain/seed/hay production in Eastern Australia.
3. To document how skeleton weed is managed in Eastern Australia for grain/seed/hay production.
4. To identify the extent to which the current management practices used in Eastern Australia reduce the impact of skeleton weed on grain/seed/hay production.

An initial scan of the relevant literature from the internet for the last 10 years showed very little documented information about skeleton weed in Eastern Australia. Even going back 20 years there is very little information available. This led the author to conclude that more direct approaches to farmers or farming groups, consultants, government agencies, agronomists and farmer groups might be a more fruitful way of understanding the situation.

Methodology

The information used to develop the conclusions within this report was gathered through a number of ways:

- An internet review of current surveys, biosecurity strategies and status reports if available for each of the Eastern States, and the western parts of the USA (where skeleton weed is widespread), and
- Consultation with a range of stakeholders with involvement in control or management of skeleton weed interstate.

In undertaking this work it quickly became clear in the first few interviews that skeleton weed is perceived quite differently in the Eastern States compared to WA. Consequently a set of 3 questions were drafted which were sent to a wide range of interviewees either in email form or as verbal questions. These questions are presented below and form the basis for the majority of direct responses. Replies where presented are marked up in red.

Questions on skeleton weed in cropping situations

1. Is skeleton weed a common or widespread weed in cropping systems where you farm? If so, is it becoming less common or more common in non-drought years?
2. Do the current range of control options provide robust management in winter crops such as wheat, canola, chickpeas, peas, or hay such that there are no issues from yield losses or harvest management?
3. Do areas outside the farm provide seed sources for on farm establishment, and if so is better management required for these of farm seed sources?

A full list of those interviewed either verbally or via email is attached in Appendix 1. Just over three quarters of the email respondents replied while a number of agronomist, consultants and government agencies/Universities were interviewed by phone or email.

Results

The body of this report is in presented in 6 sections below.

1. <u>Surveys of Skeleton Weed</u>
   Broad based surveys specifically for skeleton weed in the eastern states have not occurred in the last 20 years, and skeleton weed occurrence can only be determined by its coincidental recording in surveys of weeds in general. A small number of surveys of weeds in crops are available, both as on-site surveys or through farmer assessments, while a few observations are reported in state flora listings or on the Australian Virtual Herbarium. Table 1 below summarises the more recent results.

Table 1. Surveys of Weeds in the eastern states in which skeleton weed was recorded in the last 25 years

Author	State and year	Farmer/ Survey ranking	Density	Occurrence (% paddocks)
Lemerle et al. (1996)	NSW, 1993	10		37
Broster et al (2013)	NSW, 2010		< 1/m2	<10
Broster (pers comm)	NSW high rainfall, 2014	12	< 1/m2	2.7
	western NSW, 2015	16	< 1/m2	4.3
	northern NSW, 2016	25	< 1/m2	1.6
	NSW plains, 2016	8	< 1/m2	13.8
	southern NSW, 2017	12	< 1/m2	4.3
	NSW slopes, 2018	5	< 1/m2	23.2
Fleet et al (2017)	SA, 2015/16 summer	20		29 - Mallee 6 - other regions
Llewellyn et al (2016)	GRDC Northern cropping, 2014	<20		
	GRDC, southern cropping, 2014	12 (cereals) 12 (fallow)		

The surveys of Lemerle et al (1996), Broster et al (2013) and Broster (pers. comm.) generally involved cropping paddocks over much of the southern NSW cropping area, whereas more recent surveys involved pasture paddocks as well. Given the timing of the surveys in late spring it was assumed by the authors that herbicides would have had a significant effect on reducing weed numbers in crop.

The survey of cropping paddocks in South Australia by Fleet et al (2017) with skeleton weed in paddocks in the Mallee region lines up well with the report by Walsh (1990) that skeleton weed was becoming more common in that region and is predominantly a weed of less fertile sand dunes.

Weed control trials also offer another assessment point for the weed. In 2001 an experiment by Tony Cook (Biosecurity NSW) at Mt Russell in NSW recorded 50-200 plants per m2 in a fallow and crop situation.

Other surveys outside the cropping zone are limited largely by number of observations or funding. For example in Victoria some shires are funded by the state government to undertake roadside vegetation surveys. The Loddon shire undertook a survey of 4,600 km in 2018, but skeleton weed was not detected despite this being an area where the weed is recorded in the Vicflora database (S Dobie, Loddon Shire, pers. comm.)

One of the biggest surveys of 'Weeds of significance to the grazing industries' conducted by Grice (2002) had no mention of skeleton weed as being a problem for grazing in any state or territory of Australia despite the weed being recognised as having the potential to compete with pasture plants. As skeleton weed does not generally pose livestock grazing problems in relation to production, carcass and product damage and poisoning it is perhaps not surprising it did not make the list of major weeds in NSW. Aslin et al (2013) reviewed an extensive list of publications related to weed social surveys dating back to the early 1990's and a reading of the 120 summaries of the publications found no reference to skeleton weed.

Interrogation of the Australian Virtual Herbarium showed a significant number of locations for skeleton weed across eastern Australia, but with most historical records dated before 1970 it was of little use in understanding the current occurrences in Eastern Australia (a peak of collections in 1985/86 was heavily focussed on WA).

The introduction of biological control agents for skeleton weed had a significant impact on the level of infestation across eastern Australia with the most aggressive form - the narrow leaf - being well controlled. The consequences are seen in Fig 1. (J. Cullen, CSIRO). This high level of biological control is in attributed as the reason for lower population counts of the weed in the eastern states since the 1970's.

