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Prioritizing Weed Targets for Biological Control in the Western USA

Report on Workshop 1 (Weed Impacts & Desired Management Goals)

Report on Workshop 2 (Feasibility & Likelihood of Biological Control)

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The survey undertaken as part of this project was approved by CSIRO’s Social Science Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research (2007).

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Executive Summary

Invasive weeds represent significant threats and costs to production (rangelands, croplands) and natural landscapes. Classical biological control programs can yield substantial benefits in the management of invasive weeds and historical programs have high benefit-cost ratios. However, these programs are typically long-term investments with significant up-front costs to develop safe agents, the efficacy of which can be uncertain. Given that resources to manage weeds in any jurisdiction are often limited, there is a need to better prioritize weed targets for biological control to facilitate their management in the most cost-effective manner possible. Improving on previous prioritization processes developed and applied for weed classical biological control, we have developed a structured framework that achieves this in a consultative and transparent manner. In this study we applied this framework to assist the USDA-ARS's Exotic & Invasive Weeds Research Unit to prioritise weeds of ten western states of the continental USA as targets for biological control.

Through a combination of online surveys and a face-to-face workshop with land managers, the first and second stages elicited, captured and characterized the relative importance of a weed, its impacts and desirable management goals. These stages captured the knowledge of weed scientists and land managers to ensure that those investigating and managing impacts on the ground arrive at a list of weeds for which biological control may be desirable. The third stage subsequently assessed the feasibility of biological control and the likelihood of achieving the desired management goals for these weeds. This stage takes advantage of the collective experience of biological control scientists and practitioners to classify the prospects of biological control contributing to successfully achieving the management goals. The focus of this prioritisation study was on weeds of importance to three or more states (i.e. a regional prioritisation). The resultant matrix of weed impact by biocontrol prospects (appended below) prioritised weeds that have been historical targets (suggesting that their biocontrol may be inadequate or insufficiently widespread), also identified prospective targets for future biocontrol research. This matrix needs to be read in conjunction with detailed annotations elicited from experts on the various weeds and their biological control (provided as Appendices to this report).

Weed impact

Biocontrol prospects	Low	Mod	High
Low		*Centaurea diffusa; Iris pseudacorus;* ; *Lepidium* spp.; *Myriophyllum. spicatum; Onopordum acanthium; Pilosella aurantiaca; Potentilla recta; Rubus armeniacus*	*Bromus tectorum; Centaurea stoebe; Cirsium arvense; Lepidium draba; Pilosella caespitosa; Rhaponticum repens; Taeniatherum caput-medusa; Ventenata dubia*
Mod	*Dittrichia graveolens*	*B. incana; C. scoparius; L. vulgare; T. terrestris*	*Lepidum latifolium*
High	*Eleagnus angustifolia*	*A. petiolata; B. umbellatus; H. perforatum; I. tinctoria*	*Cynoglossum officinale; Chondrilla juncea; Cetaurea solstialis; Euphorbia esula; Linaria dalmatica; Linaria vulgaris*

1 Introduction

1.1 Background

Invasive weeds represent significant threats and costs to production (rangelands, croplands) and natural landscapes. Classical biological control can be a powerful tool in the management of invasive weeds and historical investments in biological control programs have returned significant environmental and economic benefits (Page and Lacey 2006; van Driesche et al. 2010). However, these programs are typically long-term investments with significant up-front costs to develop safe agents, the future efficacy of which can be uncertain (Briese 2004; van Driesche et al. 2016). Given that resources to manage weeds in any jurisdiction are often limited, there is a need to better prioritize weed targets for biological control to facilitate their management in the most cost-effective manner possible. Based on recent work undertaken in Australia on prioritizing weeds of natural and agricultural systems for biological control (Morin et al. 2013, 2016; van Klinken et al. 2016), we were invited by Dr Paul Pratt to provide similar guidance in the investment of the resources of USDA-ARS's Exotic & Invasive Weeds Research Unit on the biological control of weeds of the western USA.

1.2 Project scope

The scope of the project was defined in consultation with Dr Paul Pratt to be the following:

1. Consult with state weed management coordinators and other relevant stakeholders to compile list of weeds of importance to the western USA for prioritization as targets for biological control.
2. Facilitate two workshops, each involving stakeholders with the relevant expertise, to classify each weed in terms of impacts, to elicit management goals, and determine prospects for their biological control.
3. Compile all information and make recommendations on priority weeds for investment.

Building on past work and drawing on the conceptual framework of structured decision making in environmental management (Gregory et al. 2012), we developed a two-stage decision-making framework to prioritize weeds of the western USA in a consultative and transparent manner (Figure 1).

The first stage (initial consultation) harnessed the knowledge of weed scientists and land managers to compile a list of key weeds in Western USA for prioritization.

The second stage (Workshop 1) involved weed management state coordinators or delegates from across the region in a workshop setting to elicit, capture and characterize the impacts of each weed and desired management goals.

The third stage (Workshop 2) took advantage of the collective experience and expertise of biological control scientists and practitioners to assess the feasibility of undertaking a biological control program for each weed and its likelihood of successfully achieving the desired management goals.

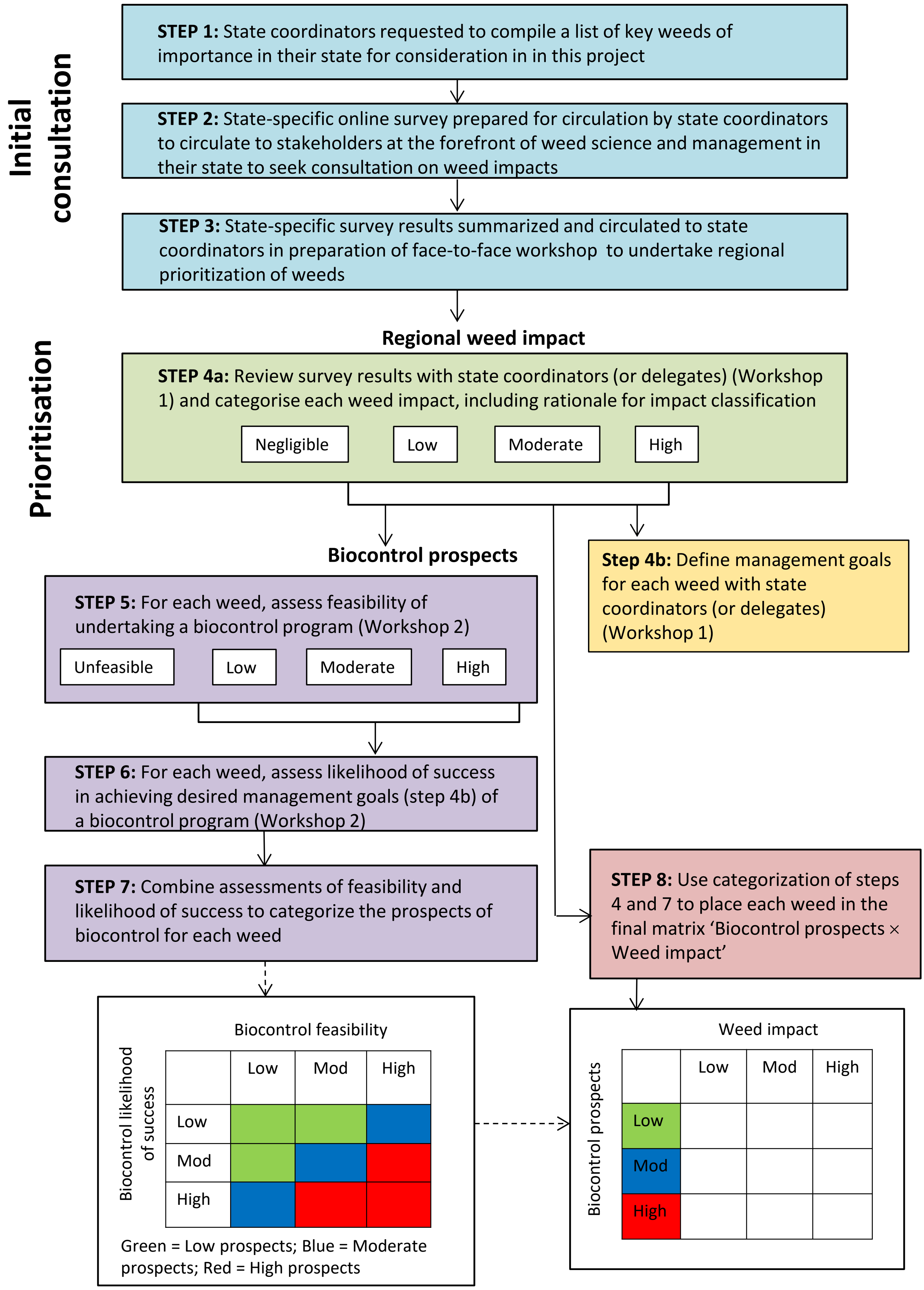

Figure 1. Outline of the prioritization process developed for this project.

2 Methods

The methods used in this study are part of a suite of approaches broadly described as structured decision making (Gregory et al. 2012) and are adapted from recent prioritization of weeds for biological control done in Australia (Morin et al. 2013, 2016; van Klinken et al. 2016). These methods rely on participatory approaches to enable stakeholders and subject-matter experts to consultatively contribute information and guide decision making in the context of the environmental issue at hand. We chose this qualitative approach for prioritizing weed targets for biological control because this approach is inclusive, explicit, transparent, context-dependent and adaptive (Gregory et al. 2012). The methods related to the first stage (Initial Consultation and Workshop 1) are outlined below.

2.1 Initial consultation

The geographic scope of the prioritization was limited to the region relevant to the Exotic & Invasive Weeds Research Unit (USDA-ARS-WRRC). This area includes 11 states (Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, Wyoming) spanning almost half the landmass of the lower 48 states of the continental USA (Figure 2). Weed management state coordinators (state coordinators, hereafter) from each of the aforementioned states were requested to provide us with a list of weeds that they wished to submit to this prioritization process. Each state had their own process by which they arrived at this list of weeds and we intentionally did not homogenize the approaches they used to prepare these lists.

Figure 2. Geographic scope of this project

Based on the list provided by each state we developed a state-specific online survey to ascertain the Impact Type (IT) and Impact Level (IL) of each of the weeds on this list. This survey was circulated by the state coordinators to land managers, landholders, weed scientists, county extensions agents and others at the forefront of weed management in the state, to seek broader consultation on the experienced/known/perceived impacts of each of the weeds. A guide was provided to survey respondents to assist their classification of impacts of the weeds (Table 1). Information gathered from these surveys were summarized and circulated to the state coordinators along with an invitation to them (or their delegate) to attend a face-to-face workshop (Workshop 1) to discuss and expand on these results.

Prior to the workshop, we held a meeting with Dr Paul Pratt to clarify how “region” would be defined from his perspective (as the person commissioning this prioritization work) to arrive at a regional prioritization of weeds. Based on this discussion, weeds represented on three or more state lists were shortlisted for this regional prioritization exercise.

Table 1. Guide provided to survey respondents and workshop participants to inform their qualitative assessment of Impact Type and Impact Level of each of the weeds in state-specific surveys

Impact Type → Impact Level ↓	Economic impact	Environmental impact
Negligible	At worst a nuisance weed that does not significantly affect production or the management of an enterprise, and rarely requires specific targeted control effort.	Present in the environment, but is a relatively innocuous component of the flora of a site and is not seen spreading.
Low	Weed can cause at least minor enterprise-level production losses, or alter the way enterprises are managed. If serious impacts occur they are localised in extent within an enterprise* or to a few properties, are the result of extended periods of poor property management, and /or are readily and cost-effectively managed.	Present in the environment, and becomes apparent particularly when a site is disturbed. Some local spread, but is mostly restricted to a few sites.
Moderate	Weed can result in serious enterprise-level production losses, or substantially alter the way enterprises are managed, even when enterprises are relatively well managed, but affects relatively few properties regionally, and/or is readily and cost-effectively managed using existing approaches.	Locally abundant and appears to be threatening a few species or processes in the ecosystems in which it occurs.
High	Weed can result in serious enterprise-level production losses, or substantially alter the way enterprises are managed, even when enterprises are relatively well managed, across a broad geographic area. Not readily or cost-effectively managed using existing approaches.	Abundant and/or widespread; appears to invade/transform otherwise intact ecosystems and threatens multiple species or processes in the ecosystems in which it occurs.

*Where the weed affects the most productive parts of the landscape then it is limited in extent there.

2.2 Workshop 1 (Weed Impacts & Desired Management Goals)

2.2.1 Workshop activities

We facilitated a workshop (held on 17-Mar-2017 at Coeur d'Alene, ID in conjunction with the Western Society of Weed Science conference) with the state coordinators (and/or their delegate). Coordinators representing Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon and Wyoming participated in this workshop; representatives of federal land management agencies and weed management consultants were also among the participants. The fourteen workshop participants represented various sectors/systems (including agriculture, forestry, rangelands, transport corridors and natural areas) affected by invasive weeds in the western US.

We opened the workshop with a brief presentation on the conceptual background and approach being taken in this project, and provided case studies of how similar processes were run in Australia. Participants had been made aware of the workshop's objectives through pre-workshop interactions in the form of a talk given by Dr Paul Pratt at a previous meeting and through email communication. The two-fold objectives of the workshop was then reiterated to the participants. These were to (1) arrive at a regional prioritization of the weeds based on their impacts and guided by the survey results for each state and the experience/expertise of workshop participants, and (2) define management goals for each of the weeds. The delimitation of the regional prioritization to those weeds represented on three or more state lists was communicated to participants. Workshop participants were then invited to nominate additional weeds that should be considered a regional priority; this was done to ensure that emerging weeds and any weeds that may have been accidentally left out of the survey could be considered in the prioritization process. The list of weeds that included those on at three of more state lists and those that were added at the workshop is hereafter referred to as the "workshop weed list".

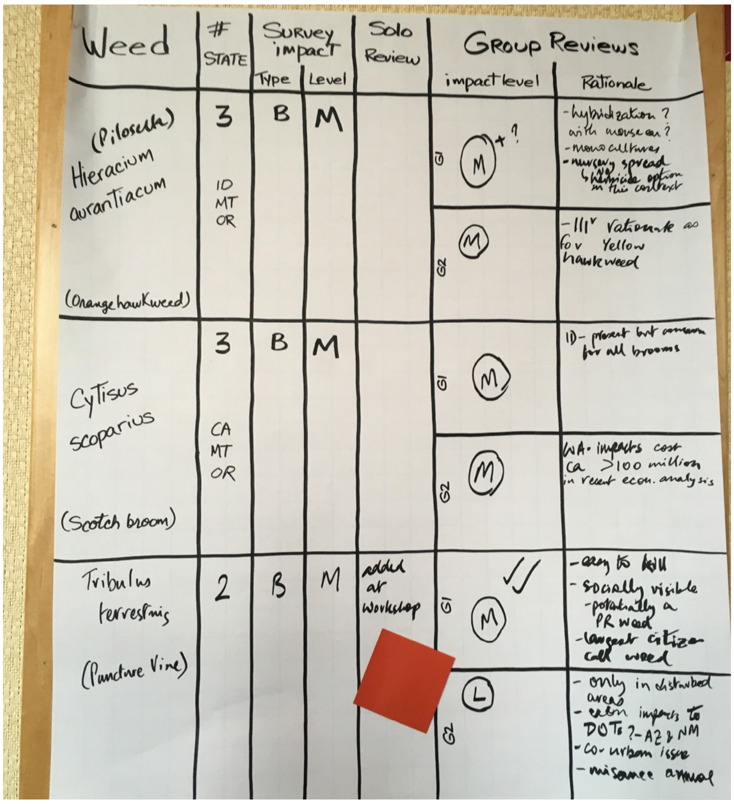

Figure 3. A sample poster from Workshop 1 showing the survey results, individual review and group review of the impact classification of each weed

The workshop objectives were facilitated through a combination of individual and group exercises. Care was taken to ensure that diverse/divergent opinions were captured by enabling the review of the survey results individually and as a group. A summary of the survey results of the workshop weed list were displayed on posters for review (Figure 3). Workshop participants were reminded of the guide provided to survey respondents to guide their

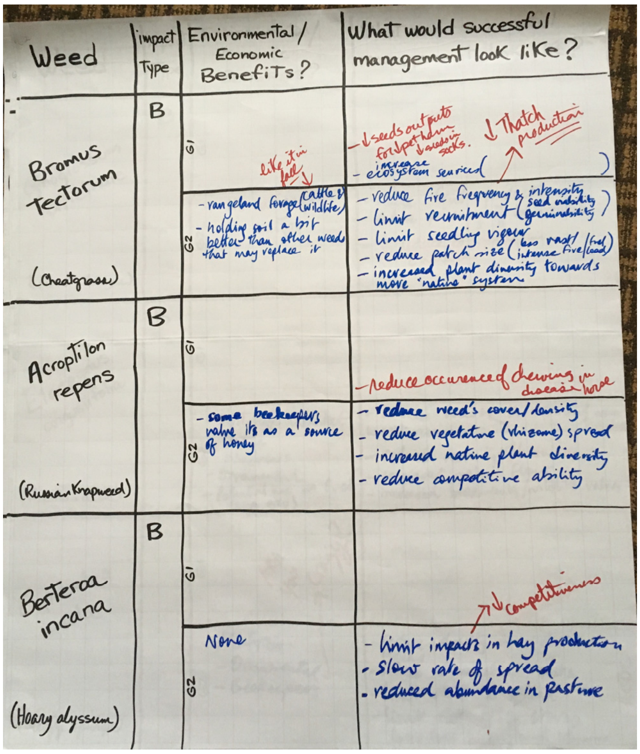

Figure 4. A sample poster from Workshop 1 showing the survey results, individual review and group review of any economic/environmental benefits and management goals of each weed.

assessment of weed impacts (Table 1). They were also provided a consolidated anonymous summary of the notes provided by survey respondents in substantiating their impact classification of each of the different weeds. After reviewing the survey results as individuals and being afforded the opportunity provide comments, workshop participants were asked to review the survey results as part of one of the two groups to which they were haphazardly assigned. Each group was assigned a half of the workshop weed list to review[1]. As part of this exercise, each group collectively reviewed the summary results from the surveys and any individual assessments to arrive at a group assessment on the impact level and type for each weed, and the rationale for their classification. Where individuals or groups of people felt that the impact level needed to be changed from the survey results, this was done through discussion, and the rationale for any change was annotated on the posters. While consensus emerging through discussion was not discouraged, no consensus was required or sought by us, and any differences of opinion were captured in writing. Each group then examined the classification and notes of the other group to ensure that all workshop participants had the opportunity to review and offer input on all weeds being considered in the workshop weed list. Once this peer-group assessment was completed the impact assessments and rationale was reviewed again by all workshop participants as a collective to provide additional opportunities of discussion and input.

The second half of the workshop was devoted to considering any economic/environmental benefits each weed may have and the desirable management goals for each weed on the workshop weed list (Figure 4). This process was facilitated in the same manner as the previous process for classifying impact, where individual and group review was done, followed by peer-group review and whole-workshop review.

2.2.2 Post-workshop activities

A summary report of the process and findings of the report was prepared for review by workshop participants and other weed managers in the western US, to add/revise relevant information on impacts and management goals to that elicited through the survey and Workshop 1. The list of

[1] Weeds from the workshop weed list were assigned haphazardly to each half list to mix the weeds in different impact classifications.

weeds identified as being of high priority and their impacts and management goals served as the basis for the feasibility and likelihood assessments by biological control experts in Workshop 2.

2.3 Workshop 2 (Feasibility of Biological Control & Likelihood of Success)

Each of the weeds identified as a priority in Workshop 1 was considered in Workshop 2 (held on 3rd and 4th Nov 2017 in Denver, CO) by experts with significant experience with developing biological control solutions for weeds in the western USA. Some experts unable to attend the workshop in person contributed through written inputs on a draft assessment template that was circulated prior to the workshop. At the workshop, the experts were guided through a structured and explicit process of assessing the feasibility and likelihood of success biological control of each of the weeds with potential, known or unknown, agents not already released in the USA.

Weeds were allocated to teams of 2-4 experts based on their experience with/knowledge of the weed and its potential biological control agents. The teams were asked to prepare a short annotated dossier on each weed that included notes on the assessments performed.

2.3.1 Pre-assessment tasks

Prior to assessments of feasibility and likelihood of success of biological control, each weed's current taxonomy was clarified. The experts then reviewed the desired management goals for the weed identified in Workshop 1, and identified the specific aspects of management that could be addressed by biological control. In addition, the experts were asked to clarify whether their assessment would be done on the basis of known candidate agent(s) or an assumed hypothetical agent. If they were undertaking the former, the taxonomic identity of the candidate agent(s) that formed the basis for the assessment was documented. Where the focal weed was a long-standing target for biological control and most/all potential agents had already been considered and released/rejected for some reason, they were asked to reflect on both the feasibility of finding new highly specific agents and the likelihood of these agents achieving the management goals if released in the USA.

2.3.2 Assessment of *feasibility* of biological control

Feasibility of biological control was defined as the capability of establishing/undertaking a biological control program on the weed. As part of its assessment, key facets considered for each weed by the teams included historical, socio-political, logistical and ecological and evolutionary attributes of the weed and putative or known, but not already released, agent(s). The experts were provided with a template of questions (Table 2) to guide their assessments of feasibility. In addition, the experts were invited to identify factors affecting feasibility that were either not identified in the template or were unique to a focal target. In addressing these questions, for each of the focal target weeds, they were requested to make detailed annotations (with any appropriate citations) and arrive at a summary assessment of their responses in terms of its influence on feasibility of undertaking a biological control program.

Given their subjective nature, these assessments were necessarily qualitative. Based on the assessment of feasibility in relation to each criterion, the team of experts arrived at an overall assessment of feasibility on an ordinal scale; a guide was provided to the teams to assist with this process (Table 3). A written summary rationale was also elicited from the experts in substantiation of this, and key knowledge gaps were identified that might help improve the feasibility of undertaking a biological control program.

Table 2. Questions to guide the qualitative assessment of feasibility of biological control

Historical dimensions
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?
Socio-political dimensions
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?
Logistical factors
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?
Ecological/evolutionary criteria
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?

Table 3. Qualitative guides to help groups with overall assessment of feasibility of biological control

Category	Feasibility of undertaking a biological control program on the weed
Unfeasible/ unnecessary*	Only insurmountable obstacle(s) (e.g. weed valued by some sectors; all realistic options for biocontrol have already been explored and there is no promising candidate agent identified)
Low	Some or many obstacles, and a limited indication that they can all be overcome.
Moderate	Some or many obstacles, and a reasonable indication that they can all be overcome.
High	No obstacles, or few obstacles that can be easily overcome.

* A weed placed in this category is not assessed further.

2.3.3 Assessment of *likelihood of success* of biological control

Likelihood of success of biological control was defined as the chance of the putative or known, but not already released, agent(s) (assuming host-specificity) contributing to or achieving the desired management goal(s) for the weed. As part of these assessments, key aspects considered for each weed by the teams included features of the weed's life cycle, characteristics of the agent's damage, the landscape context in which the weed has an impact and potential interference of biological control from higher trophic levels. The experts were provided with a template of questions (Table 4) to guide their assessments of likelihood of success, and requested to consider these and any additional factors that may influence the likelihood of successful biological control.

As in the case of assessment of feasibility, for each weed, the team of experts arrived at an overall assessment of likelihood of success on an ordinal scale; a guide was provided to the teams to assist with this process (Table 5). A written summary rationale was also provided by the experts in substantiation of this, and key knowledge gaps were identified that might help improve the likelihood of success of biological control.

2.3.4 Levels of confidence/certainty with assessments and references

The expert teams were also asked to indicate the level of confidence/certainty (low, medium, high) that they had with their overall assessments of feasibility of biological control and likelihood of success for each weed and to provide a rationale to explain their decision. They were also requested to list the sources of information (references, personal experiences/observations, expert opinion, grey literature) that led to their expert assessments.

Table 4. Questions to guide the qualitative assessment of likelihood of success of biological control

Weed life cycle
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?
How might this influence agent(s) establishment patterns?
How might this influence agent(s) impacts?
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?
Agent damage (type, severity, duration)
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?
Based on previous research on target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?
Landscape context (habitat, climate, land use, competing species)
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?
3rd trophic level
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?

Table 5. Qualitative guides to help groups with overall assessment of likelihood of success of biological control

Category	**Likelihood of success of a biological control program on the weed**
Low	Based on available knowledge, there are valid reasons why the candidate agent(s) may not achieve the stated goal of biocontrol.
Moderate	Based on available knowledge, there are at least some valid reasons why the candidate agent(s) may not achieve the stated goal of biocontrol, but there are sufficient "qualifications" or unknowns to suggest that success is still possible.
High	Based on available knowledge, there is no reason why the candidate agent(s) could not achieve the stated goal of biocontrol.

2.3.5 Group review of assessments

Each team presented their summary assessment and rationales to the entire workshop group for peer feedback and critique. In the instances where the assessments changed as a result of this feedback/group review, this information and reasons for the change in assessment was captured.

Following this group review, each of the teams reviewed and revised their dossiers for each weed.

Based on these final assessments, a matrix framework was used by the authors to place each weed in a matrix of feasibility of biological control and likelihood of success to arrive at the prospects for biological control of each weed; a weed's prospects for biological control was classed as low, medium or high based on where their feasibility and likelihood of success assessments intersected (Figure 1). This information was presented to the entire workshop group for review and discussion, and adjusted if necessary; any changes resulting from the group review was annotated.

2.4 Integrating Weed Impacts and Biological Control Prospects

A matrix was used to make explicit where each weed of regional importance sat in terms of its impacts (identified in Workshop 1) and its biological control prospects (identified in Workshop 2). This summary matrix and the information on each weed provide an explicit rationale to guide prioritization of investment in weed biological control in the western USA.

3 Results & Discussion

3.1 Initial consultation

State coordinators, representing ten states, provided us lists of weeds to take through this prioritization process; Arizona and New Mexico provided one combined list. The number weeds that were on each list ranged from 9 to 51 (Table 6). Nine state-specific on-line surveys were designed using Survey Gizmo^{TM} and circulated by the state coordinators to various stakeholders in their respective jurisdictions. In all, 187 stakeholders responded and responses ranged from 7 to 32 respondents across the surveyed jurisdictions (Table 6). One hundred and nine weed species were considered across all lists. Most of the weeds (71) only occurred in one list, but 38 occurred on two or more lists (Table 7).

Table 6. Summary of weeds on the different state-specific weed lists submitted by state coordinators to this project.

State	# Weeds	# Respondents
AZ&NM	9	26
CA	51	25
CO	25	28
ID	15	8
MT	38	32
NV	12	11
OR	14	28
WA	15	22
WY	12	7
TOTAL	**191(109)**	**187**

Table 7. Frequency of weeds on different state lists submitted by state coordinators to this project.

# State lists	# Weeds
1	71
2	14
3	12
4	7
5	3
6	1
7	1
TOTAL	**109**

A weighted average of the state-specific impact level of the 109 weed species revealed that 19 were ranked as having high impact, while 39, 24 and 27 were ranked as having medium, low and negligible impact, respectively. While 45 of the weeds were deemed to have an exclusively environmental impact, none of the weeds were assessed to exclusively have an economic impact; 64 species were deemed to have both economic and environmental impacts.

Using the criteria of being represented on three or more state lists to be considered as being of regional importance, 23 species were shortlisted (*Lepidium draba* was referred to by its old genus *Cardaria* in some lists and thus results for both names were combined) (Table 8) and presented to workshop participants. The frequency of these weeds on the different state-specific weed lists and their survey-determined impact level and type are indicated in Figure 5.

	AZ&NM	CA	CO	ID	MT	NV	OR	WA	WY
(a) No. of weeds on >= 3 state lists	3	9	15	14	19	8	7	7	10
(b) No. of weeds on state list	9	51	25	15	38	12	14	15	12
% of weeds (a/b*100)	33.3	17.6	60.0	93.3	50.0	66.7	50.0	46.7	83.3

Level	# weeds
H	10
M	9
L	3
N	1
Total	23

Type	# weeds
En	1
Ec	0
B	22
Total	23

Figure 5. Summary of distribution, impact level and impact type of weeds that were on three or more state-specific weed lists submitted by state coordinators to this project. Impact level: H = High; M = Medium; L = Low; N = Negligible. Impact Type: En = Environmental; Ec = Economic; B = Both

Table 8. Identity of weeds on three or more state lists and their survey-determined impact level and type.

Weed Species	Common name	# states	Level	Type
Lepidium latifolium	Broadleaved pepperweed	7	M	B
Isatis tinctoria	Dyer's woad	6	L	B
Taeniatherum caput-medusae	Medusahead	5	H	B
Leucanthemum vulgare	Oxeye daisy	5	M	B
Onopordum acanthium	Scotch thistle	5	M	B
Linaria vulgaris	Yellow toadflax	4	H	B
Cynoglossum officinale	Houndstongue	4	H	B
Bromus tectorum	Cheatgrass	4	H	B
Elaeagnus angustifolia	Russian olive	4	H	B
Rhaponticum repens	Russian knapweed	4	H	B
Euphorbia esula	Leafy spurge	4	H	B
Berteroa incana	Hoary alyssum	4	M	B
*Lepidium draba**	Whitetop/Hoary cress	4	M	B
*Lepidium spp.**	Hoary cress	3	H	B
Centaurea solstitialis	Yellow starthistle	3	H	B
Chondrilla juncea	Rush skeletonweed	3	H	B
Pilosella caespitose	Yellow hawkweed	3	M	B
Rubus armeniacus	Himalayan blackberry	3	M	B
Pilosella aurantiaca	Orange hawkweed	3	M	B
Cytisus scoparius	Scotch broom	3	M	B
Butomus umbellatus	Flowering rush	3	L	B
Iris pseudacorus	Yellowflag iris	3	L	En
Myriophyllum spicatum	Eurasian watermilfoil	3	N	B

3.2 Workshops

Results from both workshops have been summarized into a single table for each weed included in the prioritization process. Tables are presented at the end of this sub-section.

3.2.1 Workshop 1 (Weed Impacts & Desired Management Goals)

Workshop participants added 10 species to the list of 23 weeds that were represented on three or more state lists from the state-specific surveys. The species added at the workshop were: *Alliaria petiolata*, *Centaurea stoebe*, *Centaurea diffusa*, *Cirsium arvense*, *Dittrichia graveolens*, *Hypericum perforatum*, *Linaria dalmatica*, *Potentilla recta, Tribulus terrestris*, *Ventenata dubia*. As anticipated by the method, the rationale for these additions related to these weeds either having been accidentally left out of the weed lists submitted by state coordinators or considered as emerging and of increasing concern by states where they are not yet present. Therefore, the total number of weeds on the “workshop weed list” was 33 species; two of these have exclusively environmental impacts, while the remaining 31 had both economic and environmental impacts.

Workshop deliberations reaffirmed the majority of the survey results in terms of impact level of the weeds. Most (23) of the weed species retained their impact level determined by the survey, while 10 species’ impact levels were revised; 8 of these revisions increased the impact level and 2 of them decreased the impact level. In addition, individual, group and workshop deliberations on the workshop weed list provided rich insights on the types and levels of impacts that the different weeds were having and the rationale for the impact level classification. The discussions on defining what successful management of each weed should achieve also enabled the identification of potential economic/environmental benefits that may need to be preserved, substituted or compensated should the weed be effectively managed by biological control. These insights are likely to be vital in anticipating conflicts of interest as part of assessing a weed’s biological control prospects (Figure 1; Workshop 2).

