It takes a village: detection dogs, partnerships and volunteers aid hawkweed eradication in mainland Australia

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Summary Weed eradication is costly and challenging, but the benefits of successful eradication are considerable. Hawkweed (*Hieracium* L.) species pose a significant threat to south eastern Australia, where several small incursions are documented. Four jurisdictions are partnering to develop best practice management techniques and work towards eradication of hawkweeds from the Australian mainland. Here we discuss the application of three key tools: 1) extensive partnerships necessary to maintain the programs, 2) the sustained participation of large numbers of volunteers in surveillance, and 3) the training of Weed Eradication Detector Dogs to 'verify' hawkweed freedom and assist in delimitation. We highlight the benefits of these tools, as additions to conventional surveillance and control, and how they can aid success of eradication programs.

Keywords Detection dog, weed eradication, surveillance, partnerships, hawkweed, *Hieracium*.

INTRODUCTION

Eradication of invasive plants (weeds) is considered the most cost-effective management action once an incursion is documented in a previously un-invaded area, yet there are few examples of weed eradications globally (Panetta 2014). In part, this may be because weed eradication is costly and challenging, and requires continued commitment from those affected or potentially affected by the weed, as well as social and political commitment to resourcing the program to the end. Eradication involves the elimination of every individual and its propagules from an area where recolonisation is unlikely to occur (Myers *et al.* 1998), hence eradication programs must continue until all plants are found and controlled, and the weed seedbank is exhausted (Panetta 2014). Depending on the seed persistence of the weed, this may require ten or more years, which is longer than most governmental political and budget cycles. There are many other criteria to address when considering the feasibility of an eradication attempt (e.g. ability to delimit and control entire infestations, etc.: c.f. Wittenberg and Cock 2001, Dodd *et al.* 2014, Panetta 2014), many of which are costly or difficult to meet. Thus, weed eradication is not often attempted, despite the high cost-benefit of significant early investment in eradication versus continued costs of indefinite weed control (Wittenberg and Cock 2001).

In contrast to on-going weed control, eradication has an 'end point' where weed management costs and potential weed impacts are eliminated: These significant benefits make eradication worthy of consideration. This is especially true when the known weed risks are high, and when the weed has shown considerable negative impacts in similar environments elsewhere in the world. This is the case for hawkweed (*Hieracium* L.) species. Weed risk assessments, including potential distribution modelling, show that hawkweeds pose a significant threat to south eastern Australia, where there are similar habitats and climates to already invaded areas (Brinkley and Bomford 2002, Beaumont *et al.* 2009), such as in New Zealand (NZ) and North America, where hawkweeds cause extensive damage, impacting agriculture and the environment (Espie 2001, Williams and Holland 2007). Several small hawkweed incursions are documented from mainland Australia, primarily in the bordering alpine regions of New South Wales (NSW), Australian Capital Territory (ACT) and Victoria, and these are the subject of an eradication attempt.

Hawkweeds can be suitable eradication targets as they have short-lived soil seedbank (Bear *et al.* 2012), effective control methods, and can be detected in the landscape, especially when in flower. However, detectability decreases when flowers are not present, and thus a key challenge in hawkweed eradication is detecting small, non-flowering plants, especially those growing amongst dense vegetation. To overcome this

and other challenges, a group of partners working towards hawkweed eradication on mainland Australia are developing or refining tools to complement existing best practice weed surveillance and control methods. This paper discusses the application of three key 'tools': 1) the extensive partnership arrangements between multiple agencies, research institutions, governments and the community necessary to maintain the programs, 2) the sustained participation of large numbers of volunteers in surveillance and delimitation, and 3) the training and implementation of Weed Eradication Detector Dogs to 'verify' hawkweed freedom at individual sites and to assist in delimitation of infestations. We discuss the interactions between these components, including a recent evaluation comparing detector dog and human surveillance, and the benefits and challenges of incorporating these components into eradication programs. Background and further detail on the jurisdictional programs, including the use of other novel approaches, as well as conventional surveillance and control, are available in other publications (Hamilton *et al.* 2015, Primrose *et al.* 2016, Constantine *et al.* 2016).