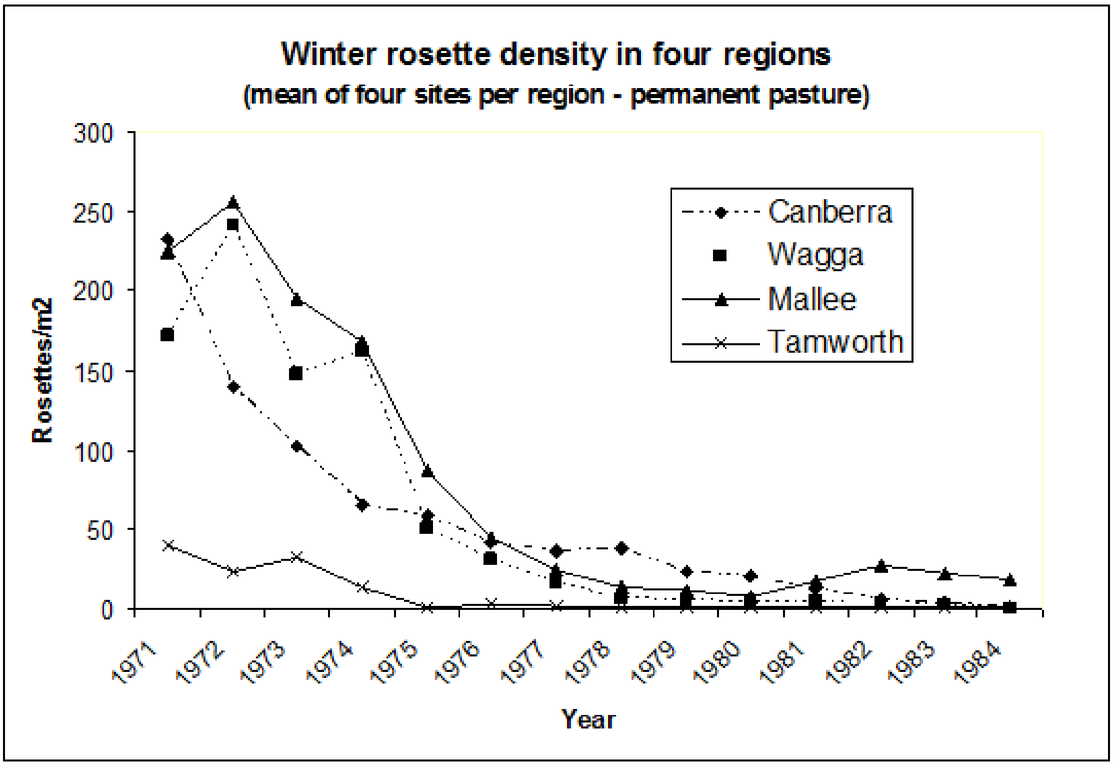

Figure 1. Density of rosettes of *Chondrilla juncea* in winter in permanent pasture in the four main regions of the distribution. (Mean of four sites per region). [Source: J Cullen, CSIRO].

2. Pest Status of Skeleton Weed by State

   a) South Australia – In 2015 the South Australian Government Declared Plant policy for skeleton weed was updated with some significant changes. Most notably the management plan for skeleton weed has an outcome of ensuring that the 'negative impacts of skeleton weed on production are minimised in rotational broadacre cropping and irrigated pasture.' The full policy is attached (Appendix 2), but the most notable aspect is the following statement:
      "Risk assessment indicates site protection as the appropriate action at State level in rotational cropping and irrigated pastures, and monitoring in rangelands. While sale and movement are prohibited uniformly across the State, regional actions vary according to the land uses in each region. Co-ordinated control programs are not conducted in areas where skeleton weed is widespread and there are few benefits from enforced control. However, all regional NRM Boards retain the power to enforce control actions if necessary."

   b) Victoria – Skeleton weed is a declared noxious in Victoria and a regionally prohibited weed in some parts around Melbourne and in the south west. As a restricted weed in much of the agricultural area trade in these weeds and their propagules, either as plants, seeds or contaminants in other materials is prohibited (DPI Vic website). White, et al (2018) provided an updated advisory of environmental weeds in Victoria and skeleton weed is now considered a medium threat, with minor potential for further spread despite having a wide range of habitats and the capacity for further spread into environmental habitats.

   c) New South Wales – Skeleton weed is no longer a declared weed in New South Wales, and under the Listing of Prohibited Weeds skeleton weed does not appear in any of the 5 categories for action (NSW DPI website).

   d) Queensland – skeleton weed has no declaration status in Queensland, but the weed is present at low levels in the south.

   e) Tasmania – Skeleton weed is a declared weed in Tasmania and has a Statutory Weed Management Plan (DPIWE). This plan prohibits entry of skeleton weed into Tasmania except for some grain products, and makes for two zones of eradication and containment by municipality. As Tasmania is currently considered free of skeleton weed the eradication zone is current for all municipalities.

3. Farmer/farming group perception of skeleton weed

   Contact was made with a number of farmers and farming groups across NSW, Victoria and SA. In each case the questions were sent via email, while NSW Farmers were also interviewed by phone in the Northern Zone. Nearly all farmers who responded (50%) indicated that the weed was either not present or of little importance. As an example the response of Andrew Hunter from Yerong Creek just south of Wagga Wagga in NSW and in a known skeleton weed area is presented below.

1. Is skeleton weed a common or widespread weed in cropping systems where you farm? If so, is it becoming less common or more common in non-drought years? It is not of much significance, at least in our short rotation system. If anything, seeing less of it. We only really see it in our lightest (gravel) soils.