3.2.2 Workshop 2 (Feasibility of Biological Control & Likelihood of Success)

The summary detailed assessments of feasibility of biological control and likelihood of success for each weed performed by the teams of experts are presented in Appendix 1 and Appendix 2 respectively. Notes from the group review of the assessments are presented in Appendix 3.

The thirty three weeds of regional importance in the western USA were assessed by experts with significant experience with developing biological control solutions for weeds. Sixteen of these were assessed to have low prospects of biological control with new agents, while six were assessed as having moderate prospects; eleven species were rated as having high prospects of biological control (Figure 6).

Biocontrol feasibility

Biocontrol likelihood of success	Low	Mod	High
Low	*Bromus tectorum; Centaurea diffusa; Centaurea stoebe; Cirsium arvense; Iris pseudacorus; Myriophyllum spicatum; Potentilla recta; Rubus armeniacus*	*Taeniatherum caput-medusa; Ventenata dubia*	
Mod	*L. draba*; *Lepidium* spp.; *O. acanthium; P. aurantiaca; P. caespitosa; R. repens*	*Berteroa incana; Cytisus scoparius; Dittrichia graveolens; Lepidium latifolium; Leucanthemum vulgare; Tribulus terrestris*	*Butomus umbellatus; Chondrilla juncea; Eleagnus angustifolia* *Euphorbia esula; Hypericum perforatum*
High		*Cynoglossum. officinale* *Isatis tinctoria*	*Alliaria petiolata; Centaurea solstialis; Linaria dalmatica; Linaria vulgaris*

Figure 6. Prospects for biological control of weeds identified as being of regional importance in the western USA. Green boxes = low biocontrol prospects; Blue boxes = Moderate biocontrol prospects; Red boxes = High biocontrol prospects.

3.2.3 Post-workshop reviews

Participants were given the opportunity to re-review each workshops' outputs to ensure that the authors had adequately captured the insights from the workshop. This also provided them with an opportunity to obtain any additional clarifications e.g. by those state/jurisdictional coordinators and weed managers and scientists, biological control scientists with relevant knowledge/expertise but who were unable to attend the workshop. This report was revised based on these inputs.

3.3 Integrating Weed Impacts and Biological Control Prospects

Alignment of the impacts of the 33 weeds of regional importance in the western USA with the assessments of their prospects of biological control enables a prioritization of these weeds as biological control targets (Figure 7).

Weed impact

Biocontrol prospects

	Low	Mod	High
Low		*Centaurea diffusa; Iris pseudacorus; ; Lepidium* spp.; *Myriophyllum. spicaturm; Onopordum acanthium; Pilosella aurantiaca; Potentilla recta; Rubus armeniacus*	*Bromus tectorum; Centaurea stoebe; Cirsium arvense; Lepidium draba; Pilosella caespitosa; Rhaponticum repens; Taeniatherum caput-medusa; Ventenata dubia*
Mod	*Dittrichia graveolens*	*B. incana; C. scoparius; L. vulgare; T. terrestris*	*Lepidum latifolium*
High	*Eleagnus angustifolia*	*A. petiolata; B. umbellatus; H. perforatum; I. tinctoria*	*Cynoglossum officinale; Chondrilla juncea; Cetaurea solstialis; Euphorbia esula; Linaria dalmatica; Linaria vulgaris*

Figure 7. Considering the biological control prospects of the thirty three weeds of regional importance in the western USA in the context of their impacts. Yellow and orange shading is provided for weeds that could be considered as high and medium priority respectively for investment in biological control.

Some key weeds that emerge in the cells of the bottom right corner of the Weed Impact x Biological Control Prospects (Figure 7) are those that have been long-term targets for biological control in the western USA (e.g. *E. esula* (leafy spurge); *H. perforatum* (St John's wort)). This outcome was partly driven by their ongoing moderate or high impacts, which suggests that current biological control is not adequate to mitigate impacts of these weeds in parts of the western USA. This may present opportunities for redistribution/augmentation of existing agent populations, investigations of if/how agent performance might currently be impacted by other factors (e.g. predation, parasitism, environmental mismatches, landscape disturbance), better integration of biological control with other weed management tactics, or pursuit of as yet unexplored biological control agents. Many of these have been identified as key avenues for further investigation by the biological control experts involved in the assessment of biological control prospects. On the other hand, investigations into new agents may be a promising avenue to pursue considering that prospects of biological control were assessed as moderate or high in the prioritization exercise. Other long-term targets (e.g. *C. arvense*) may be a high priority because of their high impacts, but any ongoing investment on them needs to proceed with the awareness that the prospects for additional biological control agent(s) contributing to their management are likely to be low. For some of these species, all likely candidate agents have already been investigated and either released or rejected.

Some of the weeds with high biological control prospects have native range exploration underway and candidate agents identified (e.g. *E. angustifolia*, *A. petiolata*, *I. tinctoria*). Others will require new programs of research in the native range to identify potential biological control agents, but the feasibility and likelihood of finding promising agents was deemed to be high. Several weeds that have a high impact are grasses (e.g. *B. tectorum*, *T. caput-medusae, V. dubia*) and their prospects for biological control have been assessed as low for various reasons (e.g. low specificity of herbivores in native range, uncertainty in likelihood of agents adversely impacting this functional group (especially those that are annuals)). The insights and knowledge gaps identified for these weeds can direct effort by biological control researchers and ecologists. Results from such research could refine a weed's position in these matrices.

Some 85 weed species were only included in one or two state weed lists submitted for this prioritization process (Appendix 4). Thirty eight of these species were characterised as having Moderate or High impact in their current distribution; twenty nine of them were regarded as having environmental and economic/agricultural impacts, while nine only had environmental impacts (Appendix 4). While some of these weeds may only be of importance to a given state, some of these species might also represent emerging regional weeds; some of these were hence added by weed managers in Workshop 1 (Appendix 4). An analyses of the biological control prospects of these remaining weeds may highlight opportunities to proactively consider investment in the biological control of these weed species before they reach their potential distribution in the western USA.

4 Conclusions

Collectively, the approach used in this consultative process has enabled the elicitation of information and knowledge gaps in a structured manner to enable the prioritization of weeds of the western USA for biological control (Gregory et al. 2012). From a potential list of some 109 weed taxa (identified by state-level and regional land managers), 33 were selected as being of regional importance through inputs from and consultation with weed scientists and land managers. These weeds were subsequently assessed for their biological control prospects. The paucity of quantitative information of various key aspects (e.g. impacts of weeds) necessitated a qualitative elicitation process that tapped into the expertise of weed scientists, land managers and biological control scientists in a structured and explicit manner. While there is a risk of biases creeping into any such process that relies on experience and expert opinion, safeguards like the structured separation of the identification of weeds of importance and the biological control research enables robust open dialogue about the prioritization of weeds as targets for biological control. In addition, the explicit capture of the rationale (and the associated uncertainties) for placement of weeds into impact categories, determination of management goals and the assessments of biological control prospects relative to those goals enabled the identification of key knowledge gaps. A significant advantage of the approach taken in this study is that position of a given weed in the decision matrices are dynamic (van Klinken et al. 2016). Weeds can move across the “feasibility x likelihood of success” and “biological control prospects x weed impact” matrices through addressing knowledge gaps, thereby relegating/elevating their attractiveness as targets for biological control.

5 References

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6 Appendices

Appendix 1. the structured assessment of feasibility of biological control and likelihood of success of biological control on weeds of the western USA

Target weed	***Alliaria petiolata* (garlic mustard)**	
Impact type	Environmental impacts	
Benefits	Potential culinary interest by 'new age' people	
Impact level	Moderate	Rationale: Bad in some areas, but not in others; Massive impact in the east (affects tall grass restoration); Many scare of it; Grow in full shade
What would successful management look like?	- Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations - Allelopathic impacts reduced - A lesser problem in urban context (eg like hawkweed)	
Agent(s) available (* indicate species on which assessments are based)	*Ophiomyia alliariae* (Diptera: Agromyzidae) – stem boring fly; *Ceutorhynchus alliariae* (Coleoptera: Curculionidae) – stem/crown mining weevil **C. constrictus* – seed feeding weevil *C. roberti* – stem/crown mining weevil **C. scrobicollis* – stem/root mining weevil *C. theonae* – seed feeding weevil	
Expected contribution of biocontrol to the weed's management goals	Based on extensive modelling studies, biocontrol appears promising for largely achieving management goals.	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: Two complementary agents are on the verge of release and have had a great deal of study in a comprehensive international program. Other candidate agents have been identified and in the event that more are needed, the native range is easily accessible.
Level of certainty in assessment	Medium	Rationale: Biocontrol program has been active since 1998. A great deal of information is available. Ecological concerns (supported by hunters) regarding survival of certain native plant species under the combined pressure from deer herbivory and garlic mustard competition seem unlikely to delay the biocontrol program, given the approval of one of the agents already.
Knowledge gaps	1. Host-range testing still underway for *C. constrictus*. 2. More information about ecophysiology (i.e. possible plant resistance to BCAs) could be useful. 3. Are weevils susceptible to parasitism?	
Likelihood of success of a biocontrol project on the weed	High	Rationale: A lot of work has been done over ~20 years, including some seminal modelling work, which suggests a high level of success for the two primary agents. The agents attack different plant parts, both of them (root and seeds) highly damaging for a biennial plant.

Target weed	***Alliaria petiolata* (garlic mustard)**	
Level of certainty in assessment	Medium	Rationale: Based on current knowledge and modelling, likelihood of success seems very high. Only the presence of populations adapted to full-sun raises doubts about colonization of agents in those environments.
Knowledge gaps	1. Information about possible genetic or physiological differences of full-sun vs. shaded populations would be useful. 2. More information about urban invasions would be useful.	
Biocontrol prospects	High	

Target weed	***Berteroa incana* (hoary alyssum)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	Moderate	Rationale: Some in workshop 1 believed this weed should have an impact level of low, because they felt there was limited information on which to suggest it has a higher impact (eg. NV-no data, CO-present, but on watch list, WA-difficult to find and kill). However further discussion resulted in retaining the higher impact rating of M because of; - Toxicity to livestock - The rapid spread rates observed in MT - Concerns about potential impacts with further spread
What would successful management look like?	Reduce competitiveness to; - Limit impacts on hay production - Slow rate of spread - Reduced abundance in pasture	
Agent(s) available (* indicate species on which assessments are based)	Unknown	
Expected contribution of biocontrol to the weed's management goals	Slow rate of spread; reduce abundance in pasture; reduce competitiveness. Biocontrol agents may be most-effective outside of hay production areas, i.e. other disturbed areas. Biocontrol is not likely to improve hay production in already-infested production fields because disturbance is too high. Dicot-specific herbicides needed. Over time, successful biocontrol will reduce the incidence of this weed in hay fields.	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: There are a lot of unknowns about *Berteroa incana*. However the infrastructure and intellectual capacity to initiate biocontrol for this type of weed is very good. However, the host plant test list for invasive Brassicaceae is long-over 100 species. The track record of finding agents for other invasive Brassicaceae that are sufficiently host specific to put through the TAG Petition/USDA-APHIS/USFWS regulatory process in the U.S. is not good. Agents have been found that appear to have a lot of impact on vulnerable plant parts such as roots and rosettes, but then it is found that they are not sufficiently host-specific.
Level of certainty in assessment	Medium	Rationale: Not certain that sufficient resources could be obtained for the very extensive host range testing that would be required, and the process would take a long time (CABi says up to 10 years based on their experience with other invasive Brassicaceae).
Knowledge gaps	1. Survey of extant herbivores in the US including also plant pathogens	

Target weed	*Berteroa incana* (hoary alyssum)	
	2. Weed ecology/demography. Determine impacts other than on pasture quality for livestock 3. Climate match-for western US-to native range, explore that area 4. What are the insects that limit rosette survival? 5. Or what insects at least limit seed production?	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Biocontrol of Brassicaceae is still a black box in terms of success of intentionally introduced agents in the US. Lots of interesting quarantine and native range work but what will happen in field, assuming an agent is approved for release? Have we learned anything from native/non-native insects doing damage to invasive Brassicaceae in US?
Level of certainty in assessment	Medium	Rationale: Lots of unknowns about this weed-ecology-herbivory. No precedent for this weed for WBC, or for Brassicaceae in general.
Knowledge gaps	1. Impact of native or adventive insects in US 2. Impacts in native range	
Biocontrol prospects	Moderate	

Target weed	***Bromus tectorum* (cheatgrass)**	
Impact type	Environmental and Economic impacts	
Benefits	It is used as forage by cattle and wildlife (esp. in the fall/autumn) in rangelands. Holds soil a bit better than other weeds that may replace it.	
Impact level	High	Rationale: Transforms ecosystems; Greater sage grouse habitat impacted; Contaminating seed mixes for restoration; Cannot clean seed stock that it contaminates to remove it; Issue for CO and NV as well, but not included on their lists submitted for this process; If there was a VH Impact Level this weed would fit that.
What would successful management look like?	- Reduced fire frequency and intensity - Reduced seed output and limit recruitment (seed viability and germinability) - Limited seedling vigour - Reduced patch size so that patches; ie less vast/intense fuel loads - Increased plant diversity, so that the system moves towards a more "native" system - Increased ecosystem services (<specific services to be improved related to this weed are needed>)	
Agent(s) available (* indicate species on which assessments are based)	New putative agents	
Expected contribution of biocontrol to the weed's management goals	Not answered	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: Feasibility was assessed as low because *Bromus tectorum* has been a target for biocontrol for years and no effective biocontrol has been identified despite the desperate need throughout the west. This is the most prolific weedy species in the west. Significant amounts of money and time have been spent addressing this species.
Level of certainty in assessment	High	Rationale: I'm familiar with past research and new, unpublished research on *Bromus tectorum* biological control and candidate agents.
Knowledge gaps	1. Mite taxonomy is the biggest knowledge gap. 2. Natural enemy diversity is another potential knowledge gap given the extent of the range.	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: Our level of certainty takes into consideration available knowledge on existing species, but the unknowns surrounding mite exploration moved the certainty in our assessment to medium.
Level of certainty in assessment	Medium	Rationale: *Bromus tectorum* has been long been a target for biological control. The current hope is that mites might be the best option given they are the least understood. The potential for classical biocontrol with insects have likely been exhausted and pathogens have not been effective.
Knowledge gaps	Other taxa that might impact *Bromus tectorum*	
Biocontrol prospects	Low	

Target weed	***Butomus umbellatus* (flowering rush)**	
Impact type	Environmental and Economic impacts	
Benefits	Habitat for warm-water fishes waterfowl forage but many other alternatives; Some ornamental value.	
Impact level	Moderate (Low in survey)	<u>Rationale</u>: Forms monocultures on lakes/channel margins (affects irrigation); Spreading fast; Difficult to control; A local issue but on watch lists; does not like warm water; Harbours predators for salmon; No control options - still exploring options; Both groups agreed that impact is higher than survey result.
What would successful management look like?	- Increase in native plant and fish abundance/diversity due to thinning out of infestations - Water quality improved - Fewer new infestations downstream (reproduction by rhizomatous bulbils) - Less impact on irrigation - Open water habitats colonization by the weed limited - Invasion meltdown weed + non-native fishes (e.g. pike) limited - Quality of recreational use of water bodies improved - Human health effects of snail induced itches reduced (snails use habitat created by the weed)	
Agent(s) available (* indicate species on which assessments are based)	*Bagous nodulosus* (Col.: Curculionidae) – focus primarily on this agent at this time *Bagous validus* (Col.: Curculionidae) *Donacia tomentosa* (Col.: Chrysomelidae) *Phytoliriomyza ornata* (Dipt.: Agromyzidae) *Hydrellia concolor* (Dipt: Ephydridae) *Glyptotendipes viridis* (Dipt.: Chironomidae)	
Expected contribution of biocontrol to the weed's management goals	Biocontrol alone is unlikely to achieve management goals for this weed; it needs to be utilized as part of an integrated weed management program. Since we do not know how it impacts the target in the native range, there is no way to know how it will affect the target weed in North America. Root feeder may reduce biomass and overall density, and other candidates could reduce aboveground biomass.	
Feasibility of undertaking a biocontrol project on the weed	High	<u>Rationale</u>: Overall a good target: a monotypic family, few native plant concerns and apparent host specific agents available. Canadian counterparts share interest in biocontrol program. WA and MT carrying most of the financial burden thus far for the program. [The assessors characterized feasibility as Mod-High, but the workshop discussion settled on High]
Level of certainty in assessment	Medium	<u>Rationale</u>: Not familiar with the program.
Knowledge gaps	1. Specific habitat/climatic limitations to BC 2. Impacts of BC agents? 3. Interactions with other management practices unknown	
Likelihood of success of a biocontrol project on the weed	Moderate	<u>Rationale</u>: These agents (or those tested) are relatively host specific and potentially damaging. [The assessors characterized feasibility as Mod-High, but the workshop discussion settled on Moderate]
Level of certainty in assessment	Medium	<u>Rationale</u>: Based on previous studies seem to be good bc potential; only species in its family in NA; rare in native range.

Target weed	*Butomus umbellatus* (flowering rush)	
		Challenges: vast belowground biomass resource and other ways to compensate for herbivory; broad ecological amplitude and geographical distribution; genotype variability and difficulty in successfully matching with agents.
Knowledge gaps	1. Impact assessment 2. Host specificity 3. Habitat limitations	
Biocontrol prospects	High	

Target weed	*Centaurea diffusa* (diffuse knapweed)	
Impact type	Environmental and Economic impacts	
Benefits	Beekeepers value it but are not dependant on it	
Impact level	Moderate	Rationale: Added to list at workshop; Similar to *C. stoebe* in impacts but not as bad
What would successful management look like?	Similar to *C. stoebe*, but not as much of a chewing disease issue	
Agent(s) available (* indicate species on which assessments are based)	No, but an eriophyid mite, *Aceria centaureae* exits that could be evaluated.	
Expected contribution of biocontrol to the weed's management goals	Biological control may be able to reduce density of the weed, but integrated management will be needed to avoid replacement by other undesirable species.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: Many agents have been released and are established; region of origin (Greece) has been well studied; low probability of finding effective new agents.
Level of certainty in assessment	High	Rationale: Many agents have been released and are established; low probability of finding effective new agents; but perhaps not all agents have been released in this region, or plants might be genetically different, or habitat different, that would open new avenues of research.
Knowledge gaps	Has the whole geographic range been explored in Eurasia?	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: There have already been 13 agents introduced, and we are not aware of other untested prospective agents. The region of origin in northern Greece has been well explored. Thus, likelihood of finding a new agent that would be more effective than existing agents appears low. However, identification of specific habitats or climatic regions to target might justify search for better adapted biotypes.
Level of certainty in assessment	Medium	Rationale: Given that we think there is low likelihood of finding a new agent that would be more effective than existing agents, likelihood of improving control appears low.
Knowledge gaps	Where is this weed a problem? This will help clarify the problem to solve.	
Biocontrol prospects	Low	

Target weed	***Centaurea solstitialis* (yellow starthistle)**	
Impact type	Environmental and Economic impacts	
Benefits	Beekeepers value it highly	
Impact level	High	Rationale: WA and ID have it and it has high impacts, but didn't include it on their lists; Actively spreading ("Don't have it, don't want it"); Concern about potential impacts in areas where it doesn't yet occur but that are suitable habitats; Insufficient biological control
What would successful management look like?	Reduce cover, density and competitiveness to; - Reduce incidence of disease of livestock (e.g. chewing disease) - Improve access of land to livestock and for recreation	
Agent(s) available (* indicate species on which assessments are based)	*Larinus filiformis* *Psylliodes* sp. nr. *chalcomera* *Ceratapion basicorne* cynipid *Puccinia solsititalis*	
Expected contribution of biocontrol to the weed's management goals	Biological control may be able to reduce density of the weed, but integrated management will be needed to avoid replacement by other undesirable species.	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: There is a strong foundation of knowledge on the target weed and prospective agents. Scientists and institutions are currently working on the project. Several prospective agents remain to be evaluated.
Level of certainty in assessment	High	Rationale: Research is currently on-going, sufficient staff and institutions, known prospective agents need to be evaluated.
Knowledge gaps	1. Host plant specificity of prospective agents. 2. Climatic range of prospective agents.	
Likelihood of success of a biocontrol project on the weed	High	Rationale: There is an existing research program, an interesting group of prospective agents, but we cannot predict how many will be approved for release or whether they will multiply enough to impact the weed in all targeted regions. Agents that reduce seed production and that reduce plant survivorship should reduce plant densities which would reduce cover and density of the weed and improve access to recreational areas. Chewing disease is usually associated with presence of the weed when preferred forage is not available; so incidence would be likely to decrease.
Level of certainty in assessment	Medium	Rationale: There are few cases of successful BC of annual weeds, but there is a diverse group of prospective agents to evaluate. The target weed is generally not highly abundant in its native range. We cannot predict whether the prospective agents will be specific enough to approve for introduction or that population densities will be high enough to control the weed.
Knowledge gaps	1. Host plant specificity of prospective agents. 2. Population density of agents after release and impact on the weed population. 3. Climatic limits to effectiveness of agents in US.	
Biocontrol prospects	High	

Target weed	***Centaurea stoebe* (=*C. maculosa*; spotted knapweed)**	
Impact type	Environmental and Economic impacts	
Benefits	Beekeepers value it but are not dependent on it	
Impact level	High	Rationale: Added to list at workshop; Toxic to livestock; Forms monocultures; Affects native and cultivated systems; Difficult to control; Has a broader range than *C. diffusa* Potential for hybridization between the two species
What would successful management look like?	- Incidence of chewing disease in livestock reduced - Increase in pasture quality due to reduction of cover, density and competitiveness of infestations	
Agent(s) available (* indicate species on which assessments are based)	There are many established agents. Including: *Urophora* spp., *Terellia* sp., *Larinus minutus*,, *Larinus obtusus*, *Bangasternus faustii*, *Chaetorellia* sp., *Metznaria*, *Agapeta*, *Cyphocleonus achates*, *Pelochrista* *Sphenoptera yugolslavica*. Unliekly to be any new agents.	
Expected contribution of biocontrol to the weed's management goals	No answer provided.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: *C. stoebe* has been extensively surveyed over the last 50 – 60 years. We expected that all potential BC agents are already known, and that those that are specific enough to permit for release have already been released.
Level of certainty in assessment	High	Rationale: None provided.
Knowledge gaps	Few knowledge gaps	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: *C. stoebe* and its biocontrols have been extensively surveyed and studied for many years. The challenges of managing weeds in disturbed / high resource systems has similarly been well studied. Based on these data and the management objectives, success seems unlikely, and the introduction of additional biocontrol agent is unlikely to contribute to reductions of the target in these areas.
Level of certainty in assessment	High	Rationale: None provided.
Knowledge gaps	Few knowledge gaps	
Biocontrol prospects	Low	

<table>
<tr><th>Target weed</th><th colspan="2">Chondrilla juncea (rush skeletonweed)</th></tr>
<tr><td>Impact type</td><td colspan="2">Environmental and Economic impacts</td></tr>
<tr><td>Benefits</td><td colspan="2">No benefits identified</td></tr>
<tr><td>Impact level</td><td>High</td><td><u>Rationale</u>: Difficult to control; Ruins rangeland; Effective at spreading; Affects row crops and combining in wheat; Very detrimental to native vegetation - displaces species</td></tr>
<tr><td>What would successful management look like?</td><td colspan="2">- Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations, as well as large belowground biomass reserves
- Fewer occurrences of new infestations (by limiting seed spread)</td></tr>
<tr><td>Agent(s) available
(* indicate species on which assessments are based)</td><td colspan="2">I'll be assessing two potential biological control agents that have been identified and are in the testing process.</td></tr>
<tr><td>Expected contribution of biocontrol to the weed's management goals</td><td colspan="2">No answers provided.</td></tr>
<tr><td>Feasibility of undertaking a biocontrol project on the weed</td><td>High</td><td><u>Rationale</u>: The feasibility of undertaking a biocontrol project on CHJU is high because of the work that has been done on this target and the promising candidates that have been identified. With the suite of existing biocontrol agents well established and having reached the extent of their control capabilities, root-feeders are the best option. Now that the genetics have been studied and biotypes have been identified, it is possible to find strains of the mite and rust that will be more biotype-specific.</td></tr>
<tr><td>Level of certainty in assessment</td><td>High</td><td><u>Rationale</u>: I did my MS on this species. I've worked on it for biocontrol feasibility for 15 years. Several other researchers have been involved with this species as well.</td></tr>
<tr><td>Knowledge gaps</td><td colspan="2">1. A study ascertaining the Achilles heel of rush skeletonweed would be beneficial. We assume it's in the roots, but that study hasn't been done.
2. Further exploration in the plant's native range for candidate biological control agents.</td></tr>
<tr><td>Likelihood of success of a biocontrol project on the weed</td><td>Moderate</td><td><u>Rationale</u>: The likelihood of finding a successful biocontrol agent that impacts the plant at a landscape level was assessed as moderate because the newer agents that have been identified as candidates attack the roots (addressing one management concern), but the above-ground seed inhibiting agents have likely been all discovered. There is an opportunity to better match biotypes of the rust and mite to their respective RSW biotypes as well.</td></tr>
<tr><td>Level of certainty in assessment</td><td>High</td><td><u>Rationale</u>: There is a lot of current research and the knowledge base for this target is high for new agents and established agents.</td></tr>
<tr><td>Knowledge gaps</td><td colspan="2">3rd trophic level parasites and predators.</td></tr>
<tr><td>Biocontrol prospects</td><td colspan="2">High</td></tr>
</table>

Target weed	***Cirsium arvense* (creeping thistle)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	High	Rationale: Added to list at workshop; Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations; Group 1 concur with the impact level 'high' from the survey; Group 2 questioned this level but in the end all agreed on 'high' primarily based on impact in row crops
What would successful management look like?	- Hindrances to livestock movement reduced - Increase in pasture quality due to reduction of cover, density and competitiveness of infestations (local spread by rhizomes) - Increase in yield (wheat, alfalfa)	
Agent(s) available (* indicate species on which assessments are based)	Here is the list of biological control agents on *C. arvense*: https://www.ibiocontrol.org/catalog/agents.cfm?weed=58&list=1 None of these have been successful in the United States. No other foreign agents have shown the host specificity required.	
Expected contribution of biocontrol to the weed's management goals	No. Without any successful new agents biocontrol will play a minimal role – possibility that the existing rust fungus may provide some control.	
Feasibility of undertaking a biocontrol project on the weed	Unfeasible/ Unnecessary –Low	Rationale: A total of six biological control agents have been released in North America. There are confamilial native thistle species in North America, which require highly host specific biological control agents. Although root feeders seem to be critical for long term control, they may increase the problems by chopping up horizontal and vertical roots releasing apical dominance and resulting in more aboveground stems. A pathogen attacking the plant/roots would be necessary to achieve management goals. Canada thistle was a project at CABI CH on and off since the 1960s. There is a very low probability or it may even be unfeasible to find any new agents for NA (also see overview by Cripps et al. 2011). From 2009-2015 CABI CH and UK investigated the potential for fungal pathogens together with our UK Centre, but the most promising one selected (a white rust) proved not specific enough (see pdf of Cirsium project from CABI CH website)
Level of certainty in assessment	High	Rationale: CABI has been searching for agents for over 60 years. Lack of host specificity is the major problem.
Knowledge gaps	1. During pre-release risk assessment, non-target impacts, both direct and indirect, should be included on federally (and state?) listed threatened and endangered thistle species in the US. 2. The intraspecific/interspecific relationships among biological control agents should be included.	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: The likelihood of success is very low due to the lack of agents. Considering the extensive work done in the biocontrol of this weed and the poor track record in the US, it is legitimate to conclude that it is a difficult target and chances of successful biocontrol is very low.
Level of certainty in assessment	Low	Rationale: There are no available agents and highly unlikely to find any agents. Certainty is low because there may be the silver bullet pathogen out there somewhere.
Knowledge gaps	1. After 42 releases in the Western US, future monitoring efforts should be maintained on its impact on various abiotic conditions.	

Target weed	***Cirsium arvense* (creeping thistle)**
	2. Although direct non-target impact will be less likely to occur, potential indirect non-target impacts on opportunistic native generalist insect herbivores, including grasshoppers and other defoliators, should be included as the post-release monitoring since the rust infection may change the nutrient profile of *C. arvense*, as indicated in Dyer's woad (*Isatis tinctoria* L.).
Biocontrol prospects	Low

Target weed	***Cynoglossum officinale* (houndstongue)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	High	<u>Rationale</u>: Recreation problems; Toxic to livestock; Can be very invasive (especially in cleared areas); Burrs latch on animal fur and affect wool quality; Grows in difficult to access areas; Very effective at spreading
What would successful management look like?	- Fewer cases of livestock poisoning - Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations - Fewer occurrence of new infestations (due to limitation of spread)	
Agent(s) available (* indicate species on which assessments are based)	*Mogulones crucifer* Pallas (Coleoptera, Curculionidae) UNKNOWN *Mogulones borraginis* F. (Coleoptera, Curculionidae) UNKNOWN NATIVE ORGANISM *Gnophaela vermiculata* (Grote) (Lepidoptera, Eberidae)	
Expected contribution of biocontrol to the weed's management goals	No answers provided	
Feasibility of undertaking a biocontrol project on the weed	Moderate	<u>Rationale</u>: There is a high prospect for feasibility of biological control of *Cynoglossum officinale* in the United States. The plant has been well controlled by a single biocontrol agent, the root-mining weevil *Mogulones crucifer* in Canada and current research aims of clearing the path to re-petition the currently prohibited insect for release in the United States. The weevil is already present in the U.S. via accidental introduction, is unfortunately also intentionally distributed and consequently there is some urgency to conduct respective research. The research addresses legitimate concerns by the U.S. FWS over the potential of non-target attack of confamilial Boraginaceae species, especially T&E listed species. The concerns originally originated from the fact that these species were not or insufficiently tested. This has been addressed. Concerns are now justified because of a recent realignment of *C. officinale* within the Boraginaceae, which places portions of the largest native genera including T&E species closer to *C. officinale*. While *M. crucifer* has a broad fundamental host range, the weevil has not expressed that oligophagy in the filed in North America this far, despite reported and unpublished non-target monitoring. However, the weevil has also not reached areas with much higher native diversities of native confamilial species yet. We conduct research to test native non-target species and to

Target weed	*Cynoglossum officinale* (houndstongue)	
		explain the discrepancy between fundamental and realized host ranges observed in the field. In addition to the root-mining *M. crucifer*, a petition for release of a congener, *Mogulones borraginis*, as seed feeding weevil is immanent. That weevil has a much more narrow fundamental host range. A problem to overcome is that most of the original host range testing relied primarily on choice testing because no-choice tests with the weevil rendered largely invalid test data (if removed from *C. officinale*, the weevil permanently stops laying eggs. It has been shown that the population biology of *C. officinale* is seed-limited and pre-release impact experiments have been conducted and demonstrated a 50% reduction in reproduction due to consumption of inflorescences and developing seeds, respectively. This species is rare and endangered in its native range. A third – unusal – potential candidate for the biological control is a native Eberidae moth, *Gnophaela vermiculata*, which is easy to propagate and can have profound effects on the reproductive output of the weed. The native host plants of the specialist moth include *Mertensia, Hackelia* and possibly (reported) *Myosotis* and *Lithospermum* spp. Apparent competitive effects may be potentially problematic and it is currently not known whether the moth sustains populations on *C. officinale*.
Level of certainty in assessment	Medium	Rationale: Given current concerns over potential non-target attack of *M. crucifer* can be adequately and convincingly addressed, the introduction of both biocontrol agents in the United States should be possible, which in turn should in all likelihood lead to the successful management of the weed.
Knowledge gaps	1. Following the new realignment of the Boraginaceae, there are numerous plant species and genera that should have been tested but never were. With regard to M. crucifer this is relevant because of the insect's demonstrated broad fundamental host range. 2. A second issue with regard to this insect is whether the ecological host range can be expected to stay narrow (in evolutionary terms) given more recent literature on the stability of host selection in the presence of novel hosts.	
Likelihood of success of a biocontrol project on the weed	High	Rationale: All biological control agents have been shown to inflict damage on the individual plant or plant population level. Two of the three arthropods considered are established in the U.S. or adjacent to the U.S. in southwestern Canada. Both classical biological control candidates are weevils and easy to propagate in large numbers. If the host range testing requirements, which are very high for these insects because of the history of the program can be achieved and the USFWS be satisfactorily convinced of the environmental safety of these insects, the weed should be successfully controlled in the U.S.
Level of certainty in assessment	Medium	Rationale: Assuming host-specificity, it is almost certain these agents will be able to control the weed throughout its distribution range in the northwestern U.S.
Knowledge gaps	1. There are questions remaining with regard to the host-specificity of the two classical biological control agents, which are currently addressed.	