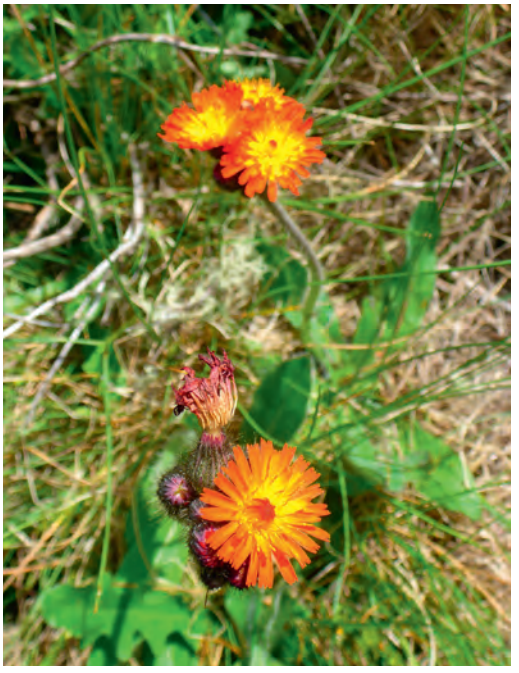

Photo 1. Orange hawkweed flowers are readily detectable, but the flowering season is restricted to summer months, and non-flowering rosettes are easily camouflaged in other vegetation. Photo: Hillary Cherry.

PARTNERSHIPS

Three high-risk hawkweed species, orange hawkweed (*Hieracium aurantiacum* L.), mouse-ear hawkweed (*H. pilosella* L.), and king devil hawkweed (*H. praealtum* Vill. ex Gochnat) are documented from four jurisdictions in Australia: ACT, NSW, Tasmania and Victoria. These are either 1) not currently considered feasible for eradication (orange hawkweed in Tasmania), 2) presumed eradicated (mouse-ear hawkweed in ACT) or 3) under eradication (in NSW: orange hawkweed since 2002 and mouse-ear hawkweed since 2015; in Victoria: orange hawkweed since 1999, king devil hawkweed since 2002 and mouse-ear hawkweed since 2011). In NSW and Victoria, the known infestations are contained mainly to publicly-managed land and distributed over a relatively limited extent, which improves the feasibility of eradication. While each jurisdiction manages a collaborative hawkweed program within their region, agency staff from the four jurisdictions, as well as other experts, partner together through a National Hawkweed Working Group (NHWG) to develop and share best practice management techniques and coordinate eradication.

The NHWG comprises conservation and primary industries agency representatives involved in on-ground aspects of the program, as well as in state-level weed strategic planning, coordination and management. This broad membership base allows networking and information sharing with international and national eradication experts and weed managers, as well as with a range of researchers to improve eradication methods, including understanding seed dispersal patterns to inform search effort (Cousens *et al.* 2012), novel detection methods (Hung and Sukkarieh 2015), and improving delimitation ability (Hauser *et al.* 2016).

While collaboration between the lead agencies and experts is critical, so too are comprehensive partnerships across government and the community. NHWG members work to ensure all levels of government are aware and supportive of the program (e.g. members liaise with and update relevant Australian Government agencies on eradication progress, and regional and local representatives are regularly invited to attend NHWG meetings). Partners also interact with community members (often via local government contacts and events such as field days), as well as the media and politicians, to encourage community support (see sections below). Given the scope of stakeholders potentially affected by hawkweeds, partners must 'throw the net widely' to seek support from all levels. The NHWG is a valuable tool that enables coordination, collaboration and improvement in the eradication program.

VOLUNTEERS

Community volunteers are an integral part of the hawkweed eradication program, and complement the work of contractors and agency staff. Volunteers assist with surveillance (actively in the eradication program and passively, e.g. when bushwalking) and improve delimitation, they promote good weed hygiene practices, and they encourage political and community support for the program. Consequently, the NSW and Victorian programs have invested time and resources to establish and support a large group of volunteers. Because activities primarily occur on high-value public land (e.g. alpine national parks), the hawkweed eradication program has strong opportunities to recruit volunteers who are passionate about protecting these landscapes, or who may already be involved in other park activities. This is also advantageous in retaining volunteers because they establish ownership of the eradication program and value their role in protecting public land, which means many volunteers return year after year.