2. Do the current range of control options provide robust management in winter crops such as wheat, canola, chickpeas, field peas, hay such that there are no issues from yield losses or harvest management? Tend to control it in the pasture or cereal phase, and don't grow much of the non-cereals other than canola, so doesn't become an issue.

3. Do areas outside the farm provide seed sources for on farm establishment, and if so is better management required for these of farm seed sources? A lot of seed is off-farm from seed companies, and grower to grower. We still only see the weed in paddocks which have a history, so wouldn't view it as a problem.

The response from the Mallee Sustainable Farming Group (Tanja Morgan) is presented below to highlight that even in an area where skeleton weed might be considered a problem it is not considered to cause too many issues except in pulse/grain legumes.

"I have received responses from our MSF farmer directors so have a summary of what is going on across NSW, Vic and SA.

1. Skeleton weed has become less of an issue for most people practicing no-till and for those with good weed management practices. Still is a problem for conventional farmers still cultivating that don't use knockdown summer weed control but they are the minority. Has become an issue again for some in legume rotations. In SA Mallee we have moved away from growing lupins as can't control skeleton weed but lupin paddocks have soils that skeleton weed seems to grow well in and in the absence of crop competition (infertile sands). In Vic/ NSW rotations with a lot of legumes can have re-occuring problems.

2. Many farmers use double knock over summer for controlling skeleton weed and other summer weeds. We are having problems in NSW where cotton and horticulture is moving in next door to large broad acre farms. The threat of spray drift is too great in these situations and summer spraying is becoming risky so skeleton weed creeping back into the system. Farmers that are consistent with controlling the weed are keeping it under control and its not an issue in crop. Those that have sporadic management tend to see it emerging late in crops.

3. All farmers said that other weeds coming in from neighbouring paddocks were a bigger issue than skeleton weed.

A similar response was received from Sarah Noack at the Hart Field site

4. Agronomist/consultant/industry perception of skeleton weed
   A number of agronomists provided responses to the questions either written or via phone. The responses confirmed those from the farmer/farming group sector and are a good summary of situations for experiences with many farmers.
   Bruce Armstrong is an agronomist with Elders at Wagga Wagga and he indicated that it would not be in the top 10 weeds of 80% of farmers, and where it did occur was on lighter soils and where disturbance was occurring.
   Two agronomists from Swan Hill in Victoria gave very similar responses to the questions on presence and possible establishment. The response below for example is from Peter Baird
   "Skeleton weed is still encountered with moderate regularity, but does vary greatly in prevalence from farm to farm where different levels of emphasis have been placed on controlling it over time. You can go onto some properties and not find a single plant, and on some other farms you can find it in the majority of paddocks."

5. Government agency/scientist views of skeleton weed
   Government points of view came from two areas – those who have a direct relationship to statutory weed management in state agencies, and weed scientists working for the agencies.
   In all cases similar responses to those highlighted above were obtained and the weed was not considered to be a major problem and rarely seen in crops.
   With the change in the SA situation more questions were asked of the SA NRM Managers who might be involved with the weed. The responses from Seb Drewer to the original three questions and some follow up questions are given below.

1. Is skeleton weed a common or widespread weed in cropping systems where you farm/consult/advise? If so, is it becoming less common or more common in non-drought years?

Currently Skeleton weed is an issue in the Lock district (Eyre Peninsula) and previously around Poochera and further west (however would need Andrew Sleeps's input to determine range and he's currently on leave). The weed seems to be more common in the Lock area in non-drought years.

Skeleton weed is still out there (on the radar) as a weed issue, especially around Lock, also at Yeelanna and Port Neill. Yes, early resistance of skeleton weed is out there, probably from repeated use of the same chemicals - as there's not many options

2. Do the current range of control options provide robust management in winter crops such as wheat, canola, chickpeas, such that there are no issues from yield losses or harvest management?

Not aware of any grain trucks being rejected from silos. The enterprise mix has changed so those with less sheep or 100% croppers have good control with Lontrel or Round-up and Amine - good residual. Thus, those cropping Canola use Lontrel for cape weed for the residual and it also kills the skeleton weed too. However, those at Lock that still have sheep would use high sheep numbers to keep in under control.

3. Do areas outside the farm provide seed sources for on farm establishment, and if so is better management required for these of farm seed sources?

Yes can be seen in roadside areas around Lock

Not aware of any off-farm areas that are a seed source. It's really an issue in broad acre cropping where all the normal weeds have been kills, so there's no competition for the skeleton weed.

Given SA went through a change to the declaration status and control for skeleton weed in 2015 I would like to know how you perceive the changes in farmer attitudes and practices, if any, that have occurred with the weed in SA since then?
I believe the change in declaration status has had no impact on farmer attitudes and practices. Skeleton weed (SW) is not considered a priority for our Board region currently and therefore we (EPNRM) do not run any targeted work or surveillance on the species. We will certainly respond to landholders if they have concern or would like management advice but SW is not the focus of any current education, awareness or control programs. This is a result of SW no longer being the threat it was perceived to be back in the 90's, and not a result of a change in declaration.

Up until the very early 2000's there was much more farmer chatter / concern about SW. I rarely hear a farmer raise SW issues / concern these days, nor do I see much of it around the place. Prior to this time (circa 2000) the Board had a dedicated SW control program complete with a dedicated spray vehicle and a very active compliance effort (I think we still have records of the huge effort that went into this somewhere that I may be able to dig up if of interest?) . Community awareness was much greater as a result of this, as was concern over the potential threat that SW posed to farmers on the EP. With the rise of chemicals there seems to be an attitude that it will be controlled as part of the general farm management / cropping program and there is no need for a dedicated approach.