Target weed	***Cynoglossum officinale* (houndstongue)**	
	2. Ultimately, it remains to be seen how the USFWS will react once the insects are petitioned.	
Biocontrol prospects	High	

Target weed	***Cytisus scoparius* (Scotch broom)**	
Impact type	Environmental and Economic impacts	
Benefits	Ornamental/nursery trade; Interest as a biofuel?	
Impact level	Moderate	Rationale: Impacts in WA alone cost >100 million in recent economic analysis; ID - Concerned about all brooms
What would successful management look like?	Reduce cover, density and competitiveness to: - Improve recruitment of tree seedlings/saplings in timberland - Reduce incidence of Scotch broom-related allergy (pollen) complaints - Reduce costs/time associated with herbicide use/other management of this weed	
Agent(s) available (* indicate species on which assessments are based)	*Agonopterix assimiella* Broom shoot moth introduced in New Zealand. There could be other agents in the native range.	
Expected contribution of biocontrol to the weed's management goals	Biocontrol could reduce cover, density, and competitiveness of *C. scoparius* (Scotch broom) in natural and disturbed semi-natural ecosystems. However, there are 12 total non-native insects already in the U.S. feeding on this weed, including 10 adventive species. Will adding a shoot-feeding moth really make any differences? Another *Agonopterix* species has not performed well on a different weed in Australia. If biocontrol is successful, it will eventually increase opportunities for recruitment of tree seedlings/saplings in timberland. However, interventions including active replanting and possibly herbicide application to facilitate replanting in advance or contemporaneous with biocontrol will be needed to facilitate improved recruitment. In the long run biocontrol should reduce the costs and effort of herbicide application. It is important to note that Scotch broom also represents a fire hazard, including in the North Bay Area which recently suffered major damage and loss of life due to fires spreading rapidly in dry habitats heavily invaded by Scotch and French broom. Biocontrol is not likely to solve the problem of allergens coming from of Scotch broom because only a few plants are needed to induce this problem and plants in highly disturbed habitats including remnant ornamental plantings will likely escape biocontrol or may even receive protection with insecticides.	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: This species has been under study for over five decades and only a few species (2) have been intentionally introduced. This may be a sign of difficulty of finding host specific herbivores. The moth *Agonopterix assimiella* was able to complete development on two lupins native to the US in NZ tests. Therefore other, new agents, from the native range may be needed.
Level of certainty in assessment	High	Rationale: Uncertainty lies in questions remaining on the specificity of discovered species, hard to colonize or work with, unclear if these difficulties have been resolved by AUS and NZ collaborators.
Knowledge gaps	Cumulative impact of all extant agents.	

Target weed	***Cytisus scoparius* (Scotch broom)**	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Shoot tip-feeding moth from New Zealand introduction, if host range issues are not present in field setting, and if introduced to the US, could contribute to impact if it can survive climates and parasitism/predation. Interactions with extant agents are likely important and should be studied (pre-release or post-release)
Level of certainty in assessment	High	Rationale: The initial 'Likelihood' rating was High because it was assumed that the *Agonopterix* moth would be readily available and was sufficiently host specific. Dialogue with the biocontrol assessment workshop group revealed that it can complete development on at least two native US lupins, and another member of the genus has not performed well in Australia on a different weed. Also, it is not certain how this new agent would interact with the extant introduced and adventive agents in the US.
Knowledge gaps	1. Climate compatibility of shoot/twig feeding moth from NZ based on its native range, NZ and with US climates 2. Impact of *Agonopterix* shoot-feeder 3. Interactions with extant agents	
Biocontrol prospects	Moderate	

Target weed	***Dittrichia graveolens* (stinkwort)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	Low (High in survey)	Rationale: -Bad in CA but not in other states; Big potential for adverse impacts and spreading; Group 1 lowered impact level to 'Low' based on the restricted distribution; this change was upheld by group 2
What would successful management look like?	- Infestation density/monocultures thinned out to open new niches for colonization by desirable species - Fewer occurrences of new infestations (due to limitation of spread)	
Agent(s) available (* indicate species on which assessments are based)	No answer provided	
Expected contribution of biocontrol to the weed's management goals	Biological control may be able to reduce density and invasiveness of the weed, but integrated management will be needed to avoid replacement by other undesirable species.	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: Little is known about the weed and natural enemies in its native range; however, its aromatic composition suggests a high probability of having host-specific natural enemies. We have an existing network to conduct research in southern Europe and Central Asia.
Level of certainty in assessment	High	Rationale: None provided.
Knowledge gaps	1. Genetic diversity of plant in USA, and identification of the native region of origin 2. Natural enemies of the plant in its native range are unknown 3. Vulnerabilities of the target weed are unknown. 4. It is a new weed so we do not know the ultimate geographical limits of its range.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Little is known about the weed and natural enemies in its native range; however, its aromatic composition suggests a high probability of having host-specific natural enemies. We have an existing network to conduct research in southern Europe and Central Asia but not in northern Africa.
Level of certainty in assessment	High	Rationale: None provided.
Knowledge gaps	Same as above	
Biocontrol prospects	Moderate	

<table>
<tr><th>Target weed</th><th colspan="2">Elaeagnus angustifolia (Russian olive)</th></tr>
<tr><td>Impact type</td><td colspan="2">Environmental and Economic impacts</td></tr>
<tr><td>Benefits</td><td colspan="2">Provides shade for livestock; Provide wildlife habitats; Used in windrows; Potential use as biofuel (high BTU); Popular in horticulture; Still seen as a desirable ornamental plants by many</td></tr>
<tr><td>Impact level</td><td>Low (High in survey)</td><td><u>Rationale</u>: Forms local monocultures and impenetrable thickets, but in limited areas; Blocks riparian access; Changes riparian areas by displacing native species; Difficult to control because of suckers; Group 1 changed impact level to 'M' because in their view there was no way it was 'high' since infestations are localized and many still value the plant. Group 2 categorized its impact as 'low' based on similar views to group 1All participants decided to give it 'L' impact level</td></tr>
<tr><td>What would successful management look like?</td><td colspan="2">- Access to riparian areas and watercourses increased
- Water flow improved
- Biodiversity/wildlife values increased
- Reduced herbicide use in wetlands/watercourses and natural areas</td></tr>
<tr><td>Agent(s) available
(* indicate species on which assessments are based)</td><td colspan="2">- 55 species attack Elaeagnus species; most herbivores are in the order Coleoptera (primarily in the families Curculionidae, Cerambycidae, Chrysomelidae), Lepidoptera (Lymantriidae, Gelechiidae) and Homoptera (Psyllidae and scale insects).
- Aceria angustifoliae (Turkey) - eriophyid mite; induces gall-like symptoms on leaves, flowers and young fruits; does not defoliate whole trees, but is likely to have a negative impact on reproductive output; based on open-field host-range tests at Shirvan, Iran inoculation of target trees with this agent is quite difficult, so establishment will likely be problematic; average number of mites found per leaf was low; might reduce fruit production in infested branches by as much as 50–75%; no-choice host-specificity tests showed a minor number of mites/leaf on a North American congener of Russian olive, Elaeagnus commutata (silverberry) and on the cultivated species Hippophae rhamnoides; these species were not attacked under open-field test conditions, but another invasive species, Elaeagnus umbellata (autumn olive), was.
- Aceria elaeagnicola (Serbia, Uzbekistan) - eriophyid mite; feeding on the lamina of the target weed's leaves causes hemispheric protrusions on the leaves.
- Ananarsia eleagnella (Uzbekistan, northeastern Iran) – gelechiid moth; eggs are deposited directly onto the fleshy part of Russian olive fruit; larvae of the first generation mine inside the shoot tips of young shoots; larvae feed on the fruit pericarp and to a lesser degree on seeds; leads to premature wilting and shedding of the fruits but viability of seeds of attacked fruits unknown; larvae have a relatively broad fundamental host range and under no choice conditions fed on fruits of relatively distantly related plant species, including apple and hawthorn; no non-target larval feeding occurred during single-choice tests with Russian olive and test species fruits provided in same petri dish; moth has never been recorded feeding on fruits of cultivated or ornamental species of the family Rosaceae; no evidence for attack on sea buckthorn; evidence indicates that moth has a narrow ecological host range.
- Temnocerus elaeagni (Uzbekistan) – rhynchitid beetle; females oviposit into young shoots or leaves where the larvae develop; infested shoots start wilting early in the season and do not produce flowers; host-range thought to be restricted to the genus Elaeagnus.
- geometrid moth (Turkey, Uzbekistan) – trees significantly defoliated by larval mining.</td></tr>
</table>

<table>
<tr><th>Target weed</th><th colspan="2">Elaeagnus angustifolia (Russian olive)</th></tr>
<tr><td></td><td colspan="2">- Altica suvorovi (tentative identification; western China) – chrysomelid beetle; heavy feeding damage caused by adult and larval stages.
- Euzophera alpherakyella (western China) – shoot boring moth,
- Various weevils, psyllids, an eriophyid mite, several pathogens (western China).</td></tr>
<tr><td>Expected contribution of biocontrol to the weed's management goals</td><td colspan="2">Biocontrol with the leaf and flower-feeding mite Aceria angustifoliae and the fruit-feeding moth Ananarsia eleagnella agents over a prolonged period (10-30 yrs), could reduce dense thickets of E. angustifolia saplings by reducing the seed bank, and thereby increase access to riparian areas if seed production is reduced. Clearing of watercourses and ditches for water conservation and flood control, and any riparian restoration project requiring less than a 10-yr timeframe, is likely to continue to require herbicides and mechanical control of saplings in coordination with biocontrol of mature trees. A long-term decline in Russian olive density will increase colonization by native plants and thus habitat value. There is a possibility that the release and success of these two agents feeding on reproductive parts could lead to new dialogue for release of additional agents that feed on vegetative parts. To date, USFWS has indicated that no such agent will be approved, because of concern for the yellow-billed cuckoo which nests in Russian olive (even though it is an inferior host, as prey availability is absent in Russian olive thickets). Restoration projects involving targeted integrated control and active planting of native trees suitable for nesting could set the stage for future biocontrol using agents that feed on vegetative plant parts and attack saplings.</td></tr>
<tr><td>Feasibility of undertaking a biocontrol project on the weed</td><td>High</td><td><u>Rationale</u>: The rating of high assumes that CABi or another lab in western or eastern Europe already has the two agents that have already been evaluated- the leaf and flower-feeding mite Aceria angustifoliae and the fruit-feeding moth Ananarsia eleagnella-in colonies, or that they can be obtained through European collaborators from the native range-potentially dangerous/difficult areas to collect. The conflicts of interest in regards to human use of Russian olive are not a major concern for the two agents that are farthest along in testing, as they both feed mostly or entirely on reproductive plant parts. Ornamental trees could be protected with acaricide or insecticide as needed.</td></tr>
<tr><td>Level of certainty in assessment</td><td>High</td><td><u>Rationale</u>: I have submitted grant proposals annually for nearly a decade from the Montana Noxious Weed Trust Fund to support CABI's overseas efforts to identify and test candidate agents for Russian olive. I also co-organized and co-led a 3-day symposium dedicated to Russian olive ecology and management in 2013.</td></tr>
<tr><td>Knowledge gaps</td><td colspan="2">1. Life history of mite in relation to host plant phenology, and overwintering
2. Develop technology to easily infest plants with mites
3. Verify narrow HR of the most advanced agents-mite and moth. Verify no damage to two native congenerics and two ornamental non-native ones, plus one other weedy one (E. umbellata)
4. Molecular ID of the mites, especially since both feed on leaves
5. Determine how the mite is dispersed in native range if possible
6. Identifying ways to improve establishment and redistribution of mite agents on the target weed</td></tr>
</table>

Target weed	***Elaeagnus angustifolia* (Russian olive)**	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: The two agents reducing reproduction (the flower and leaf-galling/rolling mite *A. angustifolia* and the fruit and seed-feeding moth *A. eleagnella*,, will attack reproductive parts for the most part, and so their impact will be very slow and may not develop at all depending on climatic suitability. Reduction of stand density will likely requires 10-30 years. Herbicides and mechanical control will continue to be needed until then to clear waterways and to initiate riparian restoration. In the future, there is a possibility to get additional agents but anything that attacks vegetative parts and kills plants may not clear regulatory process.
Level of certainty in assessment	High	Rationale: A lot is known about the target weed. Two agents have been studied and will soon be petitioned (at least the mite).
Knowledge gaps	1. Publish impact studies for the mite and moth 2. Determine climate match of native range collection locations and intended release area 3. Knowledge of seedbank including longevity and regional variation. Long-lived seedbank may further delay impact of flower- and fruit-feeding agents. 5. Russian olive pathogen in N. America. Native or non-native? Impact 4. Surveys for native and adventive insects in the US	
Biocontrol prospects	High	

Target weed	***Euphorbia esula* (*E. virgata*?) (leafy spurge)**	
Impact type	Environmental and Economic impacts	
Benefits	Used as an ornamental in some urban areas; Valued to some degree by beekeepers	
Impact level	High	Rationale: Toxic to livestock; Forms monocultures in riparian areas (eg CO rivers) and rangeland, even when well managed; Both groups fully endorsed the 'H' impact level
What would successful management look like?	- Reduce cover, density and competitiveness (and belowground biomass/root water soluble carbohydrate storage) to: - improve biodiversity of riparian areas and desirable plants species in rangeland, reduce chemical use costs, - limit occurrence of new infestations (due to vegetative spread) - Reduced herbicide use in wetlands/watercourses and natural areas	
Agent(s) available (* indicate species on which assessments are based)	*Chamaesphecia astatiformis* *Chamaesphecia crassicornis* *Chamaesphecia hungarica* *Aphthona abdominalis* (there are some indications that this species might not be specific enough) *Pegomya* spp. (*Pegomya curticorni* & *P. euphorbiae*) (taxonomy requires clarification) Note: These are not new agents, but agents that had already been released in North America, but that did not establish.	

Target weed	***Euphorbia esula*** **(*E. virgata*?) (leafy spurge)**	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: Re-studying and re-introducing herbivores that were already investigated as biocontrol agents in the past should be a relatively easy task because studies on the biology and host-specificity have already been conducted. Finding new agents will probably be more difficult. But since only parts of the native range of *E. esula* have already been surveyed, new agents could potentially be found in areas not surveyed yet.
Level of certainty in assessment	Medium	Rationale: None provided.
Knowledge gaps	1. What are the habitats/areas to be targeted for biocontrol? 2. Which is the species to be targeted for biocontrol, i.e. is the *E. esula* (=*E. virgata*) species that can be found in North America only one species or a species complex? What is the genetic diversity of the target species? Can the agents survive on all taxa/genotypes invasive in North America or are there any resistant taxa/genotypes?	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: If the agents establish in North America they could potentially have a high impact on the target weed since they are attacking the roots and at least some of them have been observed to be able to completely destroy plants in the native range. *Ch. astatiformis* and *Ch. hungarica* might have failed to established in North America because pre-release studies revealed that *E. esula* from North America are be a suboptimal host for these two species (Gassmann and Tosevski 1994).
Level of certainty in assessment	Low-Medium	Rationale: Level of certainty is low because the likelihood of success depends on whether the agents will be able to establish in the invaded range or not. If they establish they could potentially have a high impact on the target weed, however there is the risk that they fail again to establish.
Knowledge gaps	1. What are the potential reasons why the agents did not establish when they had been introduced before? 2. Will the agents be well adapted to the areas/habitats and genotypes that are targeted? 3. Are the agents specific enough, regarding the current (stricter) requirements of regarding host-specificity?	
Biocontrol prospects	High	

Target weed	***Hypericum perforatum*** **(St John's wort)**	
Impact type	Environmental and Economic impacts	
Benefits	Medicinal herb; Beekeepers?	
Impact level	Moderate	Rationale: Added to list at workshop as it is more widespread than that indicated by its presence on only one state list; ID - present along roadways and forest margins; WA – scattered; WY – present; CO & NV - ?
What would successful management look like?	Reduce cover, density and competitiveness to; - Reduce density in forestry and rangeland production systems	

Target weed	***Hypericum perforatum* (St John's wort)**	
Agent(s) available (* indicate species on which assessments are based)	We are assessing additional agents that are under investigation for SJW. The established agents (*Agrilus hyperici, Aphis chloris, Aplocera plagiata, Chrysolina hyperici, C. quadrigemina, Zeuxidiplosis giardi*) offer control ranging from very good to moderate.	
Expected contribution of biocontrol to the weed's management goals	No answer provided.	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: The feasibility is high because of the work that has been done by the primary researcher (CABI). Candidates have been identified and there are few obstacles that cannot be overcome given past research efforts. *Chrysolina quadrigemina* collected from its eastern distribution for higher altitude sites has been identified. *C. varians* was a failed establishment, but likely little effort was put into this biocontrol agent because of the success of others. There is a wide distribution in Europe so there is a greater chance of finding a climatically adapted strain. *C. brunsvicensis* host range testing was done for Australia, but not the US. There might be a climatic match. Gall midges, sawflies, and a Lep have been identified as potential new candidate agents. There are four additional biocontrol agents released in Australia and NZ, although they were not successful there.
Level of certainty in assessment	High	Rationale: The system is well known and the primary researcher (Hariet Hinz – CABI) has provided thorough background information.
Knowledge gaps	1. Why existing biocontrol is not working in some locations. Factors affecting lack of effectiveness. 2. Change in management practices. 3. Is there something influencing current biocontrol agent health? 4. Climate change influences. 5. Evolutionary adaptations of SJW to existing suite of BCAs.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Likelihood for success was assessed as medium because we don't know the reason for regional failure of biocontrol. Given that knowledge gap, it is difficult to assess potential biocontrol agents or different strains of existing biocontrol agents. However, there are several options that look promising and could be considered to address regional failures.
Level of certainty in assessment	Medium	Rationale: There are unknowns surrounding the regional failures of existing biocontrol agents and how these factors would influence any new potential biocontrol agents.
Knowledge gaps	1. Environmental characteristics impacting existing biocontrol agents and SJW. 2. Climate change influences on biocontrol and SJW.	
Biocontrol prospects	High	

Target weed	***Iris pseudacorus* (yellow flag iris)**
Impact type	Environment
Benefits	Very popular ornamental plant - grown in ponds for its beauty Still being sold and purchased

Target weed	***Iris pseudacorus* (yellow flag iris)**	
Impact level	Moderate (Low in survey)	<u>Rationale</u>: Forms monocultures; Widespread wetland weed; Limited adaptation; Recruitment can occur after 2 yrs of drought; Both groups agreed that impact is higher than survey result; Most likely ended up as 'low' because it is still limited in distribution
What would successful management look like?	- Reduce cover, density and competitiveness to: increase native plant and fish abundance/diversity, reduce impact on irrigation - Fewer new infestations downstream (prevent spread)	
Agent(s) available (* indicate species on which assessments are based)	Not known	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Low	<u>Rationale</u>: The feasibility in terms of access and availability of collaborative links and infrastructure is very good, most if not all other attributes of this weed make it unlikely that a successful biological control programme will ever be achieved. Despite this species being listed as a noxious weed in some states it is still highly valued as a horticultural species which through a conflict of interest will pose serious limitations on the initiation of a biological control programme. There are also several hybrids/variations of this species that would cause problems with host specificity of the agents selected. In addition there are several native Iris species in North America and with the current regulatory climate and increased levels of specificity expected do not improve chances of finding suitable agents.
Level of certainty in assessment	Medium	<u>Rationale</u>: Much of the rational drawn upon here is from expectation rather than taking from an existing programme elsewhere. There is little literature specific to biological control of *Iris pseudacorus* to draw upon.
Knowledge gaps	1. Addressing the conflict of interest with the horticultural industry, assessment of the likelihood of overcoming these issues. 2. Potential agent host specificity, this would need to be extremely strict since several native and economically important Iris species in the USA	
Likelihood of success of a biocontrol project on the weed	Low	<u>Rationale</u>: If specificity is assumed the precedent (Purple loosestrife) that success could be achieved, however, with a low level of certainty. Although there are several phytophagous invertebrates as well as pathogens associated with *I. pseudacorus* in the native range it is quite unlikely that all the desirable attributes to meet the management goals will be met by a suit of agents that possess the required host specificity.
Level of certainty in assessment	Low	<u>Rationale</u>: Much of the rational drawn upon here is from expectation rather than taking from an existing programme elsewhere. There is little literature specific to biological control of Iris pseudacorus to draw upon.
Knowledge gaps	1. Potential agent host specificity, this would need to be extremely strict since several native and economically important *Iris* species exist in the USA 2. Potential agent impact to meet management goals.	
Biocontrol prospects	Low	

Target weed	***Isatis tinctoria* (dyer's woad)**	
Impact type	Environmental and Economic impacts	
Benefits	Used as a source of dye	
Impact level	Moderate (Low in survey)	Rationale: -While some in the group were happy to retain the survey impact level of L because it didn't appear to widely distributed in the region, others successfully argued that its impacts were M because of the following reasons; Concerns of this species in UT were not captured by the survey; It was spreading rapidly ("on the move"); Concern about potential impacts should it move into other climatically suitable habitats.
What would successful management look like?	- Reduce seed dispersal - Reduce rosette density - Improve forage value of pasture	
Agent(s) available (* indicate species on which assessments are based)	*C. rusticus*; *C.* peyerimhoffi; Metaculus sp.	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: Pre-release experiments demonstrate substantial impact of both weevil species; Taxonomic isolation of Isatis to other mustards. But close to strep and caulanthus; Isatis does not grow on serpentine soils where some T&E relatives thrive, so is our specificity testing done on regular soil valid?; A suite of agents are identified. [The assessors characterized feasibility as Mod-High, but the workshop discussion settled on Moderate]
Level of certainty in assessment	High	Rationale: None provided
Knowledge gaps	1. Demographic model of target weed, sensitive life stages. 2. Host specificity of the mite, and it is hard to quantify efficacy.	
Likelihood of success of a biocontrol project on the weed	High	Rationale: Likelihood was rated as high due to: - The invasion occurs in relatively few habitats and climates. - The suite of agents is likely to effectively control the plant - The invasive is seed limited But, a T&E species was attacked in no-choice testing of the seed feeding agent (but not in open field testing and the T&E grows on an island off of southern CA). Not sure how any seed attack on T&E will play out with regulators, even if seed is just damaged by oviposition probing. Synchrony between Isatis and T&E on island also very different, and Isatis is not nearby, only closest populations are in northern CA. We are not sure how TAG will react to host specificity experiment results. For the root feeding weevil, high standards required for Brassicaceae (lots of native species tested) biocontrol agents causes a level of uncertainty.
Level of certainty in assessment	Medium	Rationale: None provided
Knowledge gaps	1. We are not yet sure of the host specificity of the suite of agents. 2. Additional tests satisfactorily demonstrating environmental safety.	

Target weed	*Isatis tinctoria* (dyer's woad)
Biocontrol prospects	High

Target weed	*Lepidium draba* (=*Cardaria draba*; whitetop/hoary cress)	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	High (Moderate in survey)	Rationale: While some in the group were happy to retain the survey impact level of M, others successfully argued that its impacts were H because of the following reasons; MT & ID - huge economic impacts in hayfields; WY- present but not on their list as they deal with all *Cardaria* spp. as a complex; WA - impacted by this weed, but hard to differentiate impacts of this from other *Cardaria* species because of difficulties with species diagnostics
What would successful management look like?	Reduce cover, density and competitiveness to: - Reduce impacts to forage production (hay quality and saleability) - Improve forage availability for rangeland livestock and wildlife - Limit risk of spread associated with livestock movement (as seeds are moved with livestock, and reducing reproductive output and general cover may reduce this risk)	
Agent(s) available (* indicate species on which assessments are based)	*Aceria drabae* (eriophyid mite) *Ceutorhynchus cardariae* (gall forming weevil) *C. turbatus* (seed feeding weevil) Knowledge on these three agents was used for the likelihood assessment	
Expected contribution of biocontrol to the weed's management goals	Not answered	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: It was clear from the beginning that the biocontrol project against this weed would not be easy. Experience has shown that it might be even harder than imagined, especially in view of increasing requirements for levels of host-specificity combined with the huge number of crop and native species, including T&E's. Although the possibility of finding new agents, especially maybe fungal pathogens, should not be excluded a lot has been done and a lot of funding spent. One agent is close to being released (*Aceria drabae*), one petition will be re-submitted in 2018 (*C. cardariae*) and a third agent is being tested (*C. turbatus*). If it will be possible to release these three, or at least a subset of them, I feel that this will already be an achievement and I am wondering whether it would be worth spending more funding considering the relatively low chance of finding additional agents and the huge effort connected with it.
Level of certainty in assessment	High	Rationale: We have been working on *L. draba* biocontrol since 2001 and simply have a lot of experience on this weed (at least the biocontrol side).
Knowledge gaps	1. Do fungal pathogens exist that may have potential 2. Surveys in areas not surveyed yet	

Target weed	***Lepidium draba*** **(=*Cardaria draba*; whitetop/hoary cress)**	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Despite the fact that the three agents prioritized have many attributes that should make them a successful suite of agents, *L. draba* has an enormous regrowth potential, especially when growing on wet and fertilized sites. In addition, no detailed population models exist for *L. draba* to determine sensitive life stages and further predict likely impact. We can also not be 100% sure that the agents will 1) establish and 2) reach the required densities over wide enough areas. Moreover there will always be highly disturbed areas that *L. draba* can re-invest where the agents will likely not do so well. So success will definitely be habitat dependent.
Level of certainty in assessment	Medium	Rationale: Not provided
Knowledge gaps	1. No demographic model available for *L. draba* to know exactly which life stages to target for successful population reduction 2. More precise knowledge on the climate requirements of the selected agents to predict their establishment success and population increase 3. Dispersal capabilities of selected agents	
Biocontrol prospects	Low	

Target weed	***Lepidium latifolium*** **(broadleaved pepperweed)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	High (Moderate in survey)	Rationale: Hard to control; Invades floodplain/marsh; Forms monocultures; Affects riparian and wildlife areas; Found in row crops; Affect flood irrigation lines; Generates a lot of dead matter residues; Group 1 increased impact level to 'high' based on impact rationale and this change was supported by Group 2
What would successful management look like?	- Infestation density/monocultures thinned out to open new niches for colonization by desirable species - Increase in forage production and quality - Erosion reduced in riparian areas (currently caused by the large root mass - Water losses mitigated - Reduced herbicide use in wetlands/watercourses and natural areas	
Agent(s) available (* indicate species on which assessments are based)	*Ceutorhynchus marginellus* *Melanobaris* sp. near *semistriata* *Lasiosina deviata*	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: The feasibility was assessed to be low to medium and after discussions with the whole group it was decided

Target weed	*Lepidium latifolium* (broadleaved pepperweed)	
		that it is medium. A biocontrol project against this weed is not easy because: • There are many closely related species, some of them are T & E or crops. • *L. latifolium* has an Asian distribution, which makes surveys logistically more difficult and less is known about herbivores attacking this species (e.g. compared to the closely related *Lepidium draba*, which has an European distribution). However; • Surveys revealed some potential agents where it is worth continuing research and • Not the whole native range has been surveyed yet and additional survey in new areas might reveal new potential agents.
Level of certainty in assessment	Medium	<u>Rationale</u>: None provided
Knowledge gaps	1. Host-specificity of agents? 2. What level of non-target attack by agents will be accepted? 3. Would surveys in new areas reveal new agents? 4. Is it possible to get export permits from countries not surveyed so far?	
Likelihood of success of a biocontrol project on the weed	Moderate	<u>Rationale</u>: Assuming that all agents are specific enough, they are expected to contribute to the management goals for *L. latifolium* because the agents attack multiple parts of the plants (above- and belowground) and because at least one species (*C. marginellus*) has a wide distribution in the native range and is therefore expected to be able to adapt to a wide range of climates. However, *L. latifolium* can be found in a wide range of habitats, land-use types and climates, and it is unlikely that biocontrol will be successful in all of them.
Level of certainty in assessment	Medium	<u>Rationale</u>: None provided
Knowledge gaps	1. host specificity of agents already identified and of agents not identified yet. 2. information on biology and impact of agents	
Biocontrol prospects	Moderate	

Target weed	*Lepidium* species (other than *L. draba*; hoary cress)
Impact type	Environmental and Economic impacts
Benefits	May provide some wildlife habitats; Cattle graze on it but farmers do not rely on it as feed

Target weed	***Lepidium* species (other than *L. draba*; hoary cress)**	
Impact level	Moderate (High in survey)	Rationale: Not as bad as *L. draba*; Not much known about these species, which are difficult to distinguish from each other; Group 1 reduced the level of impact to 'M'. This was questioned by group 2, but because of the high level of uncertainty in determining the impact of these species, the group accepted the change to 'M'
What would successful management look like?	- Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations - Fewer occurrences of new infestations (by limiting spread-seeds and rhizomes)	
Agent(s) available (* indicate species on which assessments are based)	*Aceria drabae* (eriophyid mite) *Ceutorhynchus cardariae* (gall forming weevil) *C. turbatus* (seed feeding weevil) Knowledge on these three agents was used for the likelihood assessment	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: It was clear from the beginning that the biocontrol project against this weed would not be easy. Experience has shown that it might be even harder than imagined, especially in view of increasing requirements for levels of host-specificity combined with the huge number of crop and native species, including T&E's. Although the possibility of finding new agents, especially maybe fungal pathogens, should not be excluded a lot has been done and a lot of funding spent. One agent is close to being released (*Aceria drabae*), one petition will be re-submitted in 2018 (*C. cardariae*) and a third agent is being tested (*C. turbatus*). If it will be possible to release these three, or at least a subset of them, I feel that this will already be an achievement and I am wondering whether it would be worth spending more funding considering the relatively low chance of finding additional agents and the huge effort connected with it.
Level of certainty in assessment	High	Rationale: We have been working on *L. draba* biocontrol since 2001 and simply have a lot of experience on this weed (at least the biocontrol side). All *L. draba* biocontrol candidates were tested against and accepted *L. chalepense* and *L. appelianum* as hosts.
Knowledge gaps	1. Areas in which *L. chalepense* and *L. appelianum* occur in Europe that have not been surveyed for unique biocontrol candidates 2. Surveys in areas not surveyed yet	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Despite the fact that the three agents prioritized have many attributes that should make them a successful suite of agents, *L. chalepense* and *L. appelianum* may have enormous regrowth potential, especially when growing on wet and fertilized sites. In addition, no detailed population models exist for any invasive *Lepidium* species yet to determine sensitive life stages and further predict likely impact. We can also not be 100% sure that the agents will 1) establish and 2) reach the required densities over wide