Photo 2. NSW Hawkweed Team members (2015/16) – volunteers assist with surveillance and are critical to program success. Photo: Steve Austin.

Victoria and NSW agency staff have developed extensive volunteer programs over the last eight years. Each year, volunteer information packages are developed, and opportunities to participate are advertised on agency websites and in other appropriate media. Volunteers are sourced from a range of entities such as community and 'friends' groups, associations (e.g. National Parks Associations), societies (e.g. Weed Society of Victoria), clubs such as bushwalking and field naturalist clubs (e.g. Canberra and NSW Bushwalking Clubs), schools, universities and other areas. They are trained by agency staff in plant identification, surveillance, safety, hygiene and, in some cases, chemical control (hand spot-spraying) of hawkweed in endangered plant communities. Lead agencies also monitor and report on volunteer participation and outcomes, and provide updates and coverage of volunteer and program activities via media and websites, (e.g. flickr pages dedicated to the program or other social media that can be shared back through the volunteer community).

Together the programs have engaged over 750 volunteers, many of which have returned for four years or more. During any given season, approximately 70% of volunteers are past participants. Most participate for one or more week-long blocks, and are provided with food, accommodation and all necessary training and tools. Volunteers have made major contributions to hawkweed surveillance: to date, volunteers have contributed over 10,000 hours of surveillance and control activities. Examples from the Victorian program illustrate the value of volunteer participation: since 2008, volunteers have surveyed over 825 ha for hawkweed (32% of the total 2574 ha searched), and approximately 21% of all known hawkweed 'sites' were found by volunteers (site = approximately 2m radius around centre point of incursion).

There are multiple benefits in training volunteers in plant identification and surveillance: Important hawkweed discoveries have been detected outside of targeted programs, assisting with delimitation. For example, volunteers discovered mouse-ear hawkweed for the first time in the Victorian Alps during recreational bushwalking. Also in Victoria, volunteers found a hawkweed infestation in a private, metropolitan park, and a backyard infestation was discovered when a NSW hawkweed volunteer recognised orange hawkweed in a photo of her Victorian friend's yard.

In January 2015, the first occurrence in NSW of mouse-ear hawkweed was detected by a bushwalker in a remote area of Kosciusko National Park, where it may have been introduced via camping equipment. A sample was rapidly identified and reported to relevant agencies by herbarium staff in Victoria, who are also involved in the Victorian eradication network. The infestation was treated within two weeks of detection and within one month, agency staff and community volunteers surveyed the surrounding landscape to ensure no other detectable infestations (Hamilton *et al.* 2015). Due to early detection and reporting, the small infestation size, and the rapid management response, it is highly feasible that this infestation can be eradicated. This was all made possible via volunteer and community networks established by the eradication programs, again illustrating the importance of these types of partnerships to support eradication attempts.

WEED ERADICATION DETECTION DOGS

Hawkweed surveillance is undertaken by trained staff, contractors and volunteers. Detection experiments have demonstrated that searchers are unable to detect

hawkweeds with 100% confidence (Moore *et al.* 2011, Hauser unpublished data). Delimitation is the greatest hurdle in the initial stages of the eradication program, because all plants must be found and controlled, and reproduction prevented, before eradication can proceed. Ideally, plants should be found prior to flowering, and controlled before setting seed. But as mentioned above, non-flowering hawkweed rosettes can be difficult to detect by humans. In addition, as management units ('sites') are cleared of hawkweed, a method is needed to quickly and effectively declare them 'free' of hawkweed so they can be retired from further surveillance effort, allowing those resources to be allocated elsewhere in the program. To address these issues, program partners worked with a professional dog trainer to train three spaniels, of varied age and experience, to distinguish hawkweed from other plant species and detect hawkweed in field situations.