Are there any other risks not forseen when the status was changed that have emerged since that time?
Increasing sheep numbers given the high wool and meat prices. With more people not continually cropping now possibility for skeleton weed to increase, although if stocking rates adequate may assist in keeping SW under control. SW resistance in some areas possibly

6. <u>Impact of Skeleton Weed and Control measures currently used in grain production in Australia and overseas</u>.
   Based on the assessments provided above skeleton weed could currently be considered to have a relatively low cost to the grains industry in eastern Australia. Llewellyn et al (2016) in their review of weeds in Australian cropping systems assessed skeleton weed as only being of significance and in the top 20 weeds in the GRDC Southern zone. Most of the cost of skeleton weed was attributed by farmers to cereal production. The authors collected data from 602 grain growers beginning in March 2014 with a range of farm-specific weed and weed management variables,

including extent of weeds and density assessments for residual in-crop weeds. Table 2 below shows estimated skeleton weed impacts compared to all weeds and fallow. The ‘all weeds’ total may have double and triple accounted so the wild radish assessments are included for comparison as being a significant and competitive weed.

Table 2. Estimates of skeleton weed impacts in cropping in the Southern GRDC Zone in 2014

Weed	Area (ha)	Yield loss (tonnes)	Cost ($ million)
Skeleton weed	86,000	3,300	0.87
All weeds	8,500,000	450,000	113
Wild radish	823,000	37,000	10.4
Fallow	140,000		1.9

No recent trials in either Australia or the US were found which looked at yield responses in any crop to density of skeleton weed. There are a small number of recent trials in Australia in which assessments have been made of efficacy of herbicides in fallow situations but they don’t appear to have been cropped in the next season (eg Ag Grow, NSW 2016, T. Cook, DPI NSW, 2001).

Most respondents indicated that grain legumes were the crop type most likely to experience difficulty with skeleton weed due to a lack of herbicides for control, and where crops such as lupins were grown on lighter soil skeleton weed could build up. In addition a number of herbicides used for skeleton weed control in cereals and canola can have crop effects on grain legumes and pastures with plant back times of up to 36 months for some herbicides, thereby limiting rotational options.

Both Bruce Armstrong (Elders agronomist) and a senior oaten hay buyer from Balco in SA highlighted the need to have paddocks with very low levels of skeleton weed prior to cropping due to the problem of clopyralid residues in hay. While no label statements on the use of hay treated with clopyralid are present in Australia, US labels explicitly state that hay treated with clopyralid or manure from animals consuming clopyralid treated crops should not be used for composting or mulching if susceptible plants are to be grown. Even animal manure from hay treated with clopyralid can have sufficient residues to affect sensitive plants when the manure is used for fertiliser. Balco requires farmers to provide assurances that clopyralid has not been used in a hay crop.

PIRSA in the 2018 Weed Control Handbook identify 7 herbicides either alone or in combination that are registered for skeleton weed control in crop or fallow situations. The handbook did not show the registration of Brodal for skeleton weed in grain legumes and pastures, where the herbicide can be used to suppress the weed.

An approach was made to Grain Corp seeking information as to how often and where crop deliveries exceeded the 20 seeds limit that is set for skeleton weed in cereals in NSW and Victoria, but no reply had been received at the time of finalising the report.

Biological control of skeleton weed using the rust fungus on the narrow leaf form remains the primary means of keeping the most competitive ecotype in check in eastern Australia. Jim Cullen, CSIRO (pers. comm.) stated that the rust continues to provide 95% control of this form, and while other agents such as a gall midge and gall mite have been introduced they have only had marginal success on the other forms due to predation by Australian insects. A fourth insect (root moth) which attacks roots appears to have died out.

Discussion

It is clear from the comments provided by growers, agronomists/consultants, state biosecurity personnel and researchers that skeleton weed is very much diminished as a weed of cropping and generally not considered to be a costly weed in cropping systems. Two respondents, who now indicated it was a minor problem, had been on farms as children and they still had memories of the serious problems encountered by their fathers in dealing with skeleton weed at harvest. The survey by Llewellyn et al (2016) bears out the relatively low cost the weed has in the eastern states.

Biological control in combination with fallow and in crop herbicides and the changed seeding systems have been an effective management combination for the weed and this has reduced the incidence of skeleton weed in the eastern states. Despite the lower levels generally being observed there were enough statements and survey results to conclude that in at least some parts of the cropping system skeleton weed is still present at levels which can lead to population densities similar to those reported prior to the skeleton weed rust release. Dr Hanwen Wu at DPI NSW (pers comm) has noted that even on the research station at ARI Wagga paddocks with moderate densities can still be found.

The South Australian experience with the change in declaration status is important . On the one hand the weed appears to be of low significance to growers who are able to rely heavily on a small number of herbicides, but against this there are areas where the weed is still found at low levels in the Mallee and on the Eyre Peninsula. The legislation does provide a backup for the biosecurity agencies to respond to increased outbreaks, but at the moment there appears little need. While conventional cropping using ploughing for fallow management and seedbed preparation is now less than in the late 1990s when no till was starting, up to 35% of respondents in the Mallee in Llewellyn's survey still use cultivation for weed management. Given the role that cultivation has in spreading the weed within paddocks it may not be surprising that this area still has a higher level of skeleton weed.