Target weed	*Lepidium* species (other than *L. draba*; hoary cress)	
		enough areas. Moreover there will always be highly disturbed areas that *L. draba* can re-invest where the agents will likely not do so well. So success will definitely be habitat dependent.
Level of certainty in assessment	Medium	<u>Rationale</u>: None provided
Knowledge gaps	1. No demographic model available for invasive *Lepidium* species to know exactly which life stages to target for successful population reduction 2. More precise knowledge on the climate requirements of the selected agents to predict their establishment success and population increase 3. Dispersal capabilities of selected agents	
Biocontrol prospects	Low	
Notes	*Lepidium chalepense, L. appelianum* were treated at times as one taxon and may be more easterly and southerly distributed than *L. draba.*	

Target weed	*Leucanthemum vulgare* (oxeye daisy)	
Impact type	Environmental and Economic impacts	
Benefits	While not sold anymore, it is valued as an ornamental by those that already have it.	
Impact level	Moderate	<u>Rationale</u>: Impacts riparian areas and hayfields (high moisture areas)
What would successful management look like?	- Reduce density and vigour to increase abundance of other species - Reduce seed spread - Reduce presence in urban context (like yellow and orange hawkweeds)	
Agent(s) available (* indicate species on which assessments are based)	*Dichrorampha aeratana* – root moth *Dichrorampha consortana* – stem attacking moth *Dichrorampha baixerasana* – root feeding moth *Oxyna nebulosa* – galling fly These species have been identified as potential biocontrol agents based on literature records and feeding niche.	
Expected contribution of biocontrol to the weed's management goals	An integrated control program will be needed for this system. Biological control is expected to play a major role in natural areas. Our assessment is based on the prediction that biocontrol may address the reduction in density and competitiveness and reproductive output and as a result improve biodiversity.	
Feasibility of undertaking a biocontrol project on the weed	Moderate	<u>Rationale</u>: Two of the agents are currently being studied by CABI while for the other two large enough populations still need to be identified to start investigations on the biology, impact and host-specificity. The fact that L. vulgare has a European distribution facilitates surveys. Both of the agents that are being studied also attack Shasta daisy, but to a much lower degree than oxeye daisy. At least one of them can complete development on Shasta daisy, but has no visible impact on this ornamental. Therefore the group discussed energetically whether this is a "show stopper" due to conflict of interests with ornamental industry. Some in the room viewed this as not an issue and therefore should be HIGH

Target weed	*Leucanthemum vulgare* (oxeye daisy)	
		while others thought this was not going to be approved by regulators and therefore should be LOW, thus the group settled on Moderate.
Level of certainty in assessment	Medium	Rationale: Based upon current studies.
Knowledge gaps	1. Will some attack by biocontrol agents on Shasta daisy be accepted by APHIS? 2. Demographics of ox-eye daisy 3. Economic/ ecological importance of oxeye daisy	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: There is a suite of candidate agents that may, combined, address the management goals. Considering the multiple species under consideration, the likelihood increases due to potential impacts. *Dichrorampha* reduces biomass and seed production. The insects should establish well in pasture and natural areas. Historically, root moths may generally have lower impact compared to other feeding guilds.
Level of certainty in assessment	Medium	Rationale: None provided
Knowledge gaps	1. Additional information regarding habitat requirements 2. Additional life history information	
Biocontrol prospects	Moderate	

Target weed	*Linaria dalmatica* (Dalmatian toadflax)	
Impact type	Environmental and Economic impacts	
Benefits	Beekeepers may value it; Some value its "pretty" status; Nurseries are still able to sell it online (it is illegal to sell in states where it is on the Noxious Weeds list)	
Impact level	High	Rationale: Added to list at workshop because it is widespread (CO, NV, ID and WA have it but didn't include it on their lists submitted to this project); Hybridization with *L. vulgaris*; CO and OR indicated that it is already well managed and in control in those suggesting that it may be have a low impact in those states
What would successful management look like?	Reduce cover, density and competitiveness to; - Limit rhizomatous spread and reduce water soluble carbohydrate reserves - Reduce density of belowground biomass - Limit postfire recruitment (it invades quickly after fire) - limit its impacts of CRP lands	
Agent(s) available (* indicate species on which assessments are based)	*Rhinusa rara* stem galler *Mecinus laeviceps* ssp. *laeviceps* *Mecinus peterharrisi*	
Expected contribution of biocontrol to the weed's management goals	No it will need to be part of an integrated weed management program. Biocontrol will definitely affect cover, density but most importantly, impact competitive ability of the target weed. Spread through rhizomes will be limited because larval feeding impedes sequestration of carbohydrates in the roots. If biocontrol is established in the vicinity, it can help to suppress domination of Dalmatian toadflax post-fire (Sing, unpublished data).	

Target weed	***Linaria dalmatica* (Dalmatian toadflax)**	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: Well documented through extensive long term monitoring and research demonstrating high likelihood of impact and host specificity in North America. Extensive network of established monitoring plots have identified limitations of current *L. dalmatica* biocontrol program and will enable consortium to identify where to focus future efforts.
Level of certainty in assessment	High	Rationale: None provided
Knowledge gaps	1. Why does it work in some places really well but not very well at all in other locations (e.g., MT, AB, CO)? 2. How widespread is hybridization and how does that impact efficacy of existing, candidate biocontrol efforts and other management strategies?	
Likelihood of success of a biocontrol project on the weed	High	Rationale: Significant amount of native range data and host specificity test results increase confidence in candidate agents having an impact and being appropriately host specific. Promising results with the already approved and released *Mecinus* species but overwintering or late summer mortality has inhibited overall success with these agents. Biology of agents under development should overcome some challenges posed by extreme environmental conditions in North America.
Level of certainty in assessment	High	Rationale: None provided
Knowledge gaps	1. How will hybrids be affected by these agents? 2. How will grazing affect candidate agents? 3. How will NA parasitoids/predators affect candidate agents? 4. Will climate hurdles be solved with stem galling agents? 5. How well will candidate agents integrate with existing management practices?	
Biocontrol prospects	High	

Target weed	***Linaria vulgaris* (yellow toadflax)**	
Impact type	Environmental and Economic impacts	
Benefits	Sold in horticulture (in seed mix); Past medicinal/dye use	
Impact level	High	Rationale: Similar to oxeye daisy but higher impacts; Hybridization with *L. dalmatica*; Higher elevation areas invaded; Forested areas impacted; NV- present but not included on list, biological control present in state
What would successful management look like?	- Reduce cover, density and competitiveness to; - Reduce seed production - Weaken root system to reduce competitiveness	
Agent(s) available (* indicate species on which assessments are based)	*Mecinus heydenii* Agent is also known to be acceptable and suitable host for hybrid toadflax under greenhouse conditions.	
Expected contribution of biocontrol to the weed's management goals	Biocontrol has definitely affected cover and density allowing competitive ability of native flora to overwhelm infestations of the target weed. If biocontrol is established in the vicinity, recolonization will help to suppress domination of yellow toadflax post-fire.	

Target weed	***Linaria vulgaris* (yellow toadflax)**	
Feasibility of undertaking a biocontrol project on the weed	High	Rationale: Well documented through extensive long term monitoring and research demonstrating high likelihood of impact and host specificity in North America. Extensive network of established monitoring plots have identified limitations of current *L. vulgaris* biocontrol program and will enable consortium to identify where to focus future efforts.
Level of certainty in assessment	High	Rationale: None provided
Knowledge gaps	1. Why is *Mecinus janthinus* establishment glacially slow in some areas? 2. How widespread is hybridization and how does that impact efficacy of existing, candidate biocontrol efforts and other management strategies?	
Likelihood of success of a biocontrol project on the weed	High	Rationale: Significant amount of native range data and host specificity test results increase confidence in candidate agents having an impact and being appropriately host specific. Promising results with the already approved and released *Mecinus* species but overwintering or late summer mortality has inhibited overall success with these agents. Biology of agents under development should overcome some challenges posed by extreme environmental conditions in North America.
Level of certainty in assessment	High	Rationale: None provided
Knowledge gaps	1. How will hybrids be affected by these agents? 2. How will grazing affect candidate agents? 3. How will NA parasitoids/predators affect candidate agents? 4. Will climate hurdles be solved with stem galling agents? 5. How well will candidate agents integrate with existing management practices?	
Biocontrol prospects	High	

Target weed	***Myriophyllum spicatum* (Eurasian watermilfoil)**	
Impact type	Environmental and Economic impacts	
Benefits	Still popular in the aquarium trade (or aerated ponds) in some states; Provide habitat for fish and waterfowls	
Impact level	Moderate (Negligible in survey)	Rationale: Block water channels; Bad in lakes; Difficult to kill; Spread via fragments; Hybridized with native *Myriophyllum* sp. and hybrids reported to be difficult to control There are reports of bears drowning because of this weed; In CA was the worst aquatic weed before *Hydrilla* invaded; In CO very concerned on how to control it; Locally present in NV but important; In WA most widespread aquatic weed; Group 1 changed impact level to 'M' because in their view there was no way it was 'negligible' Group 2 categorized its impact as 'high' based on the outlined impact rationale. All participants decided to give it 'M/H' impact level but recommended consultation with managers specialized in aquatic weed management. Retained as Moderate in matrix.
What would successful management look like?	- Infestations thinned out to increase native plant and fish abundance/diversity - Water quality improved	

Target weed	***Myriophyllum spicatum* (Eurasian watermilfoil)**	
	- Fewer new infestations downstream (reproduction by fragments) - Less impact on irrigation - Open water habitats colonization by the weed limited - Invasion meltdown weed + non-native fishes (e.g. pike) limited - Quality of recreational use of water bodies improved - drowning risks to bears and swimmers reduced - Human health effects of snail induced itches reduced (snails use habitat created by the weed)	
Agent(s) available (* indicate species on which assessments are based)	None known at this stage, but note that there is a native biocontrol agent on northern milfoil (*Euhrychiopsis lecontei*), and it prefers Eurasian milfoil. There is also an accidental introduction *Acentria emerephella.*	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: We gave a low rating for feasibility due to: 1. the difficulty in finding agents that are specific enough to M. spicatum 2. The presence of at least 2 T&E species that are closest relatives to the invasive 3. Our assessment that milfoil outbreaks are most likely driven by nutrient dynamics instead of enemy release.
Level of certainty in assessment	High	Rationale: None provided.
Knowledge gaps	Is there a specific agent that has not yet been discovered? China and Korea have not been surveyed, and they are the origin. Can we find anything that feeds on invasive and hybrid? Might be very unlikely.	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: We gave a low likelihood rating because: 1. native milfoils that are T&E will likely defeat regulatory approval 2. native milfoils reach epidemic densities in many northern American lakes and streams But, the will to do biocontrol is high. Fish predation could be an issue for any new biocontrol agent, as it is for the native weevil.
Level of certainty in assessment	High	Rationale: 1. Unlikely that we would be able to find new agents sufficiently specific to *M. spicatum*. An additional concern is that 2 very closely related species have state T&E status making regulatory approval unlikely. 2. High densities of *Myriophyllum* are likely the result of nutrients rather than a fundamental deficit of natural enemies.
Knowledge gaps	Population regulating factors for milfoils could be better explored	
Biocontrol prospects	Low	

Target weed	***Onopordum acanthium* (Scotch thistle)**
Impact type	Environmental and Economic impacts
Benefits	No benefits identified

Target weed	*Onopordum acanthium* (Scotch thistle)	
Impact level	Moderate	Rationale: Forms local monocultures; Long-lived seed bank; Can be controlled with available techniques Link: http://www.cabi.org/isc/datasheet/37456
What would successful management look like?	- Hindrances to livestock movement reduced - Increase in pasture quality due to reduction of cover, density and competitiveness of infestations - Fewer occurrences of new infestations (seed spread reduced)	
Agent(s) available (* indicate species on which assessments are based)	Very successful control in Australia; however, most of the agents appear to have a broader host range with some host shifting occurring. Currently, there are three potential agents two in Turkey, a mite and a nematode, and one in Bulgaria, a Syrphid fly; however, access is an issue. https://www.ibiocontrol.org/catalog/agents.cfm?weed=136&list=1	
Expected contribution of biocontrol to the weed's management goals	Without any successful new agents, biocontrol will play a minimal role. A host specific seed feeder and stem feeder could be effective as in Australia. Once again, host specificity is the biggest problem.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: *O. acanthium* has been studied in Europe and Australia. Unfortunately, no biological control agents are approved for field release in the US. In contrast, many biological control agents have been released in Australia, where four agents including two stem feeders, a seed feeder, and a rosette feeder play a significant role in the management of this weed. However, the direct non-target impact on threatened and endangered plant species in the US has limited available options.
Level of certainty in assessment	Medium	Rationale: Based on probability of host shifting by existing agents we selected low and upped the level to Medium with the possibility of mites, nematodes, or pathogens that could be more host specific.
Knowledge gaps	1. The indirect impact of *O. acanthium* on other insect pollinators such as bees, wasps or flies, needs to be documented. 2. The test plant list should be determined if *L. latus* is reconsidered as the potential biological control agent.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: The success in Australia suggests that biological control agents are capable of managing the weed; however, the likelihood of finding seed feeding agents or pathogens with sufficient host-specificity for release in the United States is concerning. It is hoped that one or more of the potential agents could be approved for release in the US.
Level of certainty in assessment	Medium	Rationale: While *O. acanthium* is a noxious weed in 14 states in the continental US ("A" list in CA and NM), no biological control agents have been approved to release in the field in the US. For example, *Lixus cardui* was released in Australia, but not in the US due to the results of no-choice and choice tests conducted at USDA ARS Exotic and Invasive Research Unit (Balciunas, 2007).
Knowledge gaps	1. We need to know confirm existence of any threatened and endangered native plant species in North America that belong to the Tribe Cynareae. 2. However, six native *Cirsium* spp., including *C. pitcher*, are listed as T&E plant species in the US. Any new biological control agents should be tested whether they attack the T&E *Cirsium* spp. before submitting the petition to TAG and Endangered Species Act: Section 7 Consultation	

Target weed	*Onopordum acanthium* (Scotch thistle)	
	(https://www.fws.gov/MIDWEST/ENDANGERED/section7/index.html) due to “Finding of No Significant Impact (FONSI)” by USDA APHIS.	
Biocontrol prospects	Low	

Target weed	*Pilosella aurantiaca* (=*Hieracium aurantiancum*; orange hawkweed)	
Impact type	Environmental and Economic impacts	
Benefits	Some nursery/ornamental value; Otherwise no benefits identified	
Impact level	Moderate	Rationale: Forms monocultures; Spread through the nursery trade; no herbicide option in this context; Hybridization with *Pilosella officinarum* (=*Hieracium pilosella*; mouse ear hawkweed)?; Similar rationale for impact as *Pilosella caespitosa* (=*Hieracium caespitosum*; yellow hawkweed)
What would successful management look like?	Similar to yellow hawkweed management goals, i.e. - Reduce cover, density and competitiveness to; - Reduce reproductive output and spread rate - Reduce hybridization rates - Limit impacts to forage production (quality and quantity) - Limit impacts on biodiversity - Reduce presence/abundance in lawns and gardens	
Agent(s) available (* indicate species on which assessments are based)	*Aulacidea pilosellae*, one species that is under study. This species was the focus of our Likelihood assessment but the feasibility assessment was based on the discovery of a new agent, possibly a pathogen? Syrphid fly (*Cheilosia urbana*:,will be released in Canada this autumn and TAG recommended it's release in the US).	
Expected contribution of biocontrol to the weed's management goals	An integrated control program will be needed for this system and conventional control efforts focus along vector corridors or environmentally sensitive lands. Biological control is expected to play a major role in natural areas. Our assessment is based on the prediction that biocontrol may address the reduction in cover, density, competitiveness and reproductive output and as a result improve biodiversity. Unlikely to address hybridization rates, unlikely to reduce presence in lawns and gardens. Also conflicts with other exotic hawkweed species – if you take out orange hawkweed you also need to take out meadow hawkweed complex.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: If this was a new target I would rate it as moderate, but since a number of agents have been looked at, the feasibility of finding new agents is low. The gall wasp *Aulacidea pilosellae* is currently being tested for host specificity and impact studies. The feasibility of discovering a new, specific agent is considered LOW. Numerous surveys have already been conducted, most areas have been searched. The feasibility is also low because of potential non-target feeding, thus making feasibility limited. A plant pathogen would be welcome as the weed has limited genetic variability. Agents released in NZ appear to have limited value to NA program (although not the primary target).
Level of certainty in assessment	Medium	Rationale: None provided

Target weed	***Pilosella aurantiaca*** **(=*Hieracium aurantiancum*; orange hawkweed)**	
Knowledge gaps	The limiting knowledge is whether there are additional agents available. Pathogens have not been discovered in past surveys and it is unclear who would work on them if discovered.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: The gall wasp *Aulacidea pilosellae* has the potential to address the management goals that were identified as appropriate for biocontrol listed in #3 above. Preliminary data indicate that the gall wasp reduces biomass and reproductive output. The wasp has two biotypes: one that is univoltine while another that is bivoltine, which is expected to improve establishment and impacts. The wasp has the potential to attack multiple hw targets (although somewhat specific). The wasp can be difficult to rear due to poor emergence of galls. Has strong female biased sex ratio, which can benefit population growth rate. It has medium likelihood to meet the expectations for biological control. The root-feeding hoverfly (*Cheilosia urbana*) is considered difficult to work with, didn't establish in NZ. It will be released in Canada this autumn and TAG recommended its release in the US.
Level of certainty in assessment	Medium	Rationale: Based upon lab studies. Uncertainty comes from the agent also being adventive in Canada and limited information regarding status. The role of the wasp in controlling OHW in Canada may be needed.
Knowledge gaps	Gaps are currently being addressed except the status of adventive population in Canada. Is there a host specific pathogen that can aid in this program?	
Biocontrol prospects	Low	

Target weed	***Pilosella caespitosa*** **(=*Hieracium caespitosum*; yellow or meadow hawkweed)**	
Impact type	Environment and Economic	
Benefits	No benefits identified	
Impact level	High (Moderate in survey)	Rationale: While some in the workshop were comfortable in retaining the survey rating, a general discussion led to its impact level being elevated to a H for the following reasons; Rapid rate of spread; Isolated but forms monocultures where found; Hybridization?; Potential Impact (OR & ID - vast acres of suitable habitat)
What would successful management look like?	Reduce cover, density and competitiveness to; - Reduce reproductive output and spread rate - Reduce hybridization rates - Limit impacts to forage production (quality and quantity) - Limit impacts on biodiversity - Reduce presence/abundance in lawns and gardens	
Agent(s) available (* indicate species on which assessments are based)	*Aulacidea pilosellae*, one species that is under study.	
Expected contribution of biocontrol to the weed's management goals	An integrated control program will be needed for this system and conventional control efforts focus along vector corridors or environmentally sensitive lands. Biological control is expected to play a	

Target weed	***Pilosella caespitosa*** **(=*Hieracium caespitosum*; yellow or meadow hawkweed)**	
	major role in natural areas. Our assessment is based on the prediction that biocontrol may address the reduction in cover, density, competitiveness and reproductive output and as a result improve biodiversity. Unlikely to address hybridization rates, unlikely to reduce presence in lawns and gardens. Also conflicts with other exotic hawkweed species – if you take out orange hawkweed you also need to take out meadow hawkweed complex.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: If this was a new target I would rate it as moderate, but since a number of agents have been looked at, the feasibility of finding new agents is low. The gall wasp *Aulacidea pilosellae* is currently being tested for host specificity and impact studies. The feasibility of discovering a new, specific agent is considered LOW. Numerous surveys have already been conducted, most areas have been searched. The feasibility is also low because of potential non-target feeding, thus making feasibility limited. A plant pathogen would be welcome as the weed has limited genetic variability. Agents released in NZ appear to have limited value to NA program (although not the primary target).
Level of certainty in assessment	Medium	Rationale: None provided
Knowledge gaps	The limiting knowledge is whether there are additional agents available. Pathogens have not been discovered in past surveys and it is unclear who would work on them if discovered.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: The gall wasp *Aulacidea pilosellae* has the potential to address the management goals that were identified as appropriate for biocontrol listed in #3 above. Preliminary data indicate that the gall wasp reduces biomass and reproductive output. The wasp has two biotypes: one that is univoltine while another that is bivoltine, which is expected to improve establishment and impacts. The wasp has the potential to attack multiple hw targets (although somewhat specific). The wasp can be difficult to rear due to poor emergence of galls. Has strong female biased sex ratio, which can benefit population growth rate. It has medium likelihood to meet the expectations for biological control.
Level of certainty in assessment	Medium	Rationale: Based upon lab studies. Uncertainty comes from the agent also being adventive in Canada and limited information regarding status. The role of the wasp in controlling OHW in Canada may be needed.
Knowledge gaps	Gaps are currently being addressed except the status of adventive population in Canada.	
Biocontrol prospects	Low	

Target weed	***Potentilla recta*** **(sulphur cinquefoil)**	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified	
Impact level	Moderate	Rationale: -Added to list at workshop because it is widespread (Present in ID and weedy in WY, and in CO it is difficult to separate from other native *Potentilla*, but these

Target weed	*Potentilla recta* (sulphur cinquefoil)	
		states didn't include it on their lists submitted to this project); Some in the group suggested that its impact level should be raised to H because it may be under-collected/under-recorded and because of risks of hybridization with native *Potentilla* spp (e.g. ID and OR) but after discussion, the group decided to retain the survey impact level of M
What would successful management look like?	Reduce cover, density and competitiveness to: - Limit its impacts on forage production - Limit suspected allelopathic ability - Increase native plant diversity - Reduce hybridization with native *Potentilla*	
Agent(s) available (* indicate species on which assessments are based)	No specific agents were identified for consideration in the likelihood assessment. • *Tinthia myrmosaeformis* showed good potential but larvae were able to develop on strawberries in no-choice tests and attacked native *Potentilla*'s under field tests. • Two gall wasps and a gall midge were discovered in Turkey but they were not colonized in lab or common garden.	
Expected contribution of biocontrol to the weed's management goals	An integrated control program will be needed for this system and conventional control efforts focus largely on corridors or environmentally sensitive lands. Biological control is expected to play a major role in natural areas. Our assessment is based on the prediction that biocontrol may address the reduction in cover, density, competitiveness and reproductive output and as a result improve biodiversity. Unlikely to address hybridization rates, unlikely to reduce allelopathic aspects if there is soil residual.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: This species has been under study for over two decades and only a few species (5) have been closely studied, which may be a sign of difficulty of finding herbivores. Based largely on CABI perspectives and taxonomy/phylogeny uncertainty. Feasibility assessment rating was influenced by previous agents partially developing on strawberries ("show stopper") and 65 native *Potentilla* species in NA. Most potential agents occur in Turkey and Ukraine, which may complicate foreign surveys.
Level of certainty in assessment	Medium	Rationale: Uncertainty lies in questions remaining on the specificity of discovered species, hard to colonize or work with, unclear if these difficulties have been resolved.
Knowledge gaps	1. Species complex? 2. Other possible herbivores likely to be discovered in areas that are difficult to access, export from? 3. Host range testing predictive of ecological host range? 65 native *Potentilla* species.	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: The likelihood of unknown agents to control *Potentilla recta* is rated as low because the plant has a woody tap root with high levels of starch storage that may facilitate compensation. Large plants can produce >1500 seeds, the seed bank survival length is unknown but some tests indicate that it is > 4 years. Plants reproduce both via seed and vegetatively. The plants also have variable ploidy levels that may affect impacts. It is unlikely that new agents will be discovered to meet the demands of stakeholders considering

Target weed	*Potentilla recta* (sulphur cinquefoil)	
		additional research is needed on taxonomy, foreign surveys and host range testing.
Level of certainty in assessment	Medium	Rationale: CABI and a few funding agencies have dedicated > 20 years to surveys and testing for this target but limited success.
Knowledge gaps	1. How well does the plant respond to the effects of herbivory? 2. Urs' comments: taxonomy would need to be clarified, especially further east of Turkey (Iran, Uzbekistan) considering P. recta might be a species complex. 3. Additional information regarding habitat requirements 4. Additional life history information 5. Additional survey areas	
Biocontrol prospects	Low	

Target weed	*Rhaponticum repens* (=*Acroptilon repens*; Russian knapweed)	
Impact type	Environmental and Economic impacts	
Benefits	Some beekeepers value this weed as a source of honey	
Impact level	High	Rationale: WA has current biological control and hence didn't make their list, but still of concern; WY impacted, but not included on their list
What would successful management look like?	Reduce cover, density and competitiveness to; - Reduce vegetative spread through rhizomes - Increase native plant diversity in invaded systems - Reduce occurrence/reports of chewing disease in horses - Reduce or stop further spread of the target species (added by assessors in Workshop 2)	
Agent(s) available (* indicate species on which assessments are based)	For 'feasibility': no specific agent in mind For 'likelihood of success': the mite *Aceria acroptiloni*	
Expected contribution of biocontrol to the weed's management goals	When considering the management goals for CBC of Russian knapweed as defined in Workshop 1, the likelihood of *Aceria acroptiloni* achieving the desired management goals appear to be very low. The mite can significantly reduce aboveground biomass and seed production. However, since local densities of Russian knapweed are entirely based on vegetative spread, a reduction in seed output will only lead to a reduction in long-distance spread, a management goal not considered/prioritized in Workshop 1.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: Large areas in the native range, Iran, Turkey, Kazakhstan, Uzbekistan, which are accessible have been surveyed by CABI, BBCA, USDA over the last 20 years. The remaining areas are remote or unsafe, with an unknown level of certainty of finding something new which drives the feasibility to low.
Level of certainty in assessment	High	Rationale: Based on a 20 year-experience of biological control of *R. repens.*
Knowledge gaps	1. Surveys in remote areas in Central Asia 2. % reduction in seed output necessary to reduce further spread of Russian knapweed	

Target weed	***Rhaponticum repens*** **(=*Acroptilon repens*; Russian knapweed)**	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Overall assessment considerably depends on the management goal; if the management goal is to reduce current population densities within the next decades, then BC is close to unfeasible. If the management goal is to reduce further spread by seeds, then there is a moderate likelihood.
Level of certainty in assessment	Medium	Rationale: Infested shoots can have 100% reduction in seed output; however, in the native range infested plants tend to occur only at a few sites, and high incidences of attacked shoots are only found at small scales of a few square meter.
Knowledge gaps	1. How to assess host-specificity of mites…. 2. Identification of the abiotic factors limiting population density and distribution of mites	
Biocontrol prospects	Low	

Target weed	***Rubus armeniacus*** **(Armenian or "Himalayan" blackberry)**	
Impact type	Environmental and Economic impacts	
Benefits	Excellent fruits; Food source and habitats for some wildlife (e.g. birds); Of some value to beekeepers	
Impact level	Moderate	Rationale: Horrible weed on the coast; Affects riparian areas in the interior; Forms monocultures, but does not invade large acreages so far; Encroaches in pasture; Effective colonizer following fire; Considered as having a high impact in some localities; In eastern OR: colonizes hillside from riparian areas; CO is scared of it.
What would successful management look like?	- Access to riparian areas and watercourses increased - Increase in desirable plant abundance/diversity due to reduction of cover, density and competitiveness of infestations - Fewer occurrences of new infestations (due to limitation of spread) - Reduced herbicide use in wetlands/watercourses and natural areas	
Agent(s) available (* indicate species on which assessments are based)	Likelihood of success assessment based on *Phragmidium violaceum* – rust fungus	
Expected contribution of biocontrol to the weed's management goals	Based on the lack of damage to the target by the only known agent, which was accidentally introduced into the invaded range and established on the target, control seems unlikely.	
Feasibility of undertaking a biocontrol project on the weed	Low	Rationale: Currently there is very little known about natural enemies of this weed. Native range exploration for new agents is likely to be challenging, both due to political issues surrounding the native region and the fact that one potential source of funding for such work (the US government) is not likely to be available. Host-specificity will also need to be absolute.
Level of certainty in assessment	High	Rationale: Biocontrol of this target is actively discouraged by USDA. A lot of work still needs to be done, as very little is known about natural enemies. Specificity and impact of only known candidate agent is questionable.
Knowledge gaps	1. How closely related the target to cultivated blackberry? 2. How much influence to stakeholders have who want to control this weed?	

Target weed	***Rubus armeniacus* (Armenian or "Himalayan" blackberry)**	
	3. What are alternatives to biocontrol?	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: An ideal agent would need to be extraordinarily host-specific and damaging, perhaps an eriophyid mite or a rust fungus. A rust is known but is not host-specific and does not diminish field populations, so another rust would be needed. No mites are yet known.
Level of certainty in assessment	Low	Rationale: Agent is not effective at reducing populations following accidental introduction and field infestation. No other candidate agents are known. Any effective agent would need to be extremely host-specific.
Knowledge gaps	1. Only one strain of agent has been introduced and studied only anecdotally in USA. Are there other more specific, more effective strains? 2. What other natural enemies exist in the native range? A root-damaging natural enemy that is strictly host-specific would be great. 3. Could target be successful as a niche-market wild-gathered food?	
Biocontrol prospects	Low	

Target weed	***Taeniatherum caput-medusae* (medusahead)**	
Impact type	Environmental and Economic impacts	
Benefits	Brief window of value for graziers before flowering (very brief because of too much silica in plants)	
Impact level	High	Rationale: - Low grazing value - Produces dense thatch - Forms monocultures and promote fire - Affect sage grass habitats - Can transform perennial grassland So invasive - could replace cheatgrass; lower forage value than cheatgrass
What would successful management look like?	- Thatch reduced opening niches for other desirable plants - Reduced fuel for fire as thatch is reduced	
Agent(s) available (* indicate species on which assessments are based)	Eriophyid mite, *Aculodes alta-murgiensis* A wasp species: We have found a new agent. First discovery in 2002 by R. Sforza in Turkey, and in 2017 by Marini, Kashefi, Cristofaro et al. in Greece. It is a gall maker wasp (not ID yet). One to few seeds are supporting the larval dev. On each seedhead, compeletly destroying the seed. We have material that is being keying out. Genetic analysis is also ongoing. At this stage we still don't know if findings from both periods are the belonging to the same species. Various pathogens, including: smuts, i.e *Ustilago phrygica* and *Tilletia bornmuelleri* and *Fusarium arthrosporioides*	
Expected contribution of biocontrol to the weed's management goals	Not answered	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: Much of the pathogen work has been done and shown to not be successful, either because of low efficacy or host specificity. The feasibility of finding something new is low. New agents such as eriophyid mites have not been developed or surveyed extensively yet and the feasibility of finding something new could be considered as moderate.