Dogs have long been used for detecting illegal substances and, more recently, in conservation to find endangered or pest animals (Wollett *et al.* 2013). A trial has also shown that dogs can detect a target weed in an agricultural field setting (Goodwin *et al.* 2010). Hawkweed does not have a distinctive odour to humans, and it was unknown whether it could be distinguished by a dog. The first and most vital step was to determine if dogs could detect hawkweed and distinguish it from other plant species. Victorian partners conducted an initial feasibility trial to see whether a detection dog, that was already trained to detect feral animals, could detect hawkweed. The dogs are trained on a reward system, where they receive a 'ball play' period when they correctly indicate a hawkweed plant to the handler. The trials were conducted with potted hawkweed plants in controlled environments (e.g., potted plants were hidden among other foliage at the trainer's home or nearby parks). These demonstrated that the dog could reliably detect potted hawkweed.

Photo 3. Orange hawkweed rosettes are difficult to detect when not flowering, and are visually similar to many other species in the invaded areas, thus an ideal target for scent detection dogs. Photo: Pete Turner.

The next stage of the feasibility trial was to conduct a detection experiment in Victoria at Falls Creek, in a field environment similar to that of the largest Victorian hawkweed infestations (c.f. Hauser, these proceedings for further details). The experiment provided promising results, but importantly identified several factors in the dog training and handling protocols that could limit the dog's effectiveness in detecting hawkweed. Feral animals, or their scents, were present in the field trial area, and this appeared to distract the dog from hawkweed detection at times. It was also evident that training the dog on potted plants may have confounded the 'scent picture', making it unclear to the dog if it was searching for hawkweed, the pots and/or the potting mix.

Learnings from this initial trial were incorporated into a larger Weed Eradication Detector Dog (WEDD) project undertaken by NSW partners, who engaged the same dog trainer. Two new dogs were purchased and trained from pups on hawkweed only (i.e. no prior training on pest animals or other detection targets). They were trained using only hawkweed plant fragments rather than potted plants, meaning it was only hawkweed that the dogs were learning to detect, and not a combination of scents. Much of the training occurred in situ in the hawkweed infestation at Kosciuszko National Park on naturalised hawkweed plants. Thus the dogs were trained on the exact target desired, and in same terrain and environmental conditions where detection will occur. Training began when the dogs were approximately 6 months old, and dogs were proficient at detecting hawkweed in field situations within four months. All training followed strict biosecurity protocols to ensure no spread of hawkweed.

During the 2015/16 field season, the dogs were trained and tested at hawkweed sites in the alpine region. They consistently detected hawkweeds plants, often among dense vegetation and, several times, where plants had been undiscovered by humans. Thus far, they have only indicated on hawkweed (i.e. not on any non-target species), which illustrates their ability

Photo 4. Sally, a working cocker spaniel, is the first dog trained specifically to detect hawkweeds (seen here searching alpine habitats of Kosciusko National Park, NSW). Photo: Hillary Cherry.

to discern the target. There were also instances where the dogs did not detect plants that were known to the handler: This was likely due to weather conditions (e.g. high winds) rather than a lack of ability to discern hawkweed. Many factors contribute to detection ability, including weather and terrain, as well as handler skills and ability.

In March 2016, partners conducted field trials to monitor dog detection capabilities under different environmental conditions, and evaluate dog detection abilities compared to those of humans in a field situation (see Hauser, these proceedings). While results are still being analysed, the dogs successfully found hawkweed plants that were overlooked by human searchers, thus indicating that they can significantly contribute to the eradication program. An important finding reinforced in the trial is that dogs are most effective when the target is at a very low density, as too much target scent can be overwhelming and may confuse the dogs' efforts. For this reason, dogs may

Photo 5. Connor, an English springer spaniel, began successfully detecting hawkweed plants in the field at 8 months old. Photo: Glen Sanders

be best used to 'clear' areas where all plants are assumed to be extirpated, and are not likely be useful for detecting 'widespread' or common weeds.