Herbicides are a key part of the management package but there remain issues with their use. Clopyralid is the dominant herbicide used either alone or in mixtures but brings risks such as soil residues, residue in straw or hay with potential effects on sensitive plants, and the possibility of herbicide resistance . The lack of effective herbicides in grain legumes and legume pastures is a significant risk in limiting rotational options for disease and other weeds. Fallow management is heavily reliant on herbicides in the eastern states and new modes of action are required. The research is underway to identify new molecules that are able to provide good control, and flumioxazin and pyraflufen-ethyl are both considered by agronomists as being possible mixture partners for glyphosate in fallow weed management of skeleton weed. These herbicides being non- hormone based may be useful where cotton and horticulture restrict 2,4-D use. There appears to be no new herbicide for in crop weed control tested in the eastern states or the USA that could be found in the literature, but aminopyralid which is in the same chemical group as clopyralid gives equivalent control in trials in Idaho.

There were sufficient comments from the respondents to infer that areas outside the farm or pasture were not currently causing any major increases on farm. It would appear that skeleton weed is largely remaining in patches on farm and that spread may have slowed compared to previous decades. The role of pasture is difficult to ascertain as the long term lower rainfall from 2000 to now, with shorter periods of good growth in between, has complicated interpretation of how the weed has developed in this environment. Comments on it being heavily grazed in dry years and the good prices for sheep products would indicate that graziers may be exploiting the weed more effectively.

Biological control remains the best option to contain skeleton weed and reduce its impact. CSIRO continue to do limited work on the rust (Gavin Hunter, Black Mountain) and are currently undertaking a genetic study of Skeleton weed rust (Puccinia chondrillina), the biological control agent of skeleton weed in Eastern Australia. CSIRo has collected infected skeleton weed plants from south-western NSW and north-eastern Victoria in order to isolate and culture the fungus and sequence the genomes for 15 strains of the fungus to determine what their genetic similarity. The rust was effective against the Narrow and Intermediate forms of skeleton weed but not against the Broad forms of skeleton weed. The allozyme surveys of skeleton weed in Australia (Gaskin 2013) show the similarity of the strains across Australia, and if future control of the broad leaf form is to be achieved then this information may be critical to identifying new strains of the rust for release.

Conclusions

1. Skeleton weed remains widespread across the eastern states but is generally no longer a significant weed in cropping situations.
2. Biological control, in crop and fallow cereal and canola herbicides, and no till seeding systems have largely removed it as a major threat to the production system.
3. The main problems remain firstly with grain legumes and pasture legumes where lack of herbicides may allow build up of the weed and where residues of herbicides in soil or straw can limit rotational options, and secondly with farmers who still cultivate and often have the weed.
4. The changed status of skeleton weed in South Australia has so far had little impact on the weed occurrence on farm, and while herbicides remain available for management then the low level of impact will most likely be maintained.
5. Threats may come from evolution of resistance in skeleton weed, or there is a move to cultivation for weed control if herbicide resistance in other weeds cannot be controlled by other non-herbicidal means.

6. While skeleton weed is well managed in crop, the horticulture sector was noted as having lower levels of management and might be a future reservoir for seed production
7. Investments in biological control still provide one of the best ways to ensure the weed does not re-emerge as a cropping problem.

Acknowledgements
I would like to thank John Peirce for providing contacts in South Australia, Elise Bowen for a wide range of farmer contacts in Victoria and New South Wales, and Dr Deirdre Lemerle for suggesting a range of researcher contacts across eastern Australia.

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17. Milestone label. Dow Agrosciences. Revised label, 2018

18. Weed Risk Assessment for *Chondrilla juncea L.* (Asteraceae) – Rush skeletonweed. 2016. USDA

Appendix 1. List of interviews/email respondents

1. Andrew Hunter, Yerong Creek NSW.
2. Allan Munns, Boorowa NSW.
3. Charlie and Tana Webb, Urana NSW
4. Darren Schurmann, Dunkeld VIC
5. Duncan Clowes, Millthorpe NSW
6. Stuart Robinson, Lismore VIC
7. Tom Sweeny, Casterton VIC
8. Dr Deidre Lemerle, Charles Sturt University, Wagga Wagga
9. Dr Hanwen Wu, DPI NSW, Wagga Wagga
10. Dr John Broster, DPI NSW, Wagga Wagga
11. Dr Steven Johnson DPI NSW, Orange
12. Dr Gurjeet Gill, University of Adelaide
13. Tony Cook, Biosecurity NSW, Orange
14. Ian Brown, Biosecurity and Agricultural Services, Agriculture Victoria, Swan Hill
15. Peter Baird, Dodgshunmedlin, Swan Hill, Vic
16. Kent Wooding, Agrivision Consulting, Swan Hill, Vic
17. Seb Drewer, Natural Resources Eyre Peninsula, Port Lincoln, SA
18. Sarah Noack, Hart Field Site, Hart, SA
19. Grant Roberts, Department Environment and Water, SA
20. Tanja Morgan, Mallee Sustainable Farming Group, Mildura, Vic
21. Simon Dobie, Loddon Shire Council, Vic
22. Sandy Cummings, Natural Resources SA Murray-Darling Basin
23. Dr Gavin Hunter, CSIRO, Canberra
24. Jason Elms, GRDC, Canberra
25. Dr Jim Cullen, CSIRO, Canberra

Appendix 2. Declared Plant Policy, Skeleton Weed, Government of SA, 2015

Attached document

Declared Plant Policy

Skeleton Weed (*Chondrilla juncea*)

Government of South Australia

Skeleton weed is a deep-rooted perennial weed established in the cereal growing areas of South Australia with the potential to spread rapidly and seriously reduce the yield of cereal crops.