Target weed	***Taeniatherum caput-medusae* (medusahead)**	
Level of certainty in assessment	Medium	Rationale: The feasibility is based on information collected from experts on *T. caput-medusae*.
Knowledge gaps	1. Areas where surveys have not been conducted 2. Seasonal variations in potential agent discovery should be taken into account. 3. Extend surveys focusing on Eriophyid mites	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: Pathogens have been exhausted and should not be further considered since experience has shown that they are either not specific or not capable of achieving the management goals. Too many unknowns with the invertebrates (wasp and mite) to have anything conclusive, however, the biological control of annual species especially grasses has not shown to be particularly effective. However, it could be combined with an integrated weed management programme and be effective.
Level of certainty in assessment	Low	Rationale: The assessment is based on information collected from experts on *T. caput-medusae*.
Knowledge gaps	None provided	
Biocontrol prospects	Low	

Target weed	***Tribulus terrestris* (puncture vine)**	
Impact type	Environmental and Economic impacts	
Benefits	Some medicinal value (erectile dysfunction medication?)	
Impact level	Moderate	Rationale: Added to list at workshop; Some in the workshop this should have an impact level of L because it is only an issue in disturbed areas and more of a nuisance annual that is easy to kill; However it was retained as an M (as per survey results) because other workshop attendees highlighted it as a major urban weed that is commonly visible and attracts the highest number of calls from citizens ("potentially a PR weed"); economic impacts along transport corridors
What would successful management look like?	- Reduce citizen complaints and associated cost imposts on time of weed management staff - Reduce reproductive output ("No thorns, no complaints") - Stop seed production, not just inviable seeds (as thorn issue still remains even with inviable seeds, although may dissipate over time)	
Agent(s) available (* indicate species on which assessments are based)	Not known and known	
Expected contribution of biocontrol to the weed's management goals	Not answered	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: Potential agents are known, but we do not know specificity or climate matching. Unknown is area of origin(s) for NA *Tribulus* and host specificity of potential alternate agents. There are lists of feeders from India, but may not be able to export these and these may not be a good climatic match for areas in need of additional agents. These lead us to the conclusion that there is a good (medium) chance for

Target weed	*Tribulus terrestris* (puncture vine)	
		feasibility, but we also place only medium confidence in this assessment.
Level of certainty in assessment	Medium	Rationale: None provided.
Knowledge gaps	1. Native range / Area of origin (have we looked in all the correct places). 2. Specificity of new species. 3. Specificity of exiting agents is unknown.	
Likelihood of success of a biocontrol project on the weed	Moderate	Rationale: Climate matching is a challenge, and we do not know the area of origin for NA *Tribulus* genotypes and how this may or may not interact with climate patterns of identified agents. There do appear that there are several agents that could be effective, however we do not have enough information on their climate needs to assess likelihood with high certainty. The ability of any potential biocontrol agent to thrive in disturbed habitats are also unknown.
Level of certainty in assessment	Medium	Rationale: Inadequate surveys in the native range, uncertainty about the area of origin of NA *Tribulus* types. Uncertainty about finding cold hardy biocontrol agents (existing and potential).
Knowledge gaps	1. Area of origin for NA *Tribulus* types. 2. Life history / climate needs of identified new agents. 3. Existence of other agents that would work in cold-climate parts of NA	
Biocontrol prospects	Moderate	

Target weed	*Ventenata dubia* (wiregrass)	
Impact type	Environmental and Economic impacts	
Benefits	No benefits identified; No grazing benefits	
Impact level	High	Rationale: Added to list at workshop; Spreading quickly; Affects quality of hay, pasture and rangeland; Cannot be grazed; Could displace cheatgrass; Difficult to identify; Poses a fire danger
What would successful management look like?	- Same as medusahead with regards to thatch production - Similar impact to cheatgrass, but not as tall as cheatgrass - Increase in hay (eg Timothy) quality and yield due to reduction of cover, density and competitiveness of infestations	
Agent(s) available (* indicate species on which assessments are based)	Largely unknown, but two non-specific pathogens are listed as natural enemies (*Septoria ventenatae*, *Tilletia fusca*)	
Expected contribution of biocontrol to the weed's management goals	No answer provided	
Feasibility of undertaking a biocontrol project on the weed	Moderate	Rationale: Feasibility was ranked moderate because there is so little known about this target.
Level of certainty in assessment	Low	Rationale: The likelihood of natural enemies limiting spread is unlikely (could be a pathogen), but given all of the unknowns,

Target weed	*Ventenata dubia* (wiregrass)	
		more research is needed to adequately determine biocontrol feasibility.
Knowledge gaps	1. Ecological range is currently unknown 2. Surveys for potential BCAs have not been done 3. The native range is unknown	
Likelihood of success of a biocontrol project on the weed	Low	Rationale: While winter annual grasses have not been successful biocontrol targets in the past, going into a new project with that bias might limit future research for candidate biocontrol agents. Should a biocontrol candidate be identified, landscape-level control might be achieved. We have to do the surveys to answer the questions. It is, however, a winter annual which has been a poor target for classical biocontrol in every case it has been pursued.
Level of certainty in assessment	Medium	Rationale: There are no identified potential biocontrol agents for Ventenata. There are no effective biocontrol agents for winter annuals. The native range of Ventenata has not been well-researched.
Knowledge gaps	1. No known biocontrol targets have been identified 2. The native and introduced range are poorly understood	
Biocontrol prospects	Low	

Appendix 2. Detailed dossiers on the structured assessment of feasibility of biological control and likelihood of success of biological control on weeds of the western USA

1.1. *Alliaria petiolata* (garlic mustard)

Feasibility of undertaking a biocontrol project with new agent(s) on *Alliaria petiolata*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	No releases have been made although one agent (*C. scrobicollis*) has been approved by TAG. Additional agents are considered a low priority.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Some ecologists argue that control of the target should be delayed until after control of deer populations can be accomplished, presumably by increased hunting, in order to protect certain native plant species.	-
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	An international consortium was active for at least 10 years. A CABI project started since 1998. They reviewed the literature and recorded ~69 herbivores. One of ~6 that were studied intensively has been approved by TAG. A second is still under evaluation.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Most of the native range is accessible. One candidate agent (*C. theone*) was inaccessible due to political instability (Caucasus region). However, it attacked the same plant parts as second, more accessible agent (*C. constrictus*).	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes. Active collaboration.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes. Western Europe.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes. No known taxonomic controversy. Multiple introductions into N. America inferred from genetic studies.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	No known closely related crops. No congeners in invaded range. Only tribe members in N. Am. (2 *Thlapsi* spp.) are also introduced.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the	Yes. Biennial. Roots most vulnerable. Prevention of bolting very desirable. Seed reduction desirable.	+

Dimensions/factors	Notes	Influence on feasibility [1]
vulnerable life stages of the weed known?		
Ecophysiology: Is the weed's vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Plant resistance to agent attack not well documented. Model using experimental data predicts high impact of combined *C. constrictus* and *C. strobicollis* release in the absence of such resistance.	N
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes. Plant is highly competitive and allelopathic. Primarily an environmental weed.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well known in native range. Some generalists studied in invaded range that did not affect population growth.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Alliaria petiolata*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Appears likely based on similar climates between native and invaded ranges.	+
How might this influence agent(s) establishment patterns?	Positively.	+
How might this influence agent(s) impacts?	Modeling suggests impact will be high.	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Weed is a biennial. Reduced risk.	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Modeling suggests yes.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Root attack on biennial should be highly damaging. Seed/stem feeding should complement root attack.	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Damage to other Brassicaceae targets has been good. In theory, biennials should be susceptible to root damage.	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Range of invaded habitats is relatively limited to shaded areas in or near forests with lesser invasions in urban areas. Some full-sun invasions near forests may indicate adaptation to new habitat.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Yes. Little indication that target is invading new climatic regions.	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Range of land uses invaded by target is relatively limited to forest with lesser urban invasions. Invasion into full-sun areas near forests may indicate future adaptation to different land-use regimes (e.g. agriculture).	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Little is known about parasitism of the weevils.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
Same as above.

1.2. *Berteroa incana* (hoary alyssum)

Feasibility of undertaking a biocontrol project with new agent(s) on *Berteroa incana*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Has not previously been a target in North America. Is not an active target anywhere in the world	N
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	In Europe used in mine remediation. No known value in US	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Not in this weed but there are Brassicaceae experts in CABI and in the U.S. who could provide valuable expertise in what types of agents are most likely to be effective. Suspect that pasture/livestock industries would support biocontrol	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	"Eurasia". Eastern Europe is native range, Western Europe perhaps invasive. Native range is large. Native range is accessible.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, Udaho, CABI, and network of biocontrol researchers to provide materials.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, CABI, local universities and agric. institutes	N
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Taxonomic status is clear	N
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	No native congeners. One non-native congener No native members of same clade in Alysseae Tribe Closes of concern likely hort. Alyssum Phylogeny is established	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	There are very little data on detailed demography but other plants could be used as model/surrogate. Plant produces lots of seed. Typically rosette is the most vulnerable	N
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation)	No	-

Dimensions/factors	Notes	Influence on feasibility [1]
to different types of damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Known where weed occurs. Mostly anthropogenic habitats, especially pastures. Northern across the US. Climate matches to native range should be found in accessible areas	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Little or no information. There are likely native insects or invasive pest insects that feed on it. In US Pollinators likely visit the plant. Surveys could be done and even tests of damage impact of native or non-native pests feeding on it.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Berteroa incana*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Unknown. Native range studies of insects and of life cycle of weed needed. Also climate studies	-
How might this influence agent(s) establishment patterns?	Critical. Agent must be able to tolerate climate in US while synchronizing with weed life cycle. Agent must be able to find plant in disturbed environments	N
How might this influence agent(s) impacts?	Important. Rosette-feeder must be able to tolerate harsh fall and spring climate including extremes. Bolt feeder may need to be able to tolerate low moisture stress directly and on plant	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Low risk. Plant is long-lived annual or short-lived perennial. But in pastures weed may function as an ephemeral, due to mowing, grazing	-
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Unknown	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Unknown. Agent life cycle could be interrupted by grazing, mowing	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	No prior biocontrol research on this species. Brassicaceae have no track record in terms of classical WBC in the US (field release of intentionally introduced agents). Only precedent would be adventive or native insects found to be doing a lot of damage to garlic mustard or other Brassicaceae. Compare to thistles, similar rosette and bolt long annual or biennial strategy. Success requires attack on both vegetative and reproductive parts.	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown. But native range is broad. Agents could be selected that are widely distributed. Agents could be selected from pastures or other disturbed habitats in native range	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Unknown. See above. It might be difficult to find accessible climate match in native range if drier regions are needed.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	If the restrictions above are followed, agents should be adapted to disturbed conditions, including pastures	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown. Do survey of native and adventive insects occurring on the plant and check natural enemy attack.	N
Other factors		
Can agents attack mechanically damaged plants (e.g. after mowing)	Do studies in quarantine or native range	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

There is little or no published information on biological control or herbivory in general.

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1.3. *Bromus tectorum* (cheatgrass)

Feasibility of undertaking a biocontrol project with new agent(s) on *Bromus tectorum*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	*Bromus tectorum* is a target and has been for a number of years. Field surveys have primarily focused on bacteria, fungi, and insects, but not mites. All of the above except for mites are unlikely to yield any new biological control agents.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Ranchers utilize "June grass," but it is poor quality feed with a narrow grazing window.	-
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	There is a desire to invest more resources if a promising agent is identified.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	The majority of their native range is accessible with a few genetic isolates as a counter example. Permits should not be an issue if new discoveries are made.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	On the mite side, there are collaborative links in place in the native range and expert specialists.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Facilities and specialists are available for new agent identification, but lab space for host-specificity is limited.	N
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The taxonomy shouldn't be an impediment for biocontrol. The number of introductions and potential hybridization has been studied, but more data is needed.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	*Bromus tectorum* is now three genera. The new classification should help out with biocontrol prospects as none of the *Anisantha* spp. are native to NA. Those that are present are weedy (*A. rubens*, *A. madritensis*).	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	The life cycle of *Bromus tectorum* has been studied at length.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Given the number of studies that have focused on how to control *Bromus tectorum*, the vulnerability of the plant is well understood.	+

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	The landscape context is adequately understood, but the geographic range makes a landscape approach difficult.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Aside from mites, the natural enemies in the invaded range have been well chronicled.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Bromus tectorum*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Considering the candidate biological control agents are being surveyed for in Kazakhstan, the climates should be well-matched.	+
How might this influence agent(s) establishment patterns?	A similar climate would be beneficial.	+
How might this influence agent(s) impacts?	Too many unknowns to answer this question.	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	The risk is pretty high the populations won't be sustained over time given that nothing has been established on cheatgrass to date.	-
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	The existing biological control options are not capable of controlling cheatgrass on a consistent basis.	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	The existing agents are not likely to have an appreciable impact during the weed's growing season.	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	There are not a lot of effective biological control agents for invasive grasses.	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	The suite of agents available are not capable of achieving management objectives.	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	The suite of agents available are not capable of achieving management objectives.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	The suite of agents available are not capable of achieving management objectives.	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	N/A	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
Same as above

1.4. *Butomus umbellatus* (flowering rush)

Feasibility of undertaking a biocontrol project with new agent(s) on *Butomus umbellatus*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Possible agents could be released. Unknown areas of potential surveys in Asia	+ / U
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	None – not sure of any horticultural importance considered weed	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Consortium funding – adequacy unknown; Montana has just begun allocating significant resources following recognition of weed as a major ecological threat; north western states primarily funding effort	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Native range largely assessable Unknown as to alternative areas to survey	+ / U
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Current relationships probably present & adequate but need to get up to speed (historical project)	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Unknown about new survey areas but existing facilities exist.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes limited genetic variability – only species in this family in NA	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Probably	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes – studied	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Yes – studied	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use,	Mostly – aquatic system is unique	N

Dimensions/factors	Notes	Influence on feasibility [1]
competing species) in which biocontrol is desired adequately understood?		
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well surveyed but not sure if other areas were under surveyed or not surveyed. Plant rare in much of its range (Europe)	+ / U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Butomus umbellatus*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Probably similar	+
How might this influence agent(s) establishment patterns?	Probably similar	+
How might this influence agent(s) impacts?	Probably similar	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not applicable	U
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Probable - pending populations	+ / U
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Dependent upon suitable suite of agents	+ / U
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Probable but no similar agents to compare??	+ / U
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Probable; this is a new program and no agents have been approved for release yet so there is no way to contextualize landscape impacts; also, it is considered rare in native range	+ / U

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Probable	+ / U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Lower probability in highly disturbed sites	+ / U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown vulnerability but probably low based upon habitat	+ / U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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1.5. *Centaurea diffusa* (diffuse knapweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Centaurea diffusa*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	13 agents have already been introduced, and some are at high densities. We are not aware of additional prospective agents	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	no	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	No one is currently reseaching new agents.	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Greece and other Baltic countries are accessible.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	ARS has a laboratory in Greece; known collaborators in Bulgaria.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	ARS has a laboratory in Greece; known collaborators in Bulgaria.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Taxonomy and molecular genetics have been studied, but no extensive study of genetic diversity.	N
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes. Closest related crop is safflower; bachelors button is an ornamental and invasive weed.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes; biennial. Rosette survival, seed production.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Not well known.	-
Landscape context: Is the landscape context (e.g. habitat, climate, land use,	Need control in US Forest Service lands (forest meadows).	N

Dimensions/factors	Notes	Influence on feasibility [1]
competing species) in which biocontrol is desired adequately understood?		
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Greece has been well studied; no specific indigenous enemies in USA.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Centaurea diffusa*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Host-specific agents should be naturally adapted, but synchrony might be affected by differences in latitude or elevation.	+
How might this influence agent(s) establishment patterns?	Could be limits to where the agents establish.	N
How might this influence agent(s) impacts?	Could be limits to where the agents establish.	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Host-specific agents should be naturally adapted. Seed bank usually sustains population from year to year.	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Established agents have reduced weed populations in many areas; impact of a new agent is not very predictable.	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Established agents attack roots or reduce seed production.	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Established agents have reduced weed populations in many areas.	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Existing agents come from lowland areas in Northern Greece. More extreme habitats in the US may require new agents or biotypes from similar habitats.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Established agents have reduced weed populations in many areas. More extreme climates in the US may require new agents or biotypes from similar habitats.	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Invaded regions in CA are similar to the climate of origin of the established agents.	+
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Parasitism of established agents has been low in the US, but predation of seed head insects by rodents can be high.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.6. *Centaurea solstitialis* (yellow starthistle)

Feasibility of undertaking a biocontrol project with new agent(s) on *Centaurea solstitialis*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Several potential agents are known; petition for *C. basicorne*; preliminary study of *L. filiformis* and *P. chalcomera*; *Botanophila turcica* and cynipid are unstudied; *P. solstitialis* needs better climatically adapted strain.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Valued by beekeepers, but does not currently appear to be a problem.	N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Has been studied off-and-on for 40 years, but with insufficient support. Six agents are established, some impact in OR & CA, but none in ID. Additional agents are desired. Still considered one of the most important targets in CA.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Access to Turkey is problematic; continued access to Greece, Bulgaria.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, BBCA conducts exploration, ARS laboratories in France and Greece and quarantine lab in Albany, CA.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	ARS laboratories in France and Greece; co-operators in Rome, Italy, Plovdiv Bulgaria. Known taxonomists for beetles, flies, unkown for cynipid.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Molecular genetic research has been published showing diversity and intercontinental similarities (Barker et al. 2017).	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Systematics is well studied. Closest crop is safflower, some native spp. in same tribe (Cardueae). Bachelors button is an ornamental and an invasive weed.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Life cycle is well known: winter annual that reproduces only by seed. Gutierrez et al. (2004, 2016) postulate importance of immature stages; Swope et al. (2017) matrix model.	+
Ecophysiology: Is the weed's vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	The plant rebounds after physical damage (mowing, grazing); flush of seedlings after burns; continues flowering if sufficient moisture until frost. No genotypes resistant to BC agents known.	+

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Common in grassland habitats, especially with deeper or better quality soils; especially with dry summers. Rosettes are able to survive under snow. Establishment by agents varies with habitat type in CA.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Has been extensively sampled in CA and ID. Surveys have been conducted in Greece, Turkey, France.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Centaurea solstitialis*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Host specific agents naturally must be synchronized, but this might differ with latitude or elevation.	+
How might this influence agent(s) establishment patterns?	There could be latitudinal or elevational limits to establishment.	N
How might this influence agent(s) impacts?	Possibly less impact in sub-optimal environments.	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Host specific agents naturally must be synchronized, so not a problem.	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Introduced agents all destroy seeds. Need agents that reduce survivorship and reproduction. Botanophila, Ceratapion & Psylliodes should affect rosettes, cynipid & L. filiformis should affect seed production.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Some agents would attack rosettes (Botanophila, Ceratapion), bolting plants (Psylliodes), and seed production (cynipid & L. filiformis).	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be	Annual plants are commonly thought to be difficult to control biologically. This plant has decreased in some areas of OR.	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
adequate to achieve management goals?		
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Yes, prospective agents are known in a range of habitats that are similar to those in the US. Difficult to predict effectiveness.	+
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Yes, agents from Bulgaria and eastern Turkey should be adapted to higher elevations and northern latitudes; Greece is similar to CA.	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Some grazing animals may affect agents; e.g. goats eating infested seed heads, cattle grazing delays flowering. Difficult to predict effectiveness.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Parasitism of established agents is low. Parasitism of some agents in native range occurs, but is unmeasured. Weevils are probably well-defended. Future predation of agents in US is unpredictable.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided.

1.7. *Centaurea stoebe* (=*C. maculosa*; spotted knapweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Centaurea stoebe*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Low, per CABI and extensive surveys and releases of agents over the last 50 – 60 years	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Not valued, but see Pearson et al.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	View that sufficient resources have been spent, but see recommendations below.	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Yes. Collaborations exist, probably with individuals who have surveyed for *C. stoebe* / *C. diffusa* agents before.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes. These still exist	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes. Very well studied.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Well Studied	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	There are several published works on the interaction between resources / environment and BC agents of *C. stoebe*. In general, these conclude that the existing biocontrol agents are quite effective under lower resource conditions, but may nit be effective in low competition / high resource portions of the landscape. Existing agents may not be working to meet proposed management objective, but it is not clear that additional agents will provide greater levels of control under high-resource conditions. Reduction of chewing disease,	-

Dimensions/factors	Notes	Influence on feasibility [1]
	a management objective, is unlikely as this disease is caused by a different species.	
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Well studied.	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	See Demography, above. It would be useful to conduct additional studies on resource or landscape attributes and BC efficacy would be useful in this system.	N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Very well studied.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided.

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Centaurea stoebe*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	There are 13 agents that have been established already	-
How might this influence agent(s) establishment patterns?		+
How might this influence agent(s) impacts?		+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?		NA
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	No. Management objectives request extremely low densities of the weed	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Likely	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Existing agents are reducing *C. stoebe* densities, it is unlikely that additional agents will improve this situation and meet the proposed management objectives. However, additional demographic work might identify life stages / habitats that could be targeted in future research.	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Apparently not.	-
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Yes, but apparently not in pastures.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	No	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	This does not appear to be a limiting factor for *C. stoebe* agents	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided.

1.8. *Chondrilla juncea* (rush skeletonweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Chondrilla juncea*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Very likely. There are two new root-feeding insects identified (*Sphenoptera faveola* and *Oporopsamma wertheimsteini*). In addition, with new genetic work there will likely be done on *Puccinia chondrillina* and *Eriophyes chondrillae.*	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	The weed may be valued by pollinators, but the pollination benefits would not inhibit others from controlling it.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	The current political climate surround RSW is it needs to be controlled. There is sufficient will to invest more resources to control this plant. A renewed interest in the RSW Task Force shows there is will to invest more resources to control RSW. This hasn't yet included California…	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Access to the native range is possible, but may be difficult in some areas. Current contacts are in place and have been utilized in recent field collections. Requisite required permits are obtainable.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Existing relationships in the native range are in place. BBCA (covering mostly western Europe) and the Russian Academy of Science in St. Petersburg have agreements in place to survey the native range.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Laboratory facilities are not in place in the native range where most of the exploration has occurred. We don't know where a new rust would be shipped for quarantine purposes. The majority of field collections are processed in hotel rooms with makeshift labs. With existing relationships, however, transport to proper facilities has been efficient.	N
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The taxonomy is clear. There are other *Chondrilla* spp., but none would be confused for *Chondrilla juncea.* The five genotypes have been identified and coverage of the infestation is adequate.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	*Chondrilla juncea* has not been subject to any taxonomic changes. The closest relative genetically is *Taraxacum* spp. (some of which are native).	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	The life cycle of weed and vulnerable life stages are well known. The vulnerable life stages of the plant are well known.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance,	I don't know that the weed's vulnerability is satisfactorily understood. Compensatory responses	-

Dimensions/factors	Notes	Influence on feasibility [1]
compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	and plant defences surely play a part, but the "Achilles Heel" has not been identified. Certain genotypes of the plant have been found to be resistant to rust strains.	
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	The landscape where biocontrol will be implemented is understood and well-defined. The micro-effects have been identified for certain agents. The mite micro climates have been studied, but this is not true for other species.	N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Because there aren't any native *Chondrilla* species in the US, the extent of the natural enemy diversity isn't fully understood. There are some examples of generalists (grasshoppers) that have had localized infrequent impact, but this is not common or reliable. Recent surveys have shown that there are more potential natural enemies than previously thought. There are likely more potential biological control agents in the native range given the recent field surveys that have occurred.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Chondrilla juncea*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Given the climate exploration is occurring in, the likelihood of synchrony is very good. We're matching climate with Russia for some of the new biocontrol agents. We have questions about matching synchrony with the rusts. Exploration in Mediterranean climates might hinder biocontrol establishment of certain species. RSW is very plastic so a broad range of climates is essential.	N
How might this influence agent(s) establishment patterns?	For newer candidate agents, this would enhance the potential of establishment patterns. For some of the rusts, the plasticity of the plant might cause	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
	some concerns, but rusts are mostly dependent on moisture levels.	
How might this influence agent(s) impacts?	For the newer potential agents, this would enhance the potential of the candidate agent's impacts. For the rust strains, we'll be confined to moisture microclimates.	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	N/A	
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes, the two candidate agents both impact the roots. There are several biocontrol agents established on the above-ground portion of RSW. Potential new strains of rust are unknown.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Damage over the duration of the growing season for RSW is likely, but in situ impacts won't be known until a release is made. Native plant composition is unlikely to be harmed to due allelopathy or long-term seed viability.	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Agent damage will likely be adequate to achieve management goals, but there isn't enough research done on the target or closely related species to say anything definitively. The rust was used in Australia on one of their genotypes, but control was not achieved (even though they thought they did – genotype replacement of the plant likely occurred).	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No. The suite of agents have been established since the 1970s and their extent has been reached. The newer agent, BRGI, has been underwhelming (this is still monitored annually).	-
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	No. See above.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	No. See above.	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Some of the established biocontrol agents are vulnerable to predation/parasitism (including the rust), but the root feeders may not be.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.9. *Cirsium arvense* (creeping thistle)

Feasibility of undertaking a biocontrol project with new agent(s) on *Cirsium arvense*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Very low probability to unfeasible finding any new agents for NA (also see overview by Cripps et al. 2011).)	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	It has been considered as a medicinal herb (Rogers, 1928).	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	It depends on the private landowners, and state and federal agencies. Almost everyone would like to manage this weed.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Native range includes Africa, Asia and Europe. Some EU countries should be safe for researchers and collaborators.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	CABI and others	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Possible.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes, various genotypes were identified in North America, suggesting the sexual reproduction as a common strategy (Slota et al. 2010). The local adaptation was also reported after the changed land use (Bommarco et al. 2010).	-
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Native thistle species in North America can be an issue, particularly state and federally listed threatened and endangered thistle species, e.g. *Cirsium pitcheri* (Torr. ex Eat.) Torr. & A.Gray	-
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Abiotic factors such as drought tolerance and flooding have been documented. Biotic factors are relatively understood.	+

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes	N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	There are numerous seed feeding agents and pathogens studied throughout the native and invaded range. Unfortunately, very few root feeding agents are known.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Cirsium arvense*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	There are many insects and pathogens associated with the weed that are in synchrony.	-
How might this influence agent(s) establishment patterns?	Unknown	-
How might this influence agent(s) impacts?	Root destruction is critical	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Perennial.	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Host-specific systematic pathogen	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	A pathogen would be good	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Host range is problematic with most existing agents	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Not currently	-
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	No	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	No	-
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	*unknown*	

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.10. *Cynoglossum officinale* (houndstongue)

Feasibility of undertaking a biocontrol project with new agent(s) on *Cynoglossum officinale*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Small since exhausting surveys have been conducted between 1987 – 1997 There are agents identified for which limited host range testing has been conducted Certain areas in native range were not surveyed (e.g. Bulgaria, Poland, Albania)	N
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Beekeepers but given the impact on predominant livestock and foresting industries in the northwestern U.S., negligible.	N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	In the 1990s-2000s, the project was well funded. Ultimately, the problems caused by the Pest-Alert for one of the agents dried up funding in the late 2000s	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Access to native range is largely possible and a network of researches across eastern Europe and western Asia exists via CABI. Permits are in existence or can easily be procured	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, CABI, Ivo Tosevski, Mark Volkovitsh, Rita Dolgovskaya, Massimo Cristofaro, etc.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes at CABI, BBCA, University of St. Petersburg and Belgrade Plant protection Institute	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Phylogenetic placement has recently be realigned. Yes, there are now new native closely related genera some with large numbers of species including T&E species. Genus *Cynoglossum* however not present in the U.S.	N / -
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Population modelling has been undertaken and published. There is no population biology model per se but vulnerable life stages are identified	+

Dimensions/factors	Notes	Influence on feasibility [1]
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	No specific experimentation has been undertaken but generally types of damage and the plant's compensatory reactions are known	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes, historically studied in native range and in introduced range	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well studies in both native and introduced ranges	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Cynoglossum officinale*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Excellent match (2 agents plus native moth) Inflict damage across growing season of plant	+
How might this influence agent(s) establishment patterns?	1 agent is already established in adjacent areas, the 2nd agent is an excellent climate match and we do not expect a 'no-establishment' outcome	+
How might this influence agent(s) impacts?	No adverse effect	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Very unlikely, weed is biannual – short- lived perennial Uncertainty only originates from the temporal fugitive life-history of target weed	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Demonstratively so with impact data published and unpublished for both agents and the native moth	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Competitive interactions aside, there would be damage inflicted by agents throughout the growing season of the plant	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Has been demonstrated FOR the target weed in adjacent areas in southwestern Canada	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Yes	+
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Yes	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Land use should not be a constraint for the insects	+
3rd trophic level		

Dimensions/factors	Notes	Influence on likelihood of success [1]
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	*M. borraginis* is a seed feeder and its rarity in Europe has been attributed to an undescribed Hymenopteran specialist wasp (*Triaspis* sp. nov.) Since this is a specialist it may be that the weevil stays free of respective guild parasitoids The Eberidae moth has parasitoids but the parasitism rate is not high in the field *M. crucifer* has specialist hymenopteran parasitoid but as root herbivore parasitism levels are low	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.11. *Cytisus scoparius* (Scotch broom)

Feasibility of undertaking a biocontrol project with new agent(s) on *Cytisus scoparius*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Long-term project, focus of biological control research for >50 years. Invasive pest in NA, NZ, AUS, Chile, elsewhere.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Honey bees are attracted to the plant. Some congeners are used as ornamentals. Possible soil stabilization benefits. Few conflicts.	+/ N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	A great deal of investment has been committed to this weed across numerous states and countries.	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Native to western Europe. Surveys are simplified by good collaborators and existence of international agreements. Permits can be acquired for export.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	EBCL, CABI, NZ and AUS collaborators	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	The majority if not the entirety of work has been conducted at established labs/ facilities.	N/U
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Taxonomy is fairly well understood and holds up to phylogenetic comparisons (Cubus et al. 2002, Kleist and Jasieniuk 2011).	-
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Fairly well understood at the family level but possibility of species complexes that needs to be resolved.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Some studies from AUS and US, data are available on weak links and factors that drive population growth (see references).	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Various studies on fire and draught.	-