While we now know that dogs can effectively detect hawkweed in field situations, further work remains to determine where they can most cost-effectively and efficiently be integrated into eradication efforts. The cost of purchasing and training dogs is relatively affordable, but there is a significant cost to either hiring a skilled handler or training a staff member and resourcing their time to handle the dog. There are other considerations regarding the housing and ownership of the dog (e.g. contractor vs. staff member), as well as upkeep and on-going training. As part of the WEDD project, partners are developing best practice protocols for weed detection dogs, which may assist further development of dogs as a 'tool' in weed eradication programs.

An unexpected consequence of the detection dog project is the extensive coverage by news media and other entities. The dogs generate great community interest that has in turn provided a platform for partners to highlight the hawkweed eradication program, and the need for continued support, including to politicians and government agencies. There are significant positive opportunities to engage the community and land managers when using detector dogs. Everyone, including the media, love dogs, thus they can be used as weed 'ambassadors' or 'champions', allowing eradication managers to interact with the public, politicians and funding bodies more successfully. For example, one of the dogs, 'Sally', and her handler were awarded a travel grant to attend the 20th Australasian Weeds Conference and demonstrate the dogs' weed detection skills. This allowed the WEDD project and the hawkweed program, to be presented to over 200 weed professionals from across Australasia.

DISCUSSION

The above tools were developed for the hawkweed eradication program, however they are likely to have applications to other eradication projects. The benefits of formal partnerships extend beyond ensuring strategic, best practice control and coordinated programs. The NHWG partnership has facilitated the development of research that is being actively applied and is making the eradication program more cost-efficient. The strong partnerships also support a robust volunteer program that is a necessary part of maintaining the eradication effort.

The contribution of volunteers has greater benefits than targeted surveillance during formal programs. Incorporating volunteers into the eradication program and acknowledging the value of their contribution

inspires a sense of personal investment and ownership of the eradication effort. This in turn has prompted volunteers to be vocal advocates for the program and further raise awareness in the wider community. In addition, there are limited resources to search for hawkweed outside of known areas, and large numbers of volunteers with the ability to detect and appropriately respond to hawkweed increases overall surveillance effort and improves eradication feasibility. Many volunteers recreate in environments that are at risk from hawkweed, but that may not be targeted for active surveillance: passive surveillance by volunteers in these areas extends the reach of the program.

Photo 6. The dogs are effective in a variety of habitats, including dense grassland. Photo: Jo Caldwell.

The need for improved hawkweed detection has prompted trialling of weed detection dogs, which to our knowledge has not been done in Australia previously. Early signs indicate that detector dogs are likely to improve our chances of finding hawkweed, therefore increasing the likelihood of eradication. In the future, dogs may also assist with other eradication programs, as it appears they can be easily trained on other weeds. Partners are also investigating the use of drones and remote imaging to improve surveillance (Hamilton *et al.* 2015), and ultimately hope to incorporate these into the program to complement the suite of tools necessary for eradication. But despite these new technologies, volunteers are still the best resource in the hawkweed eradication program to ensure necessary surveillance and increase delimitation area: we simply couldn't do it without them.

No surveillance method – human teams, dogs, drones, or other – is ever likely to find hawkweeds with 100% accuracy. Therefore it's important that we understand the different strengths and weaknesses of each approach, and develop a complementary set of methods that gives us the best capacity to detect hawkweeds across the variety of conditions in which they occur.

The hawkweed eradication program on mainland Australia, like most eradication attempts, is complex and requires multiple resource inputs and continued support. Formal partnership and volunteer programs are not traditionally 'costed' when scoping eradication feasibility, however given their benefits to the hawkweed program, they should be considered where relevant. Depending on the weed and the eradication environment, new or improved technologies for better detection and delimitation are also likely to be needed in novel eradication attempts, and should also be costed or considered. Many of the issues described here may apply to other high-risk weeds being considered for eradication, thus when scoping the feasibility of an eradication program, don't underestimate the costs or benefits of developing partnerships, volunteer programs and better detection methods.

ACKNOWLEDGMENTS

Many thanks to the dedicated hawkweed volunteers, and to Steve Austin, the hawkweed dog trainer. The ACT, NSW and Victorian Governments provide support and funding for hawkweed eradication.

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