Management Plan for Skeleton Weed

Outcome

- Negative impacts of skeleton weed on production minimised in rotational broad acre cropping and irrigated pastures.

Objectives

- High priority outbreaks in generally uninfested areas destroyed.
- Large outbreaks in generally uninfested areas contained and reduced in density.
- Seed dispersal prevented in generally uninfested areas.
- Impact of skeleton weed reduced in generally infested areas.

Implementation

Within areas generally free of skeleton weed,

- Natural Resources Management (NRM) authorities to ensure high priority infestations, as determined by the authority, on private or public land are controlled.
- NRM authorities to control high priority infestations on road reserves and recover costs from adjoining landholders in accordance with regional management plans.
- NRM authorities to ensure large infestations are contained by property-level management plans.
- NRM authorities to ensure contaminated seed and fodder are not brought into or distributed within their regions.

Regional Implementation

Refer to regional management plans for further details.

NRM Region	Actions
Adelaide and Mount Lofty Ranges	Manage sites
Alinytjara Wilurara	Monitor
Eyre Peninsula	Limited action
Kangaroo Island	Destroy infestations – regional alert
Northern and Yorke	Monitor
South Australian Arid Lands	Limited action
South Australian Murray-Darling Basin	Manage weed
South East	Manage sites

Declaration

To implement this policy, skeleton weed is declared under the *Natural Resources Management Act 2004* throughout the whole of the State of South Australia to minimise further spread. The movement or transport of the plant on a public road by itself or as a contaminant, or sale by itself or as a contaminant, is prohibited.

NRM authorities may require land owners to control skeleton weed plants growing on their land. NRM authorities are required to control plants on road reserves and may recover costs from the adjoining land owners.

Skeleton weed is declared in category 2 under the Act for the purpose of setting maximum penalties and for other purposes. Any permit to allow its movement or sale can only be issued by the Chief Officer pursuant to section 188. Under the *Natural Resources Management (General) Regulations 2005*, the transport or movement of grain for milling or wool for cleaning is exempt from the operation of sections 175 and the sale of wool or grain is exempt from section 177(2) if at the time of the sale the person believes on reasonable grounds that the purchaser will remove the plant from the wool or grain before any re-sale.

The following sections of the Act apply to skeleton weed throughout each of the NRM regions noted below:

Region Sections of Act	AMLR	AW	EP	KI	NY	SAAL	SAMDB	SE
175(1) Prohibiting entry to area								
175(2) Prohibiting movement on public roads	X	X	X	X	X	X	X	X
177(1) Prohibiting sale of the plant	X	X	X	X	X	X	X	X
177(2) Prohibiting sale of contaminated goods	X	X	X	X	X	X	X	X
180 Requiring notification of infestations								
182(1) Landowners to destroy the plant on their properties								
182(2) Landowners to control the plant on their properties	X	X	X	X	X	X	X	X
185 Recovery of control costs on adjoining road reserves	X	X	X	X	X	X	X	X

Review

This policy is to be reviewed by 2020, or in the event of a change in one or more regional management plans for skeleton weed.

Weed Risk

<u>Invasiveness</u>

Flowers of skeleton weed produce seed automatically without any need for pollination. One plant can annually produce 20,000 to 30,000 seeds. These are well adapted for dispersal by the wind, and are also easily transported in wool, fabric, machinery, vehicles, railway trucks, and contaminated hay or chaff.

There is little dormancy in seeds of skeleton weed, so germination usually occurs soon after seed is shed, as soon as sufficient moisture is available in autumn. Seeds will germinate with as little as 5 mm of rain; the seedlings require three to six weeks of soil moisture to establish successfully, and can develop a taproot to 1 metre deep by the following spring.

They can establish among competition from pasture or relatively undisturbed native vegetation.

Impacts

Skeleton weed is a pest of broad acre crops, pastures and occasionally roadsides. It reduces yields through competition for moisture, nitrogen and light, and has a high cost of control. Yield losses of up to 80% have occurred in densely infested cereal crops, and the wiry flowering stems can even make harvesting difficult.

It is poor fodder for cattle and can out-compete other pasture plants. However, carrying capacity for sheep may be improved by the presence of skeleton weed presence because it provides green summer fodder. In rotational systems, its impact on crops far outweighs its benefit in pastures.

Potential distribution

Skeleton weed is suited to semi-arid or Mediterranean climates, but will grow in other climates under suitable conditions. It is found primarily in areas receiving more than 300 mm mean annual rainfall. However, since it can regenerate repeatedly from deep roots, it is not limited to sites regularly receiving this rainfall but can afford to miss dry years and recover in wet years. It is tolerant of waterlogging and any levels of frost that occur in South Australia.

Skeleton weed has an advantage on deep sandy soils where its root system can exploit deep soil water resources, but can grow competitively in a wide range of soil types and is suited to the majority of the arable areas in the State.

Feasibility of Containment

Control costs

To prevent the spread of skeleton weed, seeds and roots must not be moved from infested areas. As wind dispersal of seed is important, seed set should be prevented where possible. Sheep can be useful minimising spread if placed in infested paddocks from October to November before the weed flowers. Continuous grazing will not kill the plant, but it will prevent the development of flower heads and seed production.

Herbicide control of skeleton weed is easiest in a wheat crop. If possible it is recommended wheat be sown in large infestations, with barley or oats the next best options. Lupin crops should not be used as they are highly susceptible to damage by any herbicides useful for managing skeleton weed.

In pastures, seeding with annual or perennial legumes can provide significant competition to minimise the spread of skeleton weed.