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Generally understood but there are some regions that are quite unique (Idaho) where control may differ dramatically compared to the Pacific States.	-
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	A great deal of information is available from both native and invaded areas. 243 species have been recorded on the plant during surveys. List of potentially host specific is much lower (see Syrett et al. 1999 vol 20, biocontrol news and information). Both intentional and accidental introductions have resulted in 12 exotic herbivores attack Cytisus in NA. Only two of these have been intentionally introduced. There are several additional candidates that may be considered (*Agonopterix*?)	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Cytisus scoparius*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Candidate agents are available that are synchronized to various parts of the life cycle. EG a moth that feeds inside the stems in fall-winter	+
How might this influence agent(s) establishment patterns?	Plants that are suitable are likely to be available for long periods for foliage and stem feeders	+
How might this influence agent(s) impacts?	New agents may fill in gaps and provide more impact on vegetative parts	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not applicable	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Appears that extant agents and possible candidate agents attack mature plants. Mgmt goals include reducing density of plant. Seems like an agent that will do major damage to young seedlings is needed (it may also damage mature plants).	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of	Likely because plant substrate is available for a long growing season. Seedlng feeders will have	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
severity to achieve the management goals?	supply of seedlings through most of growing season.	
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	As noted by P. Pratt, this is an old target. Two introduced insects in US, 10 others adventive. Weed is still a problem. Scotch broom psyllid already in US, impact uncertain. There is hypothesis that this psyllid, intentionally introduced in NZ and Australia, but not in US The twig-feeder could have impact late in the season in a way other agents do not.	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Coastal western US, yes Other areas, such as Idaho, unknown	+
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Unknown Match climate of natve range collection location for the twig-miner and US climates	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Yes	+
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Leps such as the twig-miner are usually susceptible to parasitism	-
Other factors		
Interactions with extant agents	Damage by adventive mite, psyllid, etc might reduce tissue availability for twig miner	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.12. *Dittrichia graveolens* (stinkwort)

Feasibility of undertaking a biocontrol project with new agent(s) on *Dittrichia graveolens*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Not known to be targeted for BC anywhere. Likelihood of finding new agents should be high.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	no	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	We are not aware of anyone working on BC of this weed. Strong concern about this relatively new weed in CA.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Southern Europe, North Africa, Central Asia and India is purported native range. Not all areas are easily accessible.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	ARS has a lab in France and Greece, CABI in Switzerland; BBCA does exploration in the region; possible collaboration with CSIRO (lab in France).	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Network of collaborators to collect plant DNA samples; DNA analysis and rearing of prospective agents in quarantine can be done at EBCL (France) or CABI (Switzerland).	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The genus has recently been revised (Brullo & Marco 2000).	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	We do not know.	N
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Annual that germinates in spring and produces seed in the fall. Vulnerability of life stages unknown.	N
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Unknown	-

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Invasive along roadsides, riparian gravel bars. In CA primarily in disturbed and agricultural habitats (Brownsey 2013)	N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Unknown.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Dittrichia graveolens*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Host specific agents should be naturally adapted to the plant, unless there are big differences in latitude.	+
How might this influence agent(s) establishment patterns?	Should establish in regions with climate similar to region of origin.	+
How might this influence agent(s) impacts?	Impact should be highest in regions with climate similar to region of origin.	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Host specific agents should be naturally adapted to the plant.	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	unknown	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	unknown	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	unknown, but compare to Parthenium in Australia.	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	unknown	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	unknown	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	unknown	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	unknown; however aromatic compounds in the plant may confer defense to host-specific arthropods.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.13. *Eleagnus angustifolia* (Russian olive)

Feasibility of undertaking a biocontrol project with new agent(s) on *Elaeagnus angustifolia*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Foreign exploration has been done but is likely not complete. This is a new program in that no agents have been released yet against the target weed; it is probable that additional agents will be found in the native range. At least three agents, the leaf bud mite, a leaf and flower-galling mite and a fruit and seed-feeding moth, have been tested in CABi quarantine and maybe in US. A release petition is being written by CABI in collaboration with a US lead.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Western NA landowners value weed for use in shelterbelts and as an ornamental plant; hunters believe it provides good habitat and is a good source of food for wildlife; biological control of this target has been plagued by conflict of interest since inception. Provides habitat for yellow-billed cuckoo (Endangered). Like saltcedar, the Russian olive is not good habitat. The reason: Their food=larvae, large insects. Not present in Russian olive.	- (significant)
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Not enough resources have been devoted to this target in the past; yes there is sufficient will to invest more resources, but within moderation. CABi has invested sufficient resources to prepare release petition for the mite.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Current political climate makes access in parts of the native range quite difficult: Uzbekistan - two pristine Russian olive habitats, in one of last remnants of the formerly widely distributed togay forest and in the mountain forests in the foothills of the Pamir Mountains are considered 'military areas'; Mashhad (north-eastern) and Täbriz (north-western) regions of Iran; future collecting and impact assessments in Turkey are uncertain	-
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, Uzbek and Iranian collaborators have played leading role in surveys and host specificity testing, etc. New collaborations with Serbian mite specialists will speed up accurate identification and host specificity testing of candidate mite agents. M. Cristofaro has good relationship with those researcheers. CABi has had this as a project since mid-2000s	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, based on preliminary results. May be more difficult now than in mid-2000s to go back and collect the mite or moth and/or get new agents and/or do local studies.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	yes, but existence of genotypes/biotypes unknown. Hybrids with other Elaeagnus?	N

Dimensions/factors	Notes	Influence on feasibility [1]
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	yes phylogenetic placement of the weed is satisfactorily resolved; closely related NA species are also culturally sensitive There are two native congeners; cultivated exotic related species is used as an ornamental and fruits are an ingredient in skin care and cosmetics products. At least one other exotic congener (umbellata) is also invasive. J. Gaskin has 11 microsatellite markers. Suggest the N.American accessions have multiple origins in native range. Iranian researchers used ISSR to determine molecular diversity in Iran	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	No. Unknown for sure, but insight can be used to guess what the most vulnerable life stage is. Probably desired to control production of seedlings/saplings; or reduce seed production; but not to kill mature trees. The mite may be especially good against sapllings. The moth may reduce seed production. Russian olive is almost entirely seed-propagated. Unknown how much damage seedlings/saplings can tolerate. Field work on efficacy of the mites: CABi. The flower and some leaf-feeding one reduced seed production? Did it kill plants? The other mite? Low impact	-
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes. Has climate matching of native range to US been done? US distribution is broad, Canada to Mexico. But area of current largest populations is Rockies riparian zones and spreading into other areas.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	well known in native range, relatively unknown in invaded range (but see ARS Sidney and Miles City MT research for preliminary data). Surveys in US for native or adventive insects still need to be done across entire invasive range	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Elaeagnus angustifolia*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	unknown but probably not a problem because the target is a moderately long lived tree species. Will the mites (especially the flower- and leaf feeding one) find saplings? Will the mite find young flush foliage?	N
How might this influence agent(s) establishment patterns?	Agents could establish on mature trees only. unknown but probably not a problem because the target is a moderately long lived tree species	N
How might this influence agent(s) impacts?	unknown but probably not a problem because the target is a moderately long lived tree species. Appears that both agents will go preferentially for mature plants. The moth would prefer mature plants that are producing lots of fruit.The mite needs flowers although it can attack leaves as well. Attack on mature plants only will make regulatory approval easier. But will reduce impact, invasiveness of Russian olive may not be reduced.	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	not applicable	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	current candidate agents were selected to inhibit unchecked spread of the target but won't kill it… agents may reduce the aesthetic value of affected plants maintained as ornamentals. Other agents beyond the mite and moth would likely be needed to kill plants. Management goals include killing the plant. Flowering mites can kill plants in general in other systems. Several generations/years. Note that toxic or hormonal effects of mites beyond where they are actually feeding. Field bindweed mite. Russian olive saplings would not be attacked by the most advanced agents-mite and moth.	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Likely as long as plant is flowering Mite is likely rapid life cycle, multiple generations per year. Moth is likely one generation per year	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	unknown – infestation rates were relatively low on target weed during host specificity testing The two most advanced agents are not likely to kill all plants. Past record of agents that attack only reproductive parts of trees. Evidence of good establishment. Impact? South African cases indicate good impact to reduce invasiveness.	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown Assume tree grows in similar habitats in native range.	U
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	unknown – climate matching is a concern; arid environmental conditions may also be a negative factor	U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Yes if native range habitats are similar. Might be good if ornamental plants do not provide suitable habitat in non-riparian areas. Seems like the two most advanced agents will not full achieve management goals	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	unknown but predation by birds and generalist insect predators and parasitoids may be a high source of mortality for lepidopteran agents Eriophyiid Mites have a history of attracting predatory mites. Lots of other organisms might take over galls/rolls	-
Other factors		
Conflict of interest in control-habitat for Endangered bird. However, if agents do not kill tree, rather reduce its fitness, might be allowed by USFWS		+
There are no agents currently advanced to the point of quarantine studies that offer the potential to kill saplings. The time trajectory of control with just the two advanced agents is likely 20-30 years		-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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1.14. *Euphorbia esula* (*E. virgata*?; leafy spurge)

Feasibility of undertaking a biocontrol project with new agent(s) on *Euphorbia esula*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	*E. esula* has been a target for biocontrol since a long time, the first agent was released in the US in 1966 and a total of 13 agents were permitted for release. Surveys for natural enemies were so far only conducted in Europe and not in Asia. Surveys in Asia could potentially lead to the finding of new agents not identified so far or they could reveal strains of already known agents that would be better adapted to potential areas where *E. esula* is still a problem (see Gassmann and Schroeder 1995). The likelihood that new agents will be found in Europe is very low and the most promising agents that had been identified in previous studies were already released. However, some of these agents did not establish in North America and it would be worth to investigate the potential reasons why they did not establish and to consider re-introducing these agents.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	There has already been substantial investment in the development and distribution of most effective agents. But it is still a problem and there are limitations in the efficacy of current agents. Agents that did not establish did not get as much research as the once that became successful. Fewer resources would need to be invested for studying and re-introducing agents that had already been introduced to North America but that did not establish than for identifying and studying potential agents that are not known yet.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	All agents that have been identified so far can be found in Europe where it is safe to travel and easy to get the necessary permits. To survey for new agents in Asia receiving permits can be difficult, but there are areas where it would be possible. Some areas might be difficult to assess.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes from previous work on this (and other) biocontrol project.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes (for Europe), partly (for Asia)	+

Dimensions/factors	Notes	Influence on feasibility [1]
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Although in North America the weed is generally known as *Euphorbia esula*, several authors (including the Flora of North America) emphasize that *Euphorbia virgata* would be the correct name for the invasive leafy spurge and that *E. esula* is a different species that is also native to Eurasia but that is only sporadically naturalized in North America. In North American *E. esula* is genetically diverse and composed of multiple genotypes introduced from several areas of Europe and Asia and some observed variation in establishment and reproduction of *Aphthona* spp. may be attributed to leafy spurge genotype (Lym and Carlson 2002), so a better understanding of the genetic diversity of *E. esula* in the introduced range could help identifying the best adapted biocontrol agents.	-
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	The phylogeny of the subgenus *Esula* (which is the subgenus *E. esula* belongs to) has recently been revised (Riina et al. 2013) but the genetic relationships among the species within these subgenus are not fully resolved. According to Bourchier et al (2006) there are 53 native North American Euphorbia species, 17 of these species are in the subgenus *Esula*. *Euphorbia pulcherrima* is an economically important plant as a Christmas pot plant, but it belongs to a different subgenus than *E. esula*.	N
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes. *E. esula* has an extensive, rapidly growing root system that contains a large nutrient reserve and the most effective biocontrol agents are those that feed on the roots. Seedling mortality is high under most conditions, a reduction of seed output is therefore less important.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	We could know more, but in general, yes.	N
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	There are small scale studies and evidence from the native range that there is variation in susceptibility to biocontrol across habitats. However, these studies often do not reflect strong evidence of variable impacts, and we do not know how well qualitative trends hold.	-
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Native range: The natural enemy diversity within the western part (=Europe) of the native range is well known (Harris et al. 1985). No or few surveys for natural enemies have been conducted in more eastern parts (=Asia) of the native range (Gassmann and Schroeder 1995).	N

Dimensions/factors	Notes	Influence on feasibility [1]
	Invaded range: Several biological control agents are already present in the introduced range and some of them are successful in controlling *E. esula*, so there is some knowledge about the natural enemies in the introduced range.	

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Euphorbia esula*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Since all agents are root-feeders they should not be specifically dependent on the weed's life-cycle. Some studies do suggest that because early life stages do not have well developed roots, root feeding agents may not be consistently able to suppress new infestations in a timely manner.	+
How might this influence agent(s) establishment patterns?	Positively	+
How might this influence agent(s) impacts?	Positively	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	*E. esula* is a perennial species	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes, *E. esula* has an extensive root system and the most effective biocontrol agents are those that feed on the roots. All of the agents mentioned above are root feeder. The most vulnerable transition stages identified in a matrix model for *E. esula* are related to vegetative buds and underground structures (Maxwell et al 1988).	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	If the agents establish, there is a good chance, see also comments below.	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	In Europe, some of the agents can completely destroy the plants, which means that if they will be able to establish in North America, the impact should be high.	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	In the native range, each of the species is reported to have quite narrow habitat preferences. *Ch. hungarica*: occurs in swampy areas, along riverbanks, at moist loamy and partly shaded sites. *Ch. astatiformis* and *Ch. crassicornis* are adapted to mesic to dry loamy habitats, and also occur on poorer soils where spurge grows intermixed with dense, high levels of vegetation (Gassmann and Tosevski, 1994). *Aphtona abdominalis* was mainly found in humid habitats humid habitats (Fornasari and Pecora 1995).	+
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Not sure, we need more information on the habitat efficacies of current agents. However, most species have a relatively wide distribution range.	U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Not sure, we don't know…	U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	In the native range several parasitoids have been collected from field collected pupae of *Ch. hungarica* (Gassmann & Tosevski 1994). In general root herbivores have been shown to aquire very few parasitoids once released.	U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.15. *Hypericum perforatum* (St John's wort)

Feasibility of undertaking a biocontrol project with new agent(s) on *Hypericum perforatum*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	SJW has been a target, but biocontrol at high elevation sites, high shading seem to not do well. This has been one of the most successful biocontrol programs in the US with some regional exceptions. The area has been well explored and target candidate species have been identified.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Herbal medicine from SJW is something some groups would value, but this has already been navigated because of the existing biocontrol program.	N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	The majority would likely say that enough resources have been devoted to SJW and that success has been achieved, but there are regional exceptions. Where there are regional exceptions, there is a will to invest more resources.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Access to the native range is not an issue. It is a safe target for researchers and collaborators. Permits for potential candidate agents are available.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Existing collaborative relationships are in place in the native range.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Laboratory facilities have been identified and are available at CABI and Australian and New Zealand collaborators as well.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	There might be some subspecies and varieties that have been mentioned anecdotally, but none are widely accepted that could be an impediment. No glaring taxonomic issues have been identified, but there hasn't been any work done before 2000.	N
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Because host specificity testing occurred in the 1940s to the 1980s, it is likely that a new test plant list will be necessary to reveal any new closely-related native (51 native *Hypericum* spp.) or crop species due to new phylogenetic placement (do we know this to be true?).	N
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	The life-cycle of the weed has been adequately characterised. The vulnerable life stages of the weed have been identified with the established biocontrol agents.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	Given the success of existing biocontrol, the vulnerability to different types of damage is satisfactorily understood (based on the success of	+

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?	existing biocontrol in NA, Australia and New Zealand).	
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	It is not clear why regional populations are not currently controlled with existing established biocontrol agents.	-
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	The natural enemy diversity is very well known in the native and invaded ranges.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Hypericum perforatum*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Synchrony is an unknown as most of the NA existing biocontrol was collected in the Mediterranean climate. Climate matching studies may be needed.	N
How might this influence agent(s) establishment patterns?	The regional locations where biocontrol is not working will influence the potential for establishment.	-
How might this influence agent(s) impacts?	The regional locations where biocontrol is not working will influence the potential for impact.	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	N/A	
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	The suite of agents would potentially target high altitude/shady areas. The damage level could be high.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Closely related existing biocontrol agents suggest that damage would persist over the duration of the growing season at levels that would meet management objectives.	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Existing agents are successful for the most part in NA. Better climatically matched biocontrol agents could result in adequate management goals.	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No (see above), but there is potential.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	No (see above), but there is potential.	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	No (see above), but there is potential.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Predation/parasitism rates are unknown.	N

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References

BRC database of insects and their host plants: http://www.brc.ac.uk/dbif/hostsresults.aspx?hostid=2744

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1.16. *Iris pseudacorus* (yellow flag iris)

Feasibility of undertaking a biocontrol project with new agent(s) on *Iris pseudacorus*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	As far I am aware this has not been a target for biological control to date.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	It is a well-known horticultural species with many varieties (http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=c797 ; https://davesgarden.com/guides/pf/go/666/) which poses a conflict of interest. However, it is listed as a noxious weed and banned/prohibited in many states (https://plants.usda.gov/core/profile?symbol=IRPS). The biocontrol agents selected would have to be specific to the species (also not attacking any hybrids developed in the horticultural sector) in order not to cause a conflict with growers of other Iris species and so as not to attack any of the Iris species native to North America.	----------------
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Unknown.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	The native range includes Europe and the British Isles, North Africa and the Mediterranean region (Cody 1961), so this would not pose many challenges for researchers. It is very likely to obtain permits for moving potential agents within the native range and to the US.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, there are several collaborative links within the native range.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, infrastructure is well developed with several European laboratories working on biological control of weeds.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	*Iris* L. is the largest and most complicated genus of the Iridaceae. The genus exhibits extreme diversity of more than 300 *Iris* species. Irises arose in the eastern and south eastern regions of Asia during the lower Tertiary. Now the range of the genus extends to all of the continents of the Northern Hemisphere. The	N

Dimensions/factors	Notes	Influence on feasibility [1]
	taxonomy and genetic identity of the weed has been satisfactorily resolved (Wilson 2009).	
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes, for details see notes above (Wilson 2009). There are several horticultural as well as the 28 native Iris species in North America.	-
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes, it is a well studies species, especially since it is a horticultural species. Vulnerable stages could be inferred, from the growth form and lifecycle.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Not specifically for *Iris pseudacorus* but inferences could be made from other species where clonal growth through rhizomes is important as well as sexual reproduction for long distance dispersal.	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes, biological control in aquatic ecosystems is relatively well understood and often successful (Paynter et al. 2012).	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	The natural enemy diversity is fairly well understood in the native range, eg. http://www.brc.ac.uk/dbif/hostsresults.aspx?hostid=2823 and Sutherland (1990) highlights several phytophagous invertebrate as well as pathogens associated with *I. pseudacorus*. There are a few generalist herbivores that feed on *I. pseudacorus* including the root boring moth, *Macronoctua onusta* in the USA, however on the large part this species is unattacked.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Iris pseudacorus*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Should not be a problem since both the invaded and native are northern hemisphere occupying similar climatic ranges.	+
How might this influence agent(s) establishment patterns?	No effect	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
How might this influence agent(s) impacts?	No effect	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	The weed is not annual or ephemeral; however, the aquatic habitat could be potentially subject to extreme conditions, flooding or drying events which may pose a risk to biological control agent populations sustaining over time.	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Currently unknown. Agents could be prioritised to inflict the desired type of damage to fulfil the management goals.	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Currently unknown, but it could be a possibility.	N
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Currently unknown, but it could be a possibility..	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Currently unknown, but it could be a possibility.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Currently unknown, but it could be a possibility.	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Currently unknown, but it could be a possibility.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Currently unknown, would depend on the agents selected for biological control.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.17. *Isatis tinctoria* (dyer's woad)

Feasibility of undertaking a biocontrol project with new agent(s) on *Isatis tinctoria*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	A CABI CH project since 2004 (since the last couple of years in collaboration with BBCA). Potential of finding new agents not studied yet is rather low considering the extensive surveys conducted. Most other agents found (e.g. Baris in Georgia) will likely not be specific enough.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Artisanal dyeing; very small group; unlikely to complain about control of this species. They can also grow it in the small numbers needed using pesticides to kill bc agents.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	No, unlike other invasive mustards, this project has always been severely underfunded to the point where it is amazing what suite of agents we have now.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Yes, CABI and its network in c and e Europe. Also current suite of agents considered is found in w Europe. Movement and permits highly likely	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, at CABI and other links	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, CABI	
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes, *I. glauca* is not considered as part of *I. tinctoria*, while *I. littoralis* was found to be within *I. tinctoria* as defined by molecular analysis. No other potential confusion.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes. Various phylogenies are established. While there are no native North American *Isatis* species, native *Streptanthus* and *Caulanthus* are closely related to *Isatis*, contain T&E species, and these two genera have serious host specificity issues for some *Lepidium* (a more distantly related Brassicaceae genus) agents.	n
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes. Winter annual in Europe. Biannual or sort of perennial in US	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	Yes, with respect to the native rust. No for the potential agents.	n

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes. Not a really wide range of habitats.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Native: Fairly well known. Invaded: Diversity is not well known, however the native rust *P. thlaspeos*, is well known to attack the ID/UT lineage.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Isatis tinctoria*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Good, assuming there are no stark differences in the life history of the plant in the native and invaded range	N
How might this influence agent(s) establishment patterns?	?	N
How might this influence agent(s) impacts?	?	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	No risk	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	The root crown feeding weevil *Ceutorhynchus rusticus* has been shown to reduce biomass and seed production and is able to kill plants. In addition, the system is similar to *Cynoglossum-M. crucifer* and *Alliaria-C. scrobicollis* in that the plant is biannual and the agent a root feeder that can kill plants. *C. rusticus* in combination with the seed	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
	feeder *C. peyerimhoffi* is expected to be an efficacious combination to control *Isatis*. Mite still needs to be investigated	
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Yes. Population biology is seed limited. Native rust is on average reducing reproductive output by 20% if linages are susceptible to attack. Additive or synergistic affects should be expected once CBCs are introduced.	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Yes. There is not a large range of habitats that are invaded by the weed.	+
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Yes, the plant is not in many climate regions	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Yes, the plant is usually in unproductive agricultural lands	+
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	The weevils will have parasitoids in the native range, and the at least the seed head weevil will be expected to attract guild parasitoids once released. Mite may be attacked by predatory mites.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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1.18. *Lepidium draba* (=*Cardaria draba*; whitetop/hoary cress)

Feasibility of undertaking a biocontrol project with new agent(s) on *Lepidium draba*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	The likelihood is relatively low since extensive surveys have been conducted in many different countries covering a large range of the distribution area of *L. draba* over many years. However, having said that, fungal pathogens were never seriously considered, apart from soil borne pathogens that USDA ARS (Tony Caesar) worked on at a certain stage	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Although *L. draba* appears to contain some chemical compounds that could be utilized for medicinal purposes I am not aware that anybody is growing it and to the best of my knowledge there should not be any conflict of interest.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	A lot of resources have been invested already since 2001 (!) I could therefore imagine that the will to invest a lot more funding might come to an end. However, there is a diverse set of stakeholders so it could be feasible.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	With the exception of Syria and Iraq, most other countries that have not been surveyed yet (China, Iran, Pakistan, Turkmenistan and Siberia) are accessible, although maybe not very easily. For some (Pakistan), export will be possible, for some it is not clear how the process currently works (China) and for yet others this would need to be established (e.g. Turkmenistan, Siberia). However, I feel that many of these countries are at the distribution edges of *L. draba* and I am wondering how useful it is to go there.	neutral
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, in some countries, e.g. we have Centres in China and Pakistan. We also have collaborators in Kazakhstan and Iran.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, the CABI Centre in Switzerland, where we also have ca. 150 taxa in the family Brassicaceae and related families, native to Europe and NA, including T&E's available as seeds or plants.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes "Subsequent phylogenetic analyses demonstrated that *Cardaria* is, after all, nested within *Lepidium* (Mummenhoff 1995, Mummenhoff et al. 2001), along with the previously independent genera *Coronopus* Zinn. and *Stroganowia* Kar. & Kir. (Al-Shehbaz et al. 2002). This resulted in the acceptance of two distinct hoary cress species: *C. draba* and *C. chalepense* were united to *L. draba* (*L. draba* L. ssp. *draba* and *L. draba* L. ssp. *chalapense* (L.) Thellung), and *C. pubescens* became *L. appelianum* (Al-Shehbaz et al. 2002). Most	+

Dimensions/factors	Notes	Influence on feasibility [1]
	recently, the two subspecies of *L. draba* have been elevated to full species status, resulting in *L. draba* and *L. chalepense* (Francis and Warwick 2008 and references therein)."	
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	More or less, but still in flux to a certain degree. "Although all genera have not yet been included, the overall structure and principal component genera will most likely remain unchanged (Al-Shehbaz 2012). " There are numerous crop species in the same family, about 30 native species in the same genus and probably several hundred native species in the same family distributed over 17 tribes, plus about 40 T&E's in the same family!	N to - In terms of closely related natives and crops a big minus!
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	No detailed demographic modelling work has been conducted on *L. draba* yet	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Information exists on responses of *L. draba* to herbicides as well as mechanical control and grazing (see Francis and Warwick 2008)	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?		N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	To a very large extent. See: Crispps et al. 2006a, b	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Lepidium draba*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	It should be good. The agents are very well synchronized with *L. draba* in the native range (e.g. aestivation period of C. cardariae during hot and dry summer period) and is expected to be similarly good in the invaded range. The growing season will likely be shorter in some areas in NA, but since this is temperature driven we expect the	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
	agents to adapt. At least *A. drabae* and *C. cardariae* also occur in continental climates.	
How might this influence agent(s) establishment patterns?	Positive- neutral	+
How might this influence agent(s) impacts?	Positive-neutral	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not applicable (*L. draba* is perennial)	
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes. *Aceria drabae* will reduce if not eliminate seed production and stunt plants. *C. cardariae* will reduce the vigour of plants and stunts growth. *C. turbatus* reduces seed production.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	At least *C. cardariae* attacks plants very early in spring over a long time period during the main growth of the weed. In addition weevils have a partial second generation in late summer which should reduce regrowth in early autumn.	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	No sure. The only one that comes to my mind that is functionally similar is Canada thistle, which is not the best positive example!	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No. This will be more likely in more stable habitats such as pastures, natural areas and less likely in roadsides, field edges and crop habitats.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	More or less. There might be particularly cold areas in Wyoming and Montana where agent establishment and impact might be limited, but as mentioned before, at least *A. drabae* and *C. cardariae* do occur in continental climates with cold winters (e.g. Romania, Kazakhstan)	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	See answer to habitats.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	*Aceria drabae* develops in gall like structures and should therefore be well protected against predation. *C. cardariae* is a gall former on the above ground plant parts and therefore much more vulnerable to parasitism. It was established that parasitoid species in the genera *Eupelmus, Necremnus* and *Trichomalus* could switch to *C. cardariae* if released. *C. turbatus*: same as for *C. cardariae:* native parasitoids could switch	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.19. *Lepidium latifolium* (broadleaved pepperweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Lepidium latifolium*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Surveys have already been conducted in Turkey, Armenia, south-eastern Kazakhstan, Georgia, western China, Bulgaria, Iran, Ukraine and in southern Russia. Additional surveys in other countries of the distribution range of *L. latifolium* that have not been surveyed so far (e.g. Mongolia, Uzbekistan) or other parts of countries (e.g. western Kazakhstan) or surveys conducted during a different time in the year (e.g. autumn) could potentially lead to the finding of new agents.	N
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	A lot of exploration work has already been done, but there is will to invest more resources.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	*L. latifolium* is native to most of Asia. It can also be found in Europe, where it has likely been introduced by humans. Only part of the native range is easy accessible and expected to be possible to acquire necessary permits (e.g. Kazakhstan). Access in countries/areas not surveyed so far is more difficult than in areas that have already been surveyed, but most of them are safe. For most of these countries it would need further investigations regarding the necessary permits. Work that had been conducted in Turkey with two agents had to be stopped because at least the eastern part is not safe anymore to travel and because it is currently not possible to acquire any of the mentioned permits.	N/-
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	For countries that have already been surveyed there are existing collaborative relationships in place. For new countries (except Uzbekistan) they would need to be established.	-
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, at least for work that can be conducted under quarantine conditions: the CABI Centre in Switzerland, has ca. 150 taxa in the family Brassicaceae and related families, native to Europe and NA, including T&E's available as seeds or plants. However, open-field tests need to be conducted in country where the agent was collected. Universities in these countries should have the necessary facilities.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily	Yes (Gaskin et al. 2013)	+

Dimensions/factors	Notes	Influence on feasibility [1]
resolved so as to not be an impediment to a biocontrol project?		
<u>Systematics:</u> Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Phylogeny is relatively well known. There are numerous crop species in the same family, about 30 native species in the same genus and probably several hundred native species in the same family distributed over 17 tribes, plus about 40 T&E's in the same family.	+(for phylogeny) - (for closely related species)
<u>Demography:</u> Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	*Lepidium latifolium* is an herbaceous, semi-woody perennial that reproduces both vegetatively and by seed. Plants regrow early each year from a dense network of creeping, horizontal roots, flower in June/July, and set seeds in July/August. Agents attacking the roots are expected to be most effective.	+
<u>Ecophysiology:</u> Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	*L. latifolium* is difficult to control because of its large, stout root system. Plants quickly resprout after mowing, and cultivation severs and transports root fragments that rapidly grow into new plants. When feasible, deep, repeated cultivation can suppress PPW. Grazing by sheep or goats may reduce weed density temporarily, but does not provide long-term control. Application of herbicides containing chlorsulfuron is most effective for suppressing PPW; however, the substance is not registered in the USA for use in many of the invaded habitats, such as in areas adjacent to water. Phenoxy herbicides, such as 2,4-D and clopyralid, will kill the shoots of PPW, but root crowns will quickly sprout new foliage. Applications may need to be repeated for up to five years to deplete the plant's abundant root reserves.	N
<u>Landscape context:</u> Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	*L. latifolium* is a highly plastic species that can grow in many different habitats and climates. Successful agents need to tolerate many climates, which may not be possible.	-
<u>Natural enemy diversity:</u> To what extent is the natural enemy diversity known in the native and invaded range?	**Native range:** In the literature only a few phytophagous species have been recorded from *Lepidium latifolium*, however, during field trips conducted by CABI and BBCA in various countries within the native range of PPW, more than 100 phytophagous organisms were sampled or reared. Among them are several species new to science as well as only recently described species. Nothing is known about the natural enemies on *L. latifolium* in countries/areas not surveyed so far. **Invaded range:** A number of insects as well as leaf and pod damage were observed on *L. latifolium* in the field in Massachussets, but none of the observed arthropods appeared to be having a significant impact on the ability *of L. latifolium* to spread either vegetatively or by seed (Forman Orth et al. 2006). A white rust (*Albugo* spp.) is known to infect *L. latifolium* and appears to largely inhibit seed production Young et al. (1997a) as cited in Francis and Warwick (2007).	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Lepidium latifolium*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	For the stem-mining fly *Lasiosina deviata* more information on the biology will be necessary to answer this question. The other two species should be well synchronized.	+
How might this influence agent(s) establishment patterns?	Positive-neutral	+
How might this influence agent(s) impacts?	Positive-Neutral	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Weed is perennial.	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	*C. marginellus* expected to be able to decrease the growth and competitive ability of *L. latifolium* above ground. *Melanobaris* sp. near *semistriata* is attacking the roots and may therefore reduce regrowth of *L. latifolium*. The impact of *Lasiosina deviata* on the target weed is currently unknown.	+/N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	*C. marginellus* has the highest impact early in the season. It is unclear whether the damage by this agent will persist over the whole growing season or not. *Melanobaris sp.* near *semistriata* larvae are developing in the roots and damage by this agent is likely to persist over a large proportion of the weed's growing season. The impact of *Lasiosina deviata* on the target weed is currently unknown.	+/N
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Unsure.	U
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Management goals may be achieved but probably not in all habitat types.	N/-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	A successful agent would have to be effective in a wide variety of climates. *C. marginellus* has a relatively wide distribution range and should be able to adapt to a wide range of climates. Not enough is known about the other two agents.	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Unlikely, because *L. latifolium* is occurring in a wide range of land-use types.	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	No information is available from the native range. However, root herbivores are usually least vulnerable, while *C. marginellus,* as a gall former is likely to aquire parasitoid species in the genera *Eupelmus, Necremnus* and *Trichomalus.*	U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.20. *Lepidium* spp. (other than *L. draba*; hoary cress)