Co-ordinated containment programs, especially on light soils, have encountered problems from the long-term persistence of herbicide in soil leading to risk of erosion. There is a specific need for alternative control strategies for large infestations on light soils.

Persistence

Skeleton weed seeds have little dormancy and are short lived. They usually germinate within six months and no seed bank is formed. The root system is long lived, enabling individual skeleton weed plants to survive for many years. It also enables mature skeleton weed plants to regenerate from deep roots, making them more difficult to kill.

Current distribution

Infestations of skeleton weed are scattered throughout the Mount Lofty Ranges, Mid North, South East and Eyre Peninsula regions. The weed is more widespread in the Mallee and Riverland regions.

State Level Risk Assessment

Assessment using the Biosecurity SA Weed Risk Management System gave the following comparative weed risk and feasibility of containment scores by land use:

Land use	Weed Risk	Feasibility of control	Response at State Level
Crop-pasture rotation	high 116	medium 32	protect sites
Irrigated pasture	high 105	medium 42	protect sites
Grazing-rangeland	low 22	very high 11	monitor
Grazing - southern	low 31	low 61	limited action
Native vegetation	low 38	medium 40	limited action

Considerations

Skeleton weed was introduced to New South Wales by 1897 when it was detected in Wagga Wagga and had spread to South Australia by 1947. Attempts at eradication programs commenced immediately, but were unsuccessful due to lack of effective control techniques. It had spread to the Upper South East, Eyre Peninsula, Yorke Peninsula and Northern areas by 1965. It has still not reached its ecological limits in South Australia, as several decades of intensive management have successfully delayed its spread. It has potential to establish and cause losses throughout the cereal areas, especially in the lower rainfall zones.

Chondrilla juncea is an aggregate of many agamospecies (clones that reproduce by non-sexually produced seeds). At least three of these agamospecies occur in South Australia, and their distribution has implications for biological control. Several of biological control agents were introduced in the 20th century and reduced the density and impacts of the commonest form of skeleton weed in heavily infested regions. However, a consequence has been an increase in the relative abundance of two other forms that are less susceptible to these agents.

Risk assessment indicates site protection as the appropriate action at State level in rotational cropping and irrigated pastures, and monitoring in rangelands. While sale and movement are prohibited uniformly across the State, regional actions vary according to the land uses in each region. Co-ordinated control programs are not conducted in areas where skeleton weed is widespread and there are few benefits from enforced control. However, all regional NRM Boards retain the power to enforce control actions if necessary.

On Kangaroo Island, skeleton weed is a regional alert species and infestations are destroyed when detected. The South Australian Murray-Darling Basin aims to manage the weed, and the South East and Adelaide Mount Lofty regions aim to manage sites.

Skeleton weed is monitored in the Alinytjara Wilurara and Northern and Yorke regions. Only limited action is undertaken in the Eyre Peninsula region where control is normally left to the judgement of landowners.

Synonymy

Chondrilla juncea L., Sp. Pl. 796 (1753)

Taxonomic synonyms:

Chondrilla acantholepis Boiss., Diagn. Pl. Orient. ser.1, 11: 48 (1849)
Chondrilla angustissima Hegetschw., Fl. Schw. 762 (1840)
Chondrilla bornmuelleri Haeckel, Repert. Spec. Nov. Regni Veg. Beih. 108: 69 (1938)
Chondrilla brevirostris Fisch. & C.A. Meyer, Index Sem. St.Petersberg 3:32 (1837)
Chondrilla canescens Kar. & Kir., Bull. Soc. Imp. Naturalistes Moscou 15: 397 (1842)
Chondrilla graminea M.Bieb., Fl. Taur.-Caucas. 2: 244 (1808)
Chondrilla gummifera Iljin, Bull. Sect. Rubber-Produc. Pl., Moscow, 3) 49: 56 (1930)
Chondrilla latifolia M.Bieb., Fl. Taur.-Caucas. 2: 244 (1808)
Chondrilla rigens Rchb., Fl. Germ. Excurs. 271 (1832)
Chondrilla virgata J.Presl & C.Presl, Delic. Prag. 116 (1822)

Other common names include devil's grass, gum succory, hogbite, naked weed, and rush skeletonweed.

Hon Ian Hunter MLC
Minister for Sustainability, Environment and Conservation

Date: 3 January 2015

United States Department of Agriculture

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

United States Department of Agriculture

Animal and Plant Health Inspection Service

September 22, 2016

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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Animal and Plant Health Inspection Service
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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).