Feasibility of undertaking a biocontrol project with new agent(s) on *for Lepidium* species (other than *L. draba*)

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	The likelihood is somewhat unknown since extensive surveys have only been conducted for *L. draba* in many different countries	N
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Although *L. chalepense* and *L. appelianum* appears to contain some chemical compounds that could be utilized for medicinal purposes I am not aware that anybody is growing it and to the best of my knowledge there should not be any conflict of interest.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	A lot of resources have been invested already since 2001 (!) I could therefore imagine that the will to invest a lot more funding might come to an end. However, there is a diverse set of stakeholders so it could be feasible.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	With the exception of Syria and Iraq, most other countries that have not been surveyed yet (China, Iran, Pakistan, Turkmenistan and Siberia) are accessible, although maybe not very easily. For some (Pakistan), export will be possible, for some it is not clear how the process currently works (China) and for yet others this would need to be established (e.g. Turkmenistan, Siberia). However, I feel that many of these countries are at the distribution edges of *L. draba* and I am wondering how useful it is to go there. *L. chalepense* and *L. appelianum* may require different countries to be surveyed	N
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, in some countries, e.g. we have Centres in China and Pakistan. We also have collaborators in Kazakhstan and Iran.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, the CABI Centre in Switzerland, where we also have ca. 150 taxa in the family Brassicaceae and related families, native to Europe and NA, including T&E's available as seeds or plants.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes and no because the taxa are sometimes lumped sometimes separated "Subsequent phylogenetic analyses demonstrated that *Cardaria* is, after all, nested within *Lepidium* (Mummenhoff 1995, Mummenhoff et al. 2001), along with the previously independent genera *Coronopus* Zinn. and *Stroganowia* Kar. & Kir. (Al-Shehbaz et al. 2002). This resulted in the acceptance of two distinct hoary cress species: *C. draba* and *C. chalepense* were united to *L. draba* (*L. draba* L. ssp. *draba* and *L. draba* L. ssp. *chalapense* (L.) Thellung), and *C. pubescens* became *L.*	N

Dimensions/factors	Notes	Influence on feasibility [1]
	appelianum (Al-Shehbaz et al. 2002). Most recently, the two subspecies of *L. draba* have been elevated to full species status, resulting in *L. draba* and *L. chalepense* (Francis and Warwick 2008 and references therein)."	
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	More or less, but still in flux to a certain degree. "Although all genera have not yet been included, the overall structure and principal component genera will most likely remain unchanged (Al-Shehbaz 2012). " There are numerous crop species in the same family, about 30 native species in the same genus and probably several hundred native species in the same family distributed over 17 tribes, plus about 40 T&E's in the same family!	N to - In terms of closely related natives and crops a big minus!
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	No demographic modelling work has been conducted on *L. chalepense* and *L. appelianum*	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Information exists on responses of *L. chalepense* and *L. appelianum* to herbicides as well as mechanical control and grazing (see Francis and Warwick 2008)	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?		N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Assuming they share similar nat. enemy assemblages with *C. draba*. See Cripps et al. 2006a, b.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Lepidium* species (other than *L. draba*)

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	It should be good. The agents are very well synchronized with *L. draba* in the native range (e.g. aestivation period of *C. cardariae* during hot and dry summer period) and is expected to be similarly good in the invaded range. The growing season will likely be shorter in some areas in NA,	+

Dimensions/factors	Notes	Influence on likelihood of success [1]
	but since this is temperature driven we expect the agents to adapt. At least *A. drabae* and *C. cardariae* also occur in continental climates.	
How might this influence agent(s) establishment patterns?	Positive- neutral	+
How might this influence agent(s) impacts?	Positive-neutral	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not applicable (*L. draba* is perennial)	
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes. *Aceria drabae* will reduce if not eliminate seed production and stunt plants. *C. cardariae* will reduce the vigour of plants and stunts growth. *C. turbatus* reduces seed production.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	At least *C. cardariae* attacks plants very early in spring over a long time period during the main growth of the weed. In addition weevils have a partial second generation in late summer which should reduce regrowth in early autumn.	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	No sure. The only one that comes to my mind that is functionally similar is Canada thistle, which is not the best positive example!	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No. This will be more likely in more stable habitats such as pastures, natural areas and less likely in roadsides, field edges and crop habitats.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	More or less. There might be particularly cold areas in Wyoming and Montana where agent establishment and impact might be limited, but as mentioned before, at least *A. drabae* and *C. cardariae* do occur in continental climates with cold winters (e.g. Romania, Kazakhstan)	+
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	See answer to habitats.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	*Aceria drabae* develops in gall like structures and should therefore be well protected against predation. *C. cardariae* is a gall former on the above ground plant parts and therefore much more vulnerable to parasitism. It was established that parasitoid species in the genera *Eupelmus, Necremnus* and *Trichomalus* could switch to *C. cardariae* if released. *C. turbatus*: same as for *C. cardariae:* native parasitoids could switch	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.21. *Leucanthemum vulgare* (oxeye daisy)

Feasibility of undertaking a biocontrol project with new agent(s) on *Leucanthemum vulgare*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	No completely new agents are expected to be found, but further surveys are necessary to find big enough populations of *Dichrorampha baixerasana* and *D. consortana* to establish rearing colonies and to conduct host-range testing.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Some possible conflicts with public (pretty daisy). Conflict with closely related Shasta daisy.	- / N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Resources have been limited (amount & geographically) but sufficient will due to progress made.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	All agents that have been identified so far can be found in Europe where it is safe to travel and easy to get the necessary permits.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	For the most part collaborative links have been established and maintained. However not sure about "early pipeline". CABI continues testing of candidates. Project has been initiated in AUS also.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	The majority if not the entirety of work has been conducted at established labs/ facilities.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Taxonomy relatively resolved. Although two closely related *Leucanthemum* species (the diploid *L. vulgare* and the tetraploid *L. ircutianum*) have been introduced to North America, surveys have revealed that only *L. vulgare* is invasive in North America (Stutz et al. 2016)	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Systematics relatively resolved although some adjustments. There are no native species within the same subtribe (Oberprieler et al. 2009). However, the popular garden plant Shasta daisy is a hybrid with *L. vulgare* as one of its parental species.	+ (for phylogeny) - (for closely related species)
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Limited studies. *L. vulgare* reproduces by rhyzomes and seeds	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance,	Limited studies	-

Dimensions/factors	Notes	Influence on feasibility [1]
compensation) to different types of damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Limited studies	-
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	The natural enemy diversity is very well studied in Europe. Surveys in North America have revealed that attack by root- und leaf-feeding herbivores is much lower than in the native range (Stutz et al. 2016)Attack rates by root- and leaf-feeding herbivores on *L. vulgare* in Europe (34 and 75 %) was higher than that on *L. vulgare* in North America (10 and 3 %).	+/U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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https://www.cabi.org/isc/datasheet/13357

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Leucanthemum vulgare*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Probably similar	+
How might this influence agent(s) establishment patterns?	Probably similar	+
How might this influence agent(s) impacts?	Probably similar	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	weed is perennial	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	*Dichrorampha aeratana* reduced plant biomass and number of flower heads in pot-experiments. *D. consortana* visible damages shoots before flowering. The impact of the other two species on *L. vulgare* is currently unknown.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Unknown – probably not persistent over growing season.	-/U
Based on previous research on the target, related species or functionally similar species is there a precedent for	Similar root moths as *D. aeratana* have impacted plants to a certain degree, although overall not	+/U

Dimensions/factors	Notes	Influence on likelihood of success [1]
believing agent damage will be adequate to achieve management goals?	the best agents. Not enough is known about the other agents	
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Probable but not known	+/U
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Most of the potential agents have a wide distribution range across Europe (the exception is *Dichrorampha baixerasana* which has so far only been found in southern Europe).	+/U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	May not be suitable in highly disturbed sites, but not known	-/U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	In the native range, relatively high parasitism rates have been found for *Oxyna nebulosa* (ca. 20-30%). Parasitoids have also been found attacking *Dichrorampha aeratana* but no information about the parasitism rate is available. No information about parasitism is available for the other two species.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
https://www.cabi.org/projects/project/56283

1.22. *Linaria dalmatica* (Dalmatian toadflax)

Feasibility of undertaking a biocontrol project with new agent(s) on *Linaria dalmatica*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Good – a number are under development	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Not widely valued, valued by some as an ornamental; nurseries in states where not listed as noxious still sell it; beekeepers believe it is a good pollen/nectar source which is not true due to the morphology of the blossoms which renders them inaccessible to only the most robust (=bumblebees) or specialized (=*Calaphasia lunula*) insects	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Yes sufficient will to continue investing especially where weed is fairly new management target	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Yes to all	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Excellent!	++
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes except that toadflax hybridization is widespread	N to -
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes, phylogenetic placement of weed is well resolved. No closely related threatened or endangered native plants species or crop species.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	Defoliation is not an effect route for biological control; also extremely difficult to kill with herbicide; hence the focus on stem miners, gallers and root feeders	+

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Interaction with specific candidate agents in terms of climate matching is not known yet; wide ecological amplitude of the target weed makes consistent control challenging	U
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well known in native range; studies have assessed it in UT and MT but in other impacted areas of NA relatively unknown	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Linaria dalmatica*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Questionable – some NA sites have fairly different seasonal cycles compared to the native range	N to U
How might this influence agent(s) establishment patterns?	Highly significant factor except that all new agents were selected specifically to be more tolerant of harsher climate	U/+
How might this influence agent(s) impacts?	If increased tolerance holds in NA releases, then impact should not be affected	U/+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not relevant	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes and this is well documented; new agents are compatible with established agents via resource partitioning and asynchronous attack on the target	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Highly likely; adults feed for at least one month on foliage; larval stages feed for 2+ months within stems	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Yes	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown at this time – issues with fluctuating spring fall and winter temperatures and snow pack should be alleviated with new suite of agents	+/U

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	As above	+/U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Grazing impacts may be factor either from livestock or wildlife	U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown at this time	U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.23. *Linaria vulgaris* (yellow toadflax)

Feasibility of undertaking a biocontrol project with new agent(s) on *Linaria vulgaris*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Good – a number are under development	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Not widely values, valued by some as an ornamental; nurseries in states where not listed as noxious still sell it; beekeepers believe it is a good pollen/nectar source which is not true due to the morphology of the blossoms which renders them inaccessible to only the most robust (=bumblebees) or specialized (=*Calaphasia lunula*) insects	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Yes sufficient will continue investing especially where weed is fairly new management target	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Yes to all	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Excellent!	++
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes except that toadflax hybridization is widespread	N to -
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes, phylogenetic placement of weed well resolved. No closely related threatened or endangered native plants species or crop species.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	Defoliation is not an effect route for biological control; also extremely difficult to kill with herbicide; hence the focus on stem miners, gallers and root feeders	+

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Interaction with specific candidate agents in terms of climate matching is not know yet; wide ecological amplitude of the target weed makes consistent control challenging	U
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well known in native range; studies have assessed it in UT and MT but in other impacted areas of NA relatively unknown	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Linaria vulgaris*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Questionable – some NA sites have fairly different seasonal cycles compared to the native range	N to U
How might this influence agent(s) establishment patterns?	Highly significant factor except that all new agents were selected specifically to be more tolerant of harsher climate	U/+
How might this influence agent(s) impacts?	If increased tolerance holds in NA releases, then impact should not be affected	U/+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Not relevant	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes and this is well documented; new agents are compatible with established agents via resource partitioning and asynchronous attack on the target	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Highly likely; adults feed for at least one month on foliage; larval stages feed for 2+ months within stems	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Yes	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown at this time – issues with fluctuating spring fall and winter temperatures and snow pack should be alleviated with new suite of agents	+/U

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	As above	+/U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Grazing impacts may be factor either from livestock or wildlife	U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown at this time	U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Toševski, I., Sing, S.E., De Clerck-Floate, R., McClay, A., Weaver, D.K., Schwarzländer, M., Krstić, O., Jović, J. and Gassmann, A., 2018. Twenty-five years after: post-introduction association of *Mecinus janthinus* sl with invasive host toadflaxes *Linaria vulgaris* and *Linaria dalmatica* in North America. *Annals of Applied Biology* 173 pp 16-34.

1.24. *Myriopyllum spicatum* (Eurasian watermilfoil)

Feasibility of undertaking a biocontrol project with new agent(s) on *Myriophyllum spicatum*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Hybridization with a native is a problem for host specificity. The hybrid is more vigorous. For pure invasive populations…	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Pond and aquarium groups. There are many alternative aquatic species for consumers, so likely they would not miss this one too much	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	No, there has not been much effort in agent exploration except by CABI. Need to look in S. Korea and China. Some US and native range exploration was done 1965-90s, and there is a review of searches in Cock 2008.	+
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Moderate access through collaborators. Safe. No permit problems.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes in China via CABI and EBCL	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Unclear. Aquatics take special equipment. Not sure if potential agents could be imported to Switzerland or France for work. Likelihood that all work would need to be done in quarantine.	-
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	And much population genetic work from Ryan Thum MSU. *M. spicatum* hybridized with *M. sibericum*, hybrid is more vigorous. We have rapid assessment of hybrid status now. An effective agent would have to feed on *M. spicatum* and hybrid. *M. sibericum* is endangered in NJ, threatened in OH and PA. *M. alterniflorum* and *M. sibericum* are closest relatives in phylogeny and both have some T&E status.	-
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	There are 12 US native species in the genus. Yes, phylogeny.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes. Well studied. Vulnerable stages not known.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	No.	-

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Water milfoil responds very positively to phosphate loading (both native and non-native). Weed may be a problem because of management practice as much as invasive status.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Needs more knowledge.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
Gassman et al. 2006 Hydrobiologia

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Myriophyllum spicatum*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Unknown agents, unknown synchrony	-
How might this influence agent(s) establishment patterns?	?	-
How might this influence agent(s) impacts?	?	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	NA	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	No agents	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Unlikely. Milfoil densities more likely reflect P and N levels in water and not a lack of natural enemies	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	No	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No	-
Is the suite of agents that are available capable of achieving management goals	No	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
across the range of climate regions invaded by the weed?		
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	No	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.25. *Onopordum acanthium* (Scotch thistle)

Feasibility of undertaking a biocontrol project with new agent(s) on *Onopordum acanthium*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Yes. Several potential agents have been identified; however, host specificity is an issue. Two potential agents were found in Turkey, an eriophyid mite and as nematode.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	None	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Not enough	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	The native range is Eurasia (Young and Evans, 1969). It may be safe for researchers and collaborators. Two potential new agents are in Turkey – currently impossible to get export permits.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	BBCA Rome	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Possible	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The chromosome number is 2n=34 (Podlech and Dieterle, 1969). A natural hybridization has occurred in Australia between O. acanthium and O. Illyricum (Michael, 1996).	–
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	More work needed in the US. ????	U
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	yes	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Reproduction only by seed.	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use,	yes	+

Dimensions/factors	Notes	Influence on feasibility [1]
competing species) in which biocontrol is desired adequately understood?		
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	These plants have been extensively studied in their native range. In the US studies of associated insects have been done (Watts and Piper 2000)	

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Young JA; Evans RA, 1969. Control and ecological studies of Scotch thistle. Weed Science, 17:60-63.

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Onopordum acanthium*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Great success with several species in Australia. If a host specific agent could be found it is likely to be good synchrony.	+
How might this influence agent(s) establishment patterns?	Reproduction by seed – so damage could be good.	+
How might this influence agent(s) impacts?	The Eriophyid mite could provide significant damage. Unknown impact at present.	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	O. acanthium is can be a monocarpic biennial, annual, or short-lived perennial (Hyde-Wyatt, 1968).	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Mite impact unknown at present	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	unknown	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Huge concerns with non-target host use to Cirsium species	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	No approved biocontrol agents available. Concern over host shifting to native thistles.	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Host specificity and difficulty doing host range testing.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Unknown Eriophyid may have potential. If any of the	-
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	No approved biocontrol agent is available in the US.	U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Balciunas, J, 2007. Lixus cardui, a biological control agent for scotch thistle (*Onopordum acanthium*): Safe for Australia, but not the USA? Biological control, 41(1):134-141.

1.26. *Pilosella aurantiaca* (=*Hieracium aurantiancum*; orange hawkweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Pilosella aurantiaca*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	A number of surveys have been conducted. Low potential of finding additional agents. Perhaps pathogens. Has been a target since 1993 in NZ (5 released in New Zealand) and 2000 in US, numerous agents have been tested or studied, one released but establishment is limited to Canada and unlikely established in US (Montana, unlikely to establish because OHW is poor host). One at TAG.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No apparent conflict. Some local use as ornamental however ill advise.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Between NZ and NA adequate funding for overseas work. Continued investment may be problematic for longterm studies. (Funding fatigue)	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Much of the range has been open for exploration, however the Caucasus and surrounding areas are problematic. Europe, haplotypes in US appear to originate from Czech Republic based on Loomis and Fishman 2009.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	For the most part collaborative links have been established and maintained. However not sure about "early pipeline". New areas may be unknown but CABI has network that may likely meet needs for new survey areas.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	The majority if not the entirety of work has been conducted at established labs/ facilities. Montana State University has plant pathogen lab that can be collaborative if needed. CABI-England has pathology team. EBCL may be a collaborator.	N/U
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The taxonomy of this species seems stable. NA plants appear to be of a single origin (i.e. genotype).	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Hawkweeds are difficult taxonomically and systematically. Problematic since there are NA native species to consider, as well as exotic invasive species.	-
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	In general adequate but no demographic studies have been conducted (unknown)	N/U
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	For NA – inadequate information, probably more for other locations such as NZ	N/U

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	For NA – inadequate information, probably more for other locations such as NZ	N/U
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Probably known in foreign range. Little is known in NA range - but probably little feeds on it. Pollination ecology not well known.	+/ U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

https://www.cabi.org/isc/datasheet/27160

https://www.fs.fed.us/database/feis/plants/forb/hieaur/all.html

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Judith Fehrer, Birgit Gemeinholzer, Jindřich Chrtek, Siegfried Bräutigam, Incongruent plastid and nuclear DNA phylogenies reveal ancient intergeneric hybridization in Pilosella hawkweeds (Hieracium, Cichorieae, Asteraceae), In Molecular Phylogenetics and Evolution, Volume 42, Issue 2, 2007, Pages 347-361, ISSN 1055-7903, https://doi.org/10.1016/j.ympev.2006.07.004.

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Pilosella aurantiaca*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Probably similar	+
How might this influence agent(s) establishment patterns?	Infest multi-plant parts	+
How might this influence agent(s) impacts?	Likely to have broad impacts on the plant due to attack on multiple plant parts.	+/U
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Probably dependent on refugia populations.	U
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Preliminary data suggest possible impacts. Research in Europe and Canada are encouraging.	U
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Two populations one has two generations which may persist over growing season, this variability may enhance survival across range of climatic areas.	U
Based on previous research on the target, related species or functionally	Limited number of similar agents to compare to. Galls can serve as resource sinks but remains	U

Dimensions/factors	Notes	Influence on likelihood of success [1]
similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	unknown if populations will reach sufficient densities to adequately suppress populations.	
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Probable – dry habitats unknown. Drier conditions in NZ resulted in plant desiccation/senescence and negatively affected closely related gall wasp.	+/U
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Probable.	+/U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	For most – unsure about roadsides, agricultural, or other lands actively managed.	+/U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Somewhat vulnerable to parasitism	-/U
Other factors		
Impact other targets	Other hw targets may be impacted – same level is unknown.	+/U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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1.27. *Pilosella caespitosa* (=*Hieracium caespitosum*; yellow or meadow hawkweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Pilosella caespitosa*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	A number of surveys have been conducted. Low potential of finding additional agents. Perhaps pathogens. Has been a target since 1993 in NZ (5 released in New Zealand) and 2000 in US, numerous agents have been tested or studied, no releases have been made against meadow hawk weed but one species is under study and host range testing should be complete in the next few years.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No apparent conflict. Some local use as ornamental however ill advise, not used as much as orange hawk weed.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Between NZ and NA adequate funding for overseas work. Continued investment may be problematic for longterm studies. (Funding fatigue)	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Much of the range has been open for exploration, however the Caucasus and surrounding areas are problematic. Europe, haplotypes in US appear to originate from Czech Republic based on Loomis and Fishman 2009.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	For the most part collaborative links have been established and maintained. However not sure about "early pipeline". New areas may be unknown but CABI has network that may likely meet needs for new survey areas.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	The majority if not the entirety of work has been conducted at established labs/ facilities. Montana State University has plant pathogen lab that can be collaborative if needed. CABI-England has pathology team. EBCL may be a collaborator.	N/U
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	The taxonomy of this species seems less stable than for orange hawk weed, more problematic for meadow hawkweed. NA plants appear to be of a single origin (i.e. genotype).	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Hawkweeds are difficult taxonomically and systematically. Problematic since there are NA native species to consider, as well as exotic invasive species.	-
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	In general adequate but no demographic studies have been conducted (unknown)	N/U
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	For NA – inadequate information.	N/U

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	For NA – inadequate information.	N/U
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Probably known in foreign range. Little is known in NA range - but probably little feeds on it. Pollination ecology not well known.	+/U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

https://www.cabi.org/isc/datasheet/27160

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Judith Fehrer, Birgit Gemeinholzer, Jindřich Chrtek, Siegfried Bräutigam, Incongruent plastid and nuclear DNA phylogenies reveal ancient intergeneric hybridization in Pilosella hawkweeds (Hieracium, Cichorieae, Asteraceae), In Molecular Phylogenetics and Evolution, Volume 42, Issue 2, 2007, Pages 347-361, ISSN 1055-7903, https://doi.org/10.1016/j.ympev.2006.07.004.

J. F. Gaskin and L. M. Wilson, 2007. Phylogenetic Relationships Among Native and Naturalized Hieracium (Asteraceae) in Canada and the United States Based on Plastid DNA Sequences

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Pilosella caespitosa*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Probably similar	+
How might this influence agent(s) establishment patterns?	Infest multi-plant parts	+
How might this influence agent(s) impacts?	unknown	+/U
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Probably dependent on refugia populations.	U
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Preliminary data suggest possible impacts. Research in Europe and Canada are encouraging.	U
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Two populations one has two generations which may persist over growing season, this variability may enhance survival across range of climatic areas.	U
Based on previous research on the target, related species or functionally	Limited number of similar agents to compare to. Galls can serve as resource sinks but remains	U

Dimensions/factors	Notes	Influence on likelihood of success [1]
similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	unknown if populations will reach sufficient densities to adequately suppress populations.	
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Probable – dry habitats unknown. Drier conditions in NZ resulted in plant desiccation/senescence and negatively affected closely related gall wasp.	+/U
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Probable.	+/U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	For most – unsure about roadsides, agricultural, or other lands actively managed.	+/U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Somewhat vulnerable to parasitism	-/U
Other factors		
Impact other targets	Other hw targets may be impacted – same level is unknown.	+/U

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.28. *Potentilla recta* (sulphur cinquefoil)

Feasibility of undertaking a biocontrol project with new agent(s) on *Potentilla recta*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	The plant has been targeted by CABI CH from 1992 through 2002 for North America. Project was started back up in 2008 with more research. Several species were discovered but not sufficiently host specific.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No important uses of the plant other than possibly as an ornamental in some areas. Bees may use it in some regions.	- / N
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Nearly 25 years of research has been dedicated, off and on, by Montana and British Columbia. CABI took lead on foreign exploration and host range testing.	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Eastern Mediterranean, Turkey and Ukraine were areas of focus for surveys. One CABI report from 2011 indicates that the native range for North American material is Central European.	-
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	For the most part collaborative links have been established and maintained, focusing on North America and CABI partners. Unsure if CABI continues to have "early pipeline" candidates.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	The majority if not the entirety of work has been conducted at established labs/ facilities.	N/U
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Taxonomy complicated, specifically due to the possibility of species complexes in native range. Taxonomy needs to be clarified for areas east of Turkey: Iran and Uzbekistan. Multiple ploidy levels.	-
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Fairly well understood at the family level but possibility of species complexes that needs to be resolved. There are other native potentilla, around ~85 NA species, a few at T&E species, a few introduced weeds. Dobes and Paula 2011 have done some phylogenetic work, falling within an unresolved group.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Limited studies.	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of	Limited studies	-

Dimensions/factors	Notes	Influence on feasibility [1]
damage (biotic, abiotic) satisfactorily understood?		
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Limited studies. There is some belief that P. recta may hybridize with native Potentilla species, complicating situation.	-
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	CABI conducted several surveys and found a root mining moth, flower bud weevil, gall weevil, stem gall wasp and gall midge but none were specific. The root moth completed partial development on strawberries in no-choice test, so a petition was never submitted. Believe to unlikely attack strawberries under field conditions.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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A comprehensive chloroplast DNA-based phylogeny of the genus *Potentilla* (Rosaceae): Implications for its geographic origin, phylogeography and generic circumscription https://doi.org/10.1016/j.ympev.2010.03.005

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Potentilla recta*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Probably similar	N
How might this influence agent(s) establishment patterns?	Unknown	N
How might this influence agent(s) impacts?	Unknown	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	The weed is perennial so refugia within the plant's form is encouraging.	-
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	The examples of studied insects appear promising but their lack of specificity limits predictions.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Likely if well synchronized but dependent on how many generations per year.	-/ U
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	The plant may be able to compensate for herbivory based on large tap root.	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Probable but not known	+ / U
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Probable but not known	+ / U
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	May not be suitable for all ranges through its wide distribution.	-/ U
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Dependent: the root mining moth would be fairly well protected while the gall midge may have higher probability of being parasitized.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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1.29. *Rhaponticum repens* (=*Acroptilon repens*; Russian knapweed)

Feasibility of undertaking a biocontrol project with new agent(s) on *Rhaponticum repens*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Surveys in relatively easily accessible regions done; remote areas in central Asia (e.g. Kyrgyzstan, Tajikistan) not yet surveyed.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Significant resources have been devoted in the past, but problem persists	U
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	See above; access is possible, but only parts of the area not yet surveyed are safe. Target plant is widespread, moving it around in the native range is not problematic; candidate agents need special permits, but it is possible to acquire the requisite permits.	N
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Collaborators from Asia can be arranged links and early pipeline work.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Not sure about facilities in the remote areas, but facilities at Universities in the larger region are available; knowledge about screening of agents is, however, quite limited among scientists in the area	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Phylogenetic placement resolved, only a few closely related native species present.	+
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Life-cycle moderately well known, demographic model for assessing contribution to population demography not available ; target life stage depends on management goal	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Moderately well known	N
Landscape context: Is the landscape context (e.g. habitat, climate, land use,	Yes, primarily a weed of disturbed rangelands and grasslands which has been well studied.	+

Dimensions/factors	Notes	Influence on feasibility [1]
competing species) in which biocontrol is desired adequately understood?		
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Well known in native range. Some generalists studied in invaded range that did not affect population growth.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Rhaponticum repens*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Likely to be high, but spring temperature in the invaded range seems to be a bit lower than in the native range	+
How might this influence agent(s) establishment patterns?	No influence expected	N
How might this influence agent(s) impacts?	If the agent's development in the invaded range is delayed, then its impact might be reduced	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Weed is perennial	+
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	High reduction of seed output is possible	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	High	+
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Spread of invasive species rarely quantified; there is some evidence that reduction in seed output reduces population densities of closely related diffuse knapweed	N
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Not clear, *Aceria acroptiloni* has only a patchy distribution in the native range	-
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Rather unlikely; at least the only agent known does not occur in various regions of the native range	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Land-use type does not seem to be a constraint, since the only agent known has been found in different land-use types in the native range	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Native, closely related herbivores are known to have a set of natural enemies; yet, they can still build up high densities at local scale	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
None provided

1.30. *Rubus armeniacus* (Armenian or "Himalayan" blackberry)

Feasibility of undertaking a biocontrol project with new agent(s) on *Rubus armeniacus*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	No active biocontrol program in N. America. One candidate agent has been accidentally introduced. New agents would likely be present in the native range.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	Target was imported to N. America in 1885 as a "larger, sweeter" variety of edible blackberry. Unclear how popular it is today.	-
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	USDA is discouraging biocontrol work on this weed due to its close relationship to cultivated blackberry. Australian group is screening for most specific and aggressive strains of *P. violaceum*.	-
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Access to some of the native range (Armenia) is possible. The other half of the native range (northern Iran) may be challenging or politically impossible, depending on the traveller.	N
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	None documented.	-
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Not really.	-
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Target appears to be clonal offspring of native range genotype that was also exported to Europe and Australia.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	USDA is discouraging biocontrol work on this weed due to its close relationship to cultivated blackberry.	-
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes. Clonally reproducing perennial. Roots most vulnerable. Destruction of stems very desirable. Seed reduction desirable to prevent spread by birds.	+
Ecophysiology: Is the weed's vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Unknown.	N

Dimensions/factors	Notes	Influence on feasibility [1]
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Invasive in much of the temperate world. Invasive in riparian areas, native to mountainous region with high seasonal humidity. Appears to need wet ground to establish but not year round.	N
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Not well known.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Flora of NW Europe: Rubus armeniacus

USDA-FS

Oregon State Univ., Extension Service

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Rubus armeniacus*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	It seems likely given that the agent was accidentally introduced and established by itself.	+
How might this influence agent(s) establishment patterns?	Seems to establish readily.	+
How might this influence agent(s) impacts?	Doesn't appear to be reducing invasive populations based on anecdotal data.	-
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Weed is perennial.	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Doesn't appear to be reducing invasive populations following accidental introduction.	-
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Not likely.	-
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	The agent has been released in S. America and Australia as a biocontrol agent of other *Rubus* spp., but does not appear to be sufficiently damaging on *R. armeniacus*.	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals	Not known. Typically fungi require a certain amount of moisture to establish and this weed also appears to need at least seasonal moisture.	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
across the range of habitats invaded by the weed?	However, agent does not appear effective in invaded habitat.	
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Unlikely. Target is invasive in most of the temperate world but invasion is not known in other climatic regions. However, agent does not appear effective in temperate region.	-
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Target invades pastures, wetlands and riparian areas. Agent is unlikely to be affected by these different areas.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Not known.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
See above.

1.31. *Taeniatherum caput-medusae* (medusahead)

Feasibility of undertaking a biocontrol project with new agent(s) on *Taeniatherum caput-medusae*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	It has been the subject of biological control programme for a long time and no agents have yet been released in North America.	N
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	No.	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Pathogens yes has been extensively studied for many years. There may be a will to invest in work on eriophyid mites since these are still being developed.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	*Taeniatherum* occurs naturally in the Mediterranean region. It reaches eastwards in Asia to Kyrgyzstan, and northwards in Europe to Budapest in Hungary. It has been introduced in the northern and northwestern parts of Europe and in the Americas, where it acts as a weed (Frederiksen, 1986). Subspecies *caput-medusae* is found in the western Mediterranean and is generally restricted to Portugal, Spain, southern France, Morocco and Algeria (Young, 1992). When collected elsewhere it is probably adventitious (Frederiksen, 1986). Subspecies *crinitum* occurs from Greece and the Balkans into Central Asia (Frederiksen, 1986; Peters, 2013). Within its native range, *T. caput-medusae* spp. *asperum* is the most widely distributed of the subspecies, occurring across the whole geographic distribution of the species. Only subspecies *asperum* has been identified in North America (Peters, 2013).	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, several: USDA, BBCA, CABI, University of Belgrade, Serbia, many botanists and universities (Morocco, Turkey, Kazakstan, Greece, etc.)	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, several see above.	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes, *Taeniatherum*, of which the three subspecies of *T. caput-medusae* are the only members, it is a distinct genus which most closely resembles species of *Elymus, Hordelymus* and *Hordeum*.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Yes (see Peters, 2013). There are several closely related species in North America, notably species in the genus *Elymus* and *Hordeum.*	+

Dimensions/factors	Notes	Influence on feasibility [1]
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes, it is an annual that relies heavily on sexual reproduction.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Being an annual, this weeds vulnerable stage is likely to be sexual reproduction and seed production.	+
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	yes	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Surveys have been conducted in the native range to identify potential biological agents (USDA and BBCA). But should be redone looking for Eriophyid mites and in other seasons.	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Taeniatherum caput-medusae*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Should not be a problem since both the invaded and native are northern hemisphere occupying similar climatic ranges.	+
How might this influence agent(s) establishment patterns?	Positively.	+
How might this influence agent(s) impacts?	Positively.	+
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	This is a potential risk as this is an annual species which is prone to fire and cold hardiness of the biological control agent.	-
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	The work with the eriophyid mite, *Aculodes alta-murgiensis* is too early to determine impact, however the mite has been collected on the seed capsule which suggests that it could potentially impact reproduction.	N (for the mite) - (for the pathogens)

Dimensions/factors	Notes	Influence on likelihood of success [1]
	Fungi that successfully reduced seed production of *T. caput-medusae* were also detrimental to desirable native vegetation and/or seed grain (Grey et al., 1995; Siegwart et al., 2003; Berner et al., 2007).	
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Unknown, but could be considered likely given the potential for populations of eriophyid mites to grow extremely rapidly, even in a short growing season. The probability of this mite to overwinter is also high since surveys for this mite has been recorded very early in the growing season and never on another species except medusahead.	N
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	There is little evidence from annual species that biological control is an effective management goal alone. However, it could be combined with an integrated weed management programme and be effective.	-
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown at this stage.	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Unknown at this stage.	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Unknown at this stage.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Eriophyid mites, such as *Aculodes alta-murgiensis,* could be potentially limited by predation, however, there are several cases where Eriophyid mites have been successful biological control agents (Winston et al., 2016)	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

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1.32. *Tribulus terrestris* (puncture vine)

Feasibility of undertaking a biocontrol project with new agent(s) on *Tribulus terrestris*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	Sankaran 1980: 9 potential agents in India. Follow up on cold adapted strain that did not establish. Good chance, however unsure about how closely related is to *Larrea* or *Kallstroemia*. Has only a fraction of native range been surveyed? . Current agents will feed on some *Kallstroemia* species. Unknown if agents are currently feeding on "acceptable" NT hosts in NA.	+
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	The plant is used as an herbal medicine in western and other traditions, raising the potential for conflicts with individuals growing the plant for commercial sale.	-
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Has not been worked on recently? Record of cold adapted Italy strain released in 1994, but did not establish.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	Yes, mostly. ? about India and exporting agents. Unsure about phylogeography of *Tribulus* and what we have in US.	N/+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Possibly? As much as would be available for other weeds from this part of the world.	N
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Yes. Not in same tribe as NA species, however, *Tribulus* has a very wide distribution and area of origin is not resolved.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Needs work, particularly with regard to related genera in NA. (see Nemando et al. 2017)	N
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Yes about LC, but not as much about vulnerable stages.	+
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance,	Seed feeders appear to be effective (HI, CA, CO?), limitation is establishment and population build up.	+

Dimensions/factors	Notes	Influence on feasibility [1]
compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	Unclear if we can stop flowering or fruiting. Preventing flower development or fruit maturation could be a new target site.	
Landscape context: Is the landscape context (e.g. habitat, climate, land use, competing species) in which biocontrol is desired adequately understood?	Yes. Cold hardy, successful in disturbed habitats.	+
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Fairly well studied over the last 40 years. However, unsure if there are areas that have not been surveyed that should be. Taxonomy and host specificity of mite species could be studied further.	+

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

Nemando, R; Boatwright, JS; Magee, AR. 2017. Systematics of the genus *Tribulus* (Zygophyllaceae) in southern Africa. SOUTH AFRICAN JOURNAL OF BOTANY. Volume: 109: 359-359

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Tribulus terrestris*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Unknown, but climate matching is a problem, as some literature suggests that *Tribulus* is a Mediterranean species and areas where agents are least effective are not.	-
How might this influence agent(s) establishment patterns?	Climate matching to cold winter areas is needed.	-
How might this influence agent(s) impacts?	Already does for existing agents in some areas.	
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	In cold climates potential agents would require a dormant stage to survive.	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Yes. Identified agents can reduce flowering and or seed set.	+
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	In areas in need of additional control, this is the big unknown.	N
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be adequate to achieve management goals?	Yes. *Microlarinus* sp. appear to have had large impacts in warm-winter areas.	+
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals	This is the question. Management goals need to be accomplished in disturbed habitats.	N

Dimensions/factors	Notes	Influence on likelihood of success [1]
across the range of habitats invaded by the weed?		
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	This is the question. Management goals need to be accomplished in disturbed habitats.	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	This is the question. Management goals need to be accomplished in disturbed habitats.	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Parasitism & predation is a huge issue for existing / identified agents	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

Sankaran, 1980. Studies on the natural enemies of puncturevine occurring in Karanataka State, India. Proceedings of the V. ISBCW. 153-160.

Nemando, R; Boatwright, JS; Magee, AR. 2017. Systematics of the genus *Tribulus* (Zygophyllaceae) in southern Africa. SOUTH AFRICAN JOURNAL OF BOTANY. Volume: 109: 359-359

1.33. *Ventenata dubia* (wiregrass)

Feasibility of undertaking a biocontrol project with new agent(s) on *Ventenata dubia*

Dimensions/factors	Notes	Influence on feasibility [1]
Historical		
Target status: If the weed has already been/is a target in N. America, what is the likelihood of finding new agents from the native range?	The native range is unclear. Little is known about natural enemies of this species.	-
Socio-political		
Values: Is the weed valued by any group and is that likely to result in a conflict of interest in developing/deploying biocontrol agents?	This species has no known economic, medicinal, or ecological value	+
Investment: Is there a view that enough resources (time, personnel, funds, etc.) have already been devoted to this in the past? Is there sufficient will to invest more resources?	Very little, if any, resources have been devoted to biocontrol efforts. This species is an increasing concern.	N
Logistical		
Native range: Is access to the native range possible? Is it safe for researchers and collaborators? Is it possible acquire the requisite permits for moving target plant and its candidate agents within the native range, and from native range to the US?	The native range is somewhat unclear. Appears to be native to Europe and Africa. Region is safe and accessible to researchers. Permits are not likely to be a problem.	+
Collaborative links: Are there existing collaborative relationships in place in the native range to enable early pipeline work to occur?	Yes, many European collaborators. Collaborators in ARS, Serbia, and Kazakhstan.	+
Infrastructure: Are there requisite facilities available in the native range to enable initial research and screening (systematics, biology and host-specificity) of agents to be done?	Yes, CABI, ARS, and EBCL could likely provide support	+
Ecological/evolutionary		
Taxonomy: Is the taxonomic/genetic identity of the weed satisfactorily resolved so as to not be an impediment to a biocontrol project?	Based off a brief online search, there do not appear to be problems with the taxonomy. There are 8 species within the *Ventenata* genus.	+
Systematics: Is the phylogenetic placement of the weed satisfactorily resolved? Are there closely-related native or crop species?	Unknown.	N
Demography: Is the life-cycle of the weed adequately characterised? Are the vulnerable life stages of the weed known?	Winter annual grass, rare in the intermountain west, but expanding to the east from PNW.	-
Ecophysiology: Is the weeds vulnerability (e.g. resistance, tolerance, compensation) to different types of damage (biotic, abiotic) satisfactorily understood?	There are four journal articles on Ventenata from 2014-2017. This is a large knowledge gap. Wide germination peak, short-lived seed bank.	-
Landscape context: Is the landscape context (e.g. habitat, climate, land use,	With management goals similar to *Bromus tectorum and Taeniatherum caput-medusae*, the	N

Dimensions/factors	Notes	Influence on feasibility [1]
competing species) in which biocontrol is desired adequately understood?	land use is adequately understood, but the extent of Ventenata may not be entirely mapped.	
Natural enemy diversity: To what extent is the natural enemy diversity known in the native and invaded range?	Unknown. Two pathogens (*Septoria ventenatae, Tilletia fusca*) neither of which are specific.	-

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References
Comparisons of Canyon Grassland Vegetation and Seed Banks Along an Early Successional Gradient
By: Bernards, Samantha J.; Morris, Lesley R. NORTHWEST SCIENCE Volume: 91 Issue: 1 Pages: 27-40 Published: JAN 2017
Aminopyralid Constrains Seed Production of the Invasive Annual Grasses Medusahead and Ventenata
By: Rinella, Matthew J.; Bellows, Susan E.; Roth, Aaron D. RANGELAND ECOLOGY & MANAGEMENT Volume: 67 Issue: 4 Pages: 406-411 Published: JUL 2014
The effects of precipitation and soil type on three invasive annual grasses in the western United States
By: Bansal, Sheel; James, Jeremy J.; Sheley, Roger L. JOURNAL OF ARID ENVIRONMENTS Volume: 104 Pages: 38-42 Published: MAY 2014
Ecological Characteristics of Ventenata dubia in the Intermountain Pacific Northwest
By: Wallace, John M.; Pavek, Pamela L. S.; Prather, Timothy S. INVASIVE PLANT SCIENCE AND MANAGEMENT Volume: 8 Issue: 1 Pages: 57-71 Published: JAN-MAR 2015

Likelihood of new agent(s) achieving the desired management goals (assuming host-specificity) for *Ventenata dubia*

Dimensions/factors	Notes	Influence on likelihood of success [1]
Weed life cycle		
What is the likely synchrony of the agent(s) with the weed's life-cycle in the invaded range?	Unknown	N
How might this influence agent(s) establishment patterns?	Unknown	N
How might this influence agent(s) impacts?	Unknown	N
What is the risk that populations may not be sustained over time if the weed is an annual/ephemeral?	Unknown	N
Agent damage (type, severity, duration)		
Is the agent/suite of agents, capable of inflicting the type of damage that is desirable (consult weed demography and ecophysiology notes under feasibility)?	Unknown	N
How likely is the damage by suite of agents to persist over the duration of the weed's growing season at a level of severity to achieve the management goals?	Unknown	N
Based on previous research on the target, related species or functionally similar species is there a precedent for believing agent damage will be	Research on other winter annuals has yielded few biocontrol options and no effective biocontrol to date.	-

Dimensions/factors	Notes	Influence on likelihood of success [1]
adequate to achieve management goals?		
Landscape context (habitat, climate, land use, competing species)		
Is the suite of agents that are available capable of achieving management goals across the range of habitats invaded by the weed?	Unknown	N
Is the suite of agents that are available capable of achieving management goals across the range of climate regions invaded by the weed?	Unknown	N
Is the suite of agents that are available capable of achieving management goals across the range of land-uses invaded by the weed?	Unknown	N
3rd trophic level		
How vulnerable are the suite of agents that are available to predation/parasitism, and how might this affect their ability to contribute to achieving the management goals?	Unknown	N

[1] +: positive influence. -: negative influence. N: neutral influence. U: unknown influence

References

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Appendix 3. Notes taken during presentations on each weed by participants who performed the assessments (Appendix 1) during Workshop 2, and the resultant group review

Alliaria petiolata

High feasibility

Lot of work done on this plants by CABI in collaboration with eastern US scientists. Lots known. A weevil attacked the roots (TAG approved) and another weevils attacks the seeds (testing almost finishing). Complimentary agents. Nice modelling work done to predict the effect – models show that success is very likely. No NA plants in the genus. Only 2 NA plants in the tribe and those two plants are introduced. Pretty promising.

Native range western and Eastern Europe. Easy to travel in.

Possible opposition but not likely to be continued for long

High likelihood

On the strength of the modelling work done. Good work.

<u>Discussion</u>

Q: how do you deal with the assumption that the weeds will disappear if all the deer are killed?

A: Ranger said difficult to control deer. But the argument of retaining an exotic species so that deer can have food is spurious.

Berteroa incana

Moderate feasibility

Based on other work done on Brassicacea by CABI and others. Most found in disturbed area – so biocontrol may not be that good but it also occur in more stable areas. Lots of unanswered questions. Native range in Europe would be easy. No native members of this genus in the US. 100-150 species that would have to be tested because it's a Brassicaceae. If agent univoltine then would take a long time and lots of money – Long-term project.

Moderate likelihood

So many unanswered questions. Don't have a track records of biocontrol on Brassicacea post-release which bring a level of uncertainty to it. Weeds of disturbed habitat and biocontrol not typically effective in such area. Rosette feeder would be needed for max impact (similar to thistle agents).

***Bromus tecto*rum**

Probably most invasive in the US.

Low feasibility

Only hope with mites. No other prospects. Focus on mites because would need something with a fast lifecycle for a fast lifecycle plants. Have found mites but not adequate so far for a range of reasons. Assessment considered on the extensive body of work done so far. Native range well identified – Russia. Native range is so broad so difficult to know you are searching on the centre of origin.

Some work on fungi found in the US (associated with dieback).

<u>Discussion</u>

Q: How extensive have the native range searches done? Thoroughly done. Has been a target for years and lots of money poured into it.

Comment: USDA Lab in France do not target *Bromus* because of potential non-target effect.

Other comment: A rust has been collected but ARS not allow to work on it. Reason for not pursuing pathogens is because no petition for release has been successful so far.

Low likelihood

Based on past experience – no previous success in biocontrol of grass like *Bromus* before.

Butomus umbellatus

Moderate-**High** feasibility

Only species in that genus in NA. A few candidates already identified.

<u>Discussion</u>

Comment: Smut fungus attacks submerged plants. There is a genotype issue, which could influence feasibility.

Moderate-High likelihood

Don't know anything to compare with so selected moderate.

<u>Discussion</u>

Comment: huge range of the plant; major root reserves, are justifications for moderate rank.

Centaurea diffusa

Wondered why it was on the list – because it's been a successful project.

<u>Discussion</u>

Comment: a mite has been recorded in Greece and could have potential.

Low feasibility

Not aware of additional agents that could be evaluated.

Low likelihood

A participant said: “If you can’t find agents then automatic low likelihood”

Centaurea solstitialis

High feasibility

6-7 agents have been introduced. Half are having impact. Some people claim that biocontrol is working. There are other options that have not been explored. Prospective agents (from Turkey and Bulgaria) would complement existing agents – attack different parts of the plants. No serious issues with no-target species. In 1984 – mismatch between first agent and biotype of the weed. There hasn’t been modern genetic study until very recently. Safflower is the close related crop at risk, but prospective agents don’t attack it.

High likelihood

See assessment sheet

Centaurea stoebe

Challenge here with management goals. How to manage the weed at low level.

Low feasibility

Weed has been studied over many decades. We’ve probably introduced everything that exist.

Low likelihood

Because we want to use biocontrol in highly disturbed area – very low chance of success.

Chondrilla juncea

High feasibility

We have a suit of agents that attack above ground, only one that attack the roots (boring moths). There are two other root borers that people are working with. Root system is the Achilles heel of this plants.

Moderate likelihood

Current root boring insect doesn’t seem to be that impactful, but the other moths seems more promising in testing setting.

Cirsium arvense

Unfeasible/Unnecessary–**Low** feasibility (could be unfeasible? Room didn’t care about this)

Lots of previous efforts. Nothing more out there. Native species closely-related – a serious problem.

Low likelihood

Many agents introduced and established but didn’t do much. Would require a root feeder?

Discussion

Comment: Naturalised fungus is showing promise – wort annotated but not included in this assessment.

Cynoglossum officinale

Assessment based on 2 agents

Moderate feasibility (Was thinking should be between moderate and high)

Weevil released in Canada, then a petition in the US but didn't get permission. Has a broad range – will develop on one other species. Plant studied well and impact of the insects documented. Main issue 'level of specificity'. There's been non-target monitoring in the field in Canada – just found transitory attack on a non-target. Very sporadic attack of natives and if so very negligible. More studies (chemical ecology) done gathered evidence of host-specificity (repellent effect). Unusual host-specificity situation so don't know how APHIS will react to it.

High likelihood

Little doubt that they wouldn't be successful.

Discussion

Comment: Has modelling been done? A: some a long time ago on the plant and both agents.

Cytisus scoparius

Moderate feasibility

Adventive mite species in the US. Track records of agents not having as much impact. Focused on a moth (*Aganotrix*) that attack shoots (low hanging fruit) already released in NZ. Can access agent from NZ. Some additional testing would only need to be done.

Discussion

Comment: Some native lupins in the US were attacked in NZ test.

High likelihood – changed to **Moderate** after whole workshop consultation

Scotch broom contributes to fire. In NZ too early to measure impact.

Discussion

Comment: Not much success with *Aganotrix* on gorse. There is already 10 species feeding on the plant would one more change likelihood of impact?

Dittrichia graveolens

Moderate feasibility

New target we don't much about. Put in Mod because of this. Weed not closely related to other species.

Moderate likelihood

There may be many agents specialised on it because it has strong volatiles.

Elaeagnus angustifolia

Goal for biocontrol – reduce spread and later lead to reduced density of new tickets.

High feasibility

Has been extensively studied – several potential agents identified and in the pipeline (testing on-going and impact study happening). A petition in the process. 80 natural enemies identified but only focused on agents that affect reproductive outputs.

Concern about the plant – conflict of interest possible – We think that regulatory would be favourable if agents only attack seed.

Moderate likelihood

With agents that only attack reproductive parts – could take up to 30 years to see success.

Euphorbia esula

High feasibility

Re-introducing existing insects that haven't established – Try to find new agents in areas outside of Europe. There are quite a lot of native species in the same genus. Several open questions? What are the areas to target with biocontrol? Identity of the target is not clear – could be a species complex. Maybe some of the insects released before were not suited to the right target.

Given uncertainties discus

Moderate likelihood

Several agents would have to be introduced. One big questions – all these insects have been introduced once so how can you be sure they'll establish? But if they established could have a good impact.

<u>Discussion</u>

Q: Is there comprehensive information about the reason why they didn't established? How similar are the leafy spurge from NA and the native range?

A: For some insects they found that the NA leafy spurge was not the most suitable host.

Genotype matching is a key knowledge gap.

Workshop believes that there isn't funding fatigue.

Hypericum perforatum

High feasibility

Regional area where current agents do not work. CABI has been working on it and have identified some options that may work. A lot of research has been piggybacking. Areas CABI will be looking are acceptable

Moderate likelihood

Because we don't understand the reasons for the current failure of existing agents.

Iris pseudocorus

Low feasibility

Still used in ornamental. Many native Iris in USA.

Low likelihood (maybe moderate)

Big rhizomes and seeds that are spread by water.

Isatis tinctoria

Moderate/High feasibility

Weed is a mustard – so possible problem with host-specificity. [comment from workshop about phylogenetic placement]. There is a mite in Turkey, but found it in Italy and Germany as well. Agents will need to be tested on 100s species, but CABI has sourced most of them. Native species at risk occurs in an island off the coast of California and has a different phenology to the weed. Comment: No need to move it to low feasibility because CABI claims they have a good argument to show that it won't feed on the native at risk.

High Likelihood

Doesn't grow in many different habitats – climate the same – so a plus. The suite of agent is likely to work well.

Seed-limited weed.

Lepidium draba

Assessment on three agents currently in pipeline

Low feasibility

Concerns re host-specificity – so many species to test because a Brassicacea. Finding additional agents, including pathogens, not very likely.

Moderate likelihood

Data exist on agents types of damage – looks good. Big rhizome plants, resilient – if all three could be released may be good – but would not work well on disturbed sites.

Lepidium latifolium

Moderate feasibility (could be Low)

Assessment based on 3-4 species – many native/economic species closely-related – an obstacle. Distribution mostly Asian – a bit more complicated. No list of natural enemies that we already know. Started doing work in Turkey when can't get export permits anymore and not safe in western Turkey. Surveys already done in the some of the native range – some potential insects. Other areas may reveal more agent. Several tests have been started. Host-specificity is a big issue.

One insect (flea beetle), one mite and one pathogen were looked at but discarded because of lack of specificity

Moderate likelihood

Plants can be found in a wide range of habitat and climates so unlikely that the agents would be good across all areas. One agent wouldn't work.

<u>Discussion</u>

Comment: plant fitness is very high – each stem produces huge amount of seeds.

Comment: Indigenous pathogen looked at as a potential bioherbicide – but not relevant here.

***Lepidium* species (other than *L. draba*)**

Assessments similar to *L. draba* – see above

Agents on *L. draba* in the pipeline also affect these species-but are not preferred hosts (Phil's comment). Sometimes one of the species is considered as a subspecies of *L. draba* sometimes it's not. Some areas in native range may not have been surveyed and in surveyed areas potential agents may have been overlooked since the focus of CABI surveys have been *L. draba*.

Leucanthemum vulgare

Goals: More a landscape use for biocontrol.

Moderate feasibility

Lost of agents identified in the literature. Many to choose from. Non-target closely-related – chaster daisy (hybrid of four species) is the main concern. Well-studied from a biocontrol stand point. Root moth being considered – testing near completion – two others species and a root-galling.

<u>Discussion</u>

Q: Is the fact that the insects attack Chaster daisy an unsurmountable obstacle (show stopper)? Opinion of room – Some think that APHIS would not accept release application. Others think that a good case that show that while the insect develop on the non-target it doesn't cause any damage then it may have a chance.

Moderate likelihood

Moderate because of track records of root moths in general.

Linaria dalmatica* and *L. vulgaris

[similar write-up for both species] With current agents – we don't know why they don't work effectively everywhere.

High feasibility

High likelihood

Agents are very host specific so could make it more difficult to be effective across the board considering the occurrence of hybrids.

<u>Discussion</u>

Q: Could the hybrids take over the true species if biocontrol was very successful.

Participant read the notes from their assessment – consult sheet.

Don't know what hybrids will do – hybrids are more widespread than we thought.

How would they be integrated with other methods?

Myriophyllum spicatum

Low feasibility

Difficulties in finding agents that wouldn't attack the native species. Spicatum hybridized with one of the native that is on two state endangered lists. Outbreak of the weeds and the native species are often the results of eutrophication (phosphate loading) - not a classical enemy release situation. Would need to feed on the hybrid as well as the exotic – so quite a challenge.

Comment: region of origin of NA population just been tracked to somewhere in China.

Low likelihood

Lots of unknown. There is a native weevil that exert some control (private business) – dubious claims. Practitioners not very excited with this native weevils because they haven't seen much reduction. Fish predation on native weevil – so could be limiting to any new agent.

Onopordum acanthium

Low feasibility

There have been very good agents released in Australia, but none are sufficiently host-specific for introduction in the US – all would attack several native cirsium. There are a mite and a nematode found in Turkey and a stem fly in Bulgaria but there are issue with export. Issue with hybridization – but well documented. Plants only reproduce by seeds.

Comment: Massimo – tried many times in Bulgaria to get testing done on Larinus. 3-4 insects with potential narrow range??? Would need good field data testing to show no feeding on Cirsium. Much more pessimistic with regards with Canada thistle.

Low likelihood – changed to **Moderate** after whole workshop consultation

If the agents known were host-specific enough, then based on previous experience they should be pretty impactful.

***Pilosella* species** (discussed as a complex)

Taxonomically confusing. There is a native hawkweed, though now split from *Hieracium*.

Management goals – target low value land.

Low feasibility

Lots of surveys have been done and many agents tested. Some agents released in NZ. Low because we are at the end of the exploration/survey activities. Funding fatigue. Needs very host-specific. CABI is testing one agent – which attack several hawkweeds but not the native sp. Two possible biotypes of the agent (univoltine and multivoltine). Root fly released in Canada but difficult to work with so low potential. Potential for two agents (and possibly three) for release on hawkweed in US.

Moderate likelihood

Based on the insect agent.

<u>Discussion</u>

Q: Why low feasibility considering that there are agents being tested... [should be moderate?]

Potentilla recta

Low feasibility

On and off biocontrol projects for years. Aggressive weed – 100s of species related that are native and introduced (e.g. ornamentals), including 5-6 endangered. No clear phylogenetic for the weed. Most agents probably found – low potential to find new agents. Root mining moth almost went to tag but there was attack on strawberry and another species. Survey for new agents in Turkey/Ukraine would be difficult.

Low likelihood

Based on a midge – probably not effective in achieving management goal. Issue with allelopathy that biocontrol wouldn't influence.

Rhaponticum repens

Low feasibility

Native range – safe areas have been surveyed but not the difficult areas. Central Asia doesn't have natural enemies records. Mites extremely sensitive (mite affect flowers – high incidence in the native range). Host range testing wouldn't be complicated. Not particularly related to NA species. Artichoke may be at risk.

Moderate likelihood

Focus on the mites. Would contribute to reduce spread (a subset of the management goal).

Rubus armeniacus

Low Feasibility

Rubus is genus of blackberry-so many closely-related taxa. Native range Armenia and norther Iran. Searches would have to be done there. There is little work on this plants done in terms of natural enemies – rust fungus has been arrived in Oregon but not effective. USDA on record to say that they do not support biocontrol for this weed at all.

Low likelihood (limited certainty)

If could find something specific, you could envision an agent that could work. A challenge to imagine an agent that would be able to cause sufficient damage to control the populations without help from other methods. Would need more than one agent. You would ideally need a root feeder agent.

Taeniatherum caput-medusae

Moderate feasibility

Work so far focused on pathogens which turned out not to be specific. Recent work on mites – should now be focussing on these.

<u>Discussion</u>

Comment: Range is Mediterranean to central Asia – current genetic work point to Asia. There is genetic diversity in the NA population.

Comment: Some land-managers like the weed for controlling soil erosion.

Low likelihood

No previous success with biocontrol of annual (?) grass.

Tribulus terrestris

Lots of uncertainty-it's an annual so this is a challenge.

Moderate feasibility

Broad distribution native range. A wide areas where searches could happen. Needs something climate matching and specific.

Moderate likelihood

Areas that need help are not Mediterranean so agents may not work well. Weed in disturbed areas – may not be ideal for biocontrol impact.

<u>Discussion</u>

Comment: In California grows extensively in canals. In New Mexico, weed create solid carpet this year. Seeds are long-lived and very abundant.

Ventenata dubia

Emerging invader – major problem in some area. Participants discussed that it may be too early to target

Moderate feasibility

Ranking selected because we know anything – Plant difficult to identify in the field in native range.

Low likelihood

March 2015 – first major ecology paper on it.

PRESENTATION OF FINAL MATRIX *Biocontrol prospects vs weed impacts*

<u>Discussion</u>

Workshop 2 participants surprised by *E. angustifolia* rated low for impact and *L. dalmatica* rated high for impact.

Would be good for research investment to focus on improving the prospects of biocontrol of grasses.

Bromus tectorum: USDA decided not to work with it. The assessment could be done again assuming that ARS is behind biocontrol for this target and there is lots of funding. How would this change prospects and likelihood of success?

Recognition by people concerned about fire that these grasses are becoming so important.

Appendix 4. Weeds provided for this prioritization exercise that were only present on the lists of one or two states in the western USA.

Species	# states	Impact Level[1]	Impact Type[2]
Cirsium arvense	2	H	B
Linaria dalmatica	2	H	B
Alliaria petiolata	2	M	En
Centaurea diffusa	2	M	B
Centaurea maculosa	2	M	B
Convolvulus arvensis	2	M	B
Phragmites australis	2	M	En
Potentilla recta	2	M	B
Tanacetum vulgare	2	M	B
Tribulus terrestris	2	M	B
Ulex europaeus	2	M	B
Alhagi pseudalhagi	2	L	En
Lythrum salicaria	2	L	En
Egeria densa	2	N	En
Aegilops triuncialis	1	H	B
Arundo donax	1	H	B
Centaurea stoebe	1	H	B
Dittrichia viscosa	1	H	B
Fallopia japonica	1	H	B
Genista monspessulana	1	H	B
Ventenata dubia	1	H	B
Avena fatua	1	M	B
Bromus diandrus	1	M	B
Bryobia abla	1	M	En
Buddleja davidii	1	M	En
Carduus nutans	1	M	En
Carduus pycnocephalus	1	M	B
Centaurea biebersteinii	1	M	B
Cortaderia jubata	1	M	En
Fallopia sachalinensis	1	M	B
Hedera helix, H. canariensis	1	M	En
Hypericum perforatum	1	M	B
Lepidium chalepensis	1	M	B
Lepidium pubescens	1	M	B
Polygonum polystachyum	1	M	En
Salsola tragus	1	M	B
Senecio jacobaea	1	M	B
Spartium junceum	1	M	En
Tamarix ramosissima, T. gallica, T. chinensis	1	M	B
Tamarix spp.	1	M	B
Ulmus pumila	1	M	B
Amorpha fruticosa	1	L	En

Species	# states	Impact Level[1]	Impact Type[2]
Brassica nigra	1	L	B
Brassica tournefortii	1	L	B
Bromus hordaceus	1	L	En
Bromus madritensis ssp. rubens	1	L	B
Carduus acanthoides	1	L	B
Carpobrotus chilensis	1	L	En
Carpobrotus edulis	1	L	En
Clematis orientalis	1	L	En
Cortaderia selloana	1	L	En
Delairea odorata	1	L	En
Dipsacus fullonum	1	L	En
Dipsacus spp.	1	L	En
Echium vulgare	1	L	B
Foeniculum vulgare	1	L	En
Hirschfeldia incana	1	L	En
Potamogeton crispus	1	L	En
Ranunculus acris	1	L	B
Tamarix parviflora	1	L	B
Ammophila arenaria	1	N	En
Asphodelus fistulosus	1	N	En
Avena barbata	1	N	B
Brachypodium distachyon	1	N	En
Calystegia sepium	1	N	B
Chrysanthemoides monilifera	1	N	En
Crupina vulgaris	1	N	B
Cynosurus echinatus	1	N	En
Ehrharta calycina	1	N	En
Euphorbia terracina	1	N	En
Euryops subcarnosus	1	N	En
Holcus lanatus	1	N	En
Hydrilla verticillata	1	N	En
Juniperus virginiana	1	N	En
Lolium multiflorum	1	N	En
Ludwigia peploides	1	N	B
Myriophyllum aquaticum	1	N	En
Polygonum cuspidatum	1	N	En
Robinia pseudoacacia	1	N	En
Rumex acetosella	1	N	En
Salvia aethiopsis	1	N	En
Schismus arabicus, S. barbatus	1	N	En
Sisymbrium irio	1	N	B
Volutaria tubulifera	1	N	En
Vulpia myuros	1	N	En

1. Impact Level (N = Negligible; L = Low; M = Moderate; H = High); 2. Impact Type (Ec = Economic/Agricultural; En = Environmental; B = Both environmental and agricultural).

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