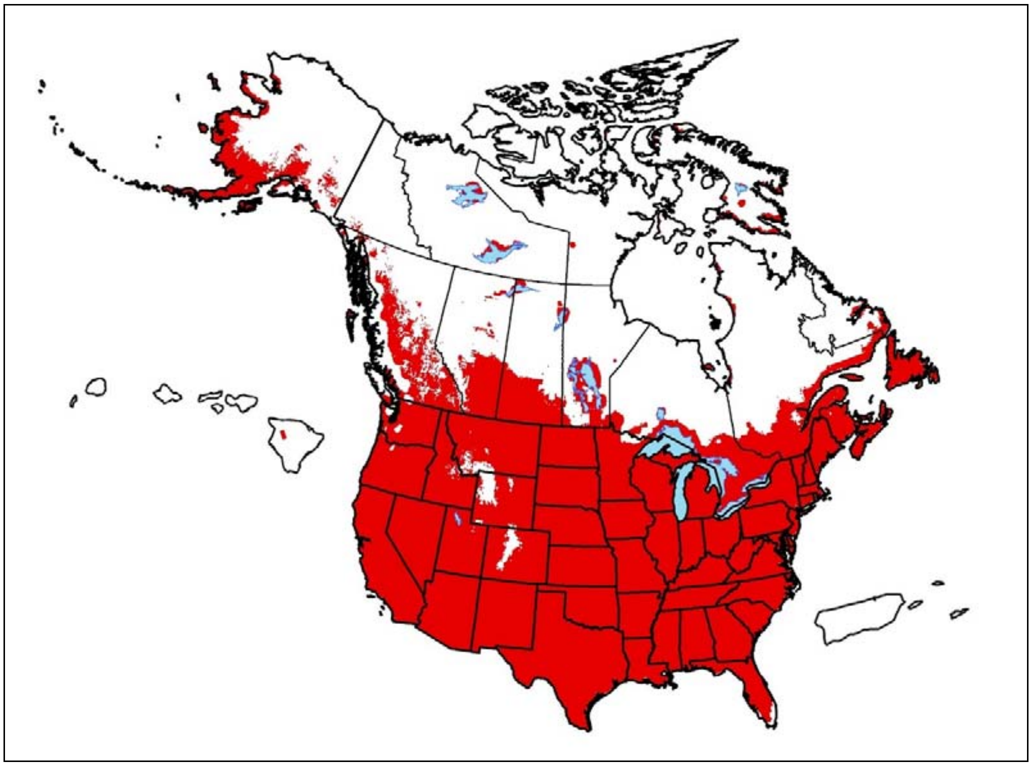

Figure 1. Potential geographic distribution of *Chondrilla juncea* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

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

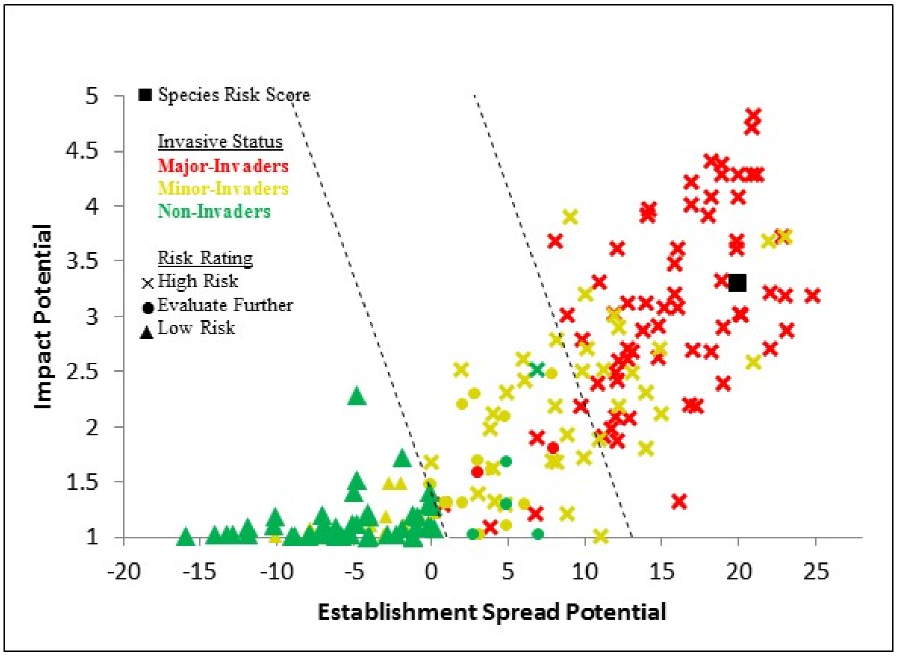

Figure 2. *Chondrilla juncea* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

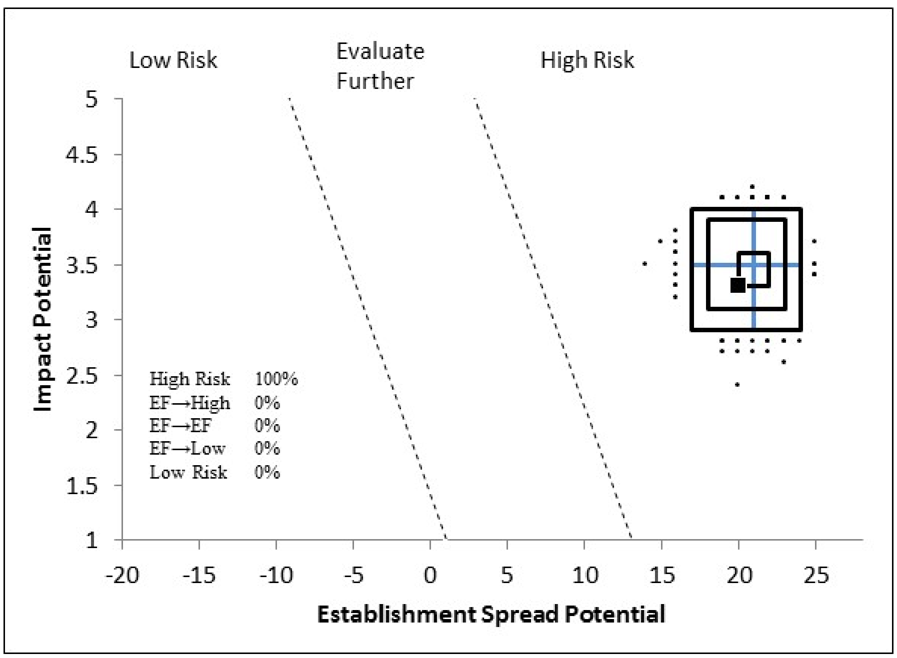

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *C. juncea*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

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	