Innovation vs. invasion: innovative techniques to assist the eradication of weed populations

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Summary The successful eradication of weed species is often a challenging prospect, especially when they are widely distributed by birds, grow in difficult terrain and are hidden from view. Initial results may be encouraging, but achieving eradication relies on removing that last 1% of the population. Historically, eradication attempts have relied on more traditional techniques such as unassisted ground searching that can become less effective when controlling a widely distributed yet sparse population. Thus, more innovative approaches are required.

This paper discusses innovative techniques to assist in the eradication of weeds and uses white bryony (*Bryonia cretica* L. subsp. *dioica* (Jacq.) Tutin) in New Zealand as an example. As the population has decreased significantly since work began in 2007, innovative techniques aimed at achieving eradication have been researched. Abseiling is being used to control 6.5 km of previously unmanaged cliff face; making eradication a realistic goal. Cost efficiency of abseiling is being improved by developing digital recognition software to target abseiling efforts by analysing high resolution, GPS-referenced, images taken from an unmanned aerial vehicle. Initial findings indicate a high success rate of locating inconspicuous plants with the assistance of a detector dog.

These innovative techniques have the potential to increase the likelihood of success and efficiency of other weed eradications and may help to broaden the way future eradication attempts are approached.

Keywords Abseiling, detector dog, digital recognition software, eradication, innovative, innovation, unmanned aerial vehicle, white bryony.

INTRODUCTION

Efficient and accurate delimitation of the spread of an invasive species is crucial when attempting to understand the extent of an infestation (Panetta and Lawes 2005). Knowing the extent of an infestation is vital to guide important management decisions when evaluating if eradication attempts are feasible or not (Rejmánek and Pitcairn 2002).

More traditionally the approach to weed delimitation and surveillance has centred around ground based manual searching and surveys of a location(s) reported to be infested due to the detection of a weed species (Stephenson *et al.* 2003). These more traditional approaches can be effective, especially when; the unwanted species is abundant, easily identified (either due to size or other characteristics that make it stand out) and the terrain makes searching efficient (Cacho *et al.* 2010). However, when one or more of these factors are not present manual searching tends to become less effective compared to the amount of resources required (Cacho *et al.* 2010). This limitation can become problematic especially during eradication attempts, as achieving eradication relies on removing that last 1% of the population. The limited effectiveness of this approach has triggered thought and consequently research into, and the development of innovative techniques to assist with the delimitation and surveillance of weed infestations.

This paper uses white bryony (*Bryonia cretica* subsp. *dioica*), present in two regions of New Zealand as an example. Specific delimitation and surveillance tools are being used or developed to increase the efficiency of this eradication attempt.

Human based grid searching of areas that can be accessed and searched efficiently was used for the initial part of the response and has been effective while numbers of *B. cretica* were high. Additionally, abseiling has been used to find and control any *B. cretica* present on vertical river cliffs. The development of a detector dog that will be able to detect the scent associated with *B. cretica* is underway to increase search efficiency. Digital recognition software is also being developed; the aim is for this software to be able to detect *B. cretica* where previously the eradication attempt has been completely reliant on human based searching. Once the software is fully developed the final step is to mount cameras to an unmanned aerial vehicle so images can be taken, located using GPS coordinates and streamed back live to the software and stored on the camera for processing.

MATERIALS AND METHODS

Abseiling to search for and control plants is carried out by a team of four abseilers. An initial delimiting survey was undertaken and current abseil work involves researching lines where *B. cretica* was found previously.

Abseilers slowly descended lines 3–4 m apart in dense bush and up to 10 m apart in more open terrain while searching for *B. cretica*. When *B. cretica* is found the abseilers record the plants size class (Table 1) and location before treating the plant. Treatment consists of either hand pulling or cutting the stem and applying a herbicide gel containing aminopyralid to the cut stem and removing any reproductive parts.

Table 1. Description of *B. cretica* size classes.

Size class	Description
1	seedling
2	carrot, <300 g
3	kumara, 300–1200 g
4	turnip, <1200 g

Each line is logged and overlaid on a digital image of the cliff to illustrate where the line went and how many *B. cretica* were found on each line (Figure 1).

Figure 1. Digital image of abseil lines (in red) and *B. cretica* finds (yellow symbols) in one section of the river cliffs.

The **development of a detector dog** involves two main phases lasting approximately five months with the whole process having multiple milestones (Table 2).

The initial three month training programme is a generic training programme for all detector dogs that are potentially going to be used by the Ministry for Primary Industries. This training concludes whether or not the dog is capable of being a detector dog. The programme primarily focuses on; assessing how the dog interacts with people, obedience and indication training and evaluation. Once this is completed and the trainer is confident the dog has achieved the desired level of performance the next phase can commence.

Table 2. Milestones and timeframes associated with the development of a detector dog.

Milestone	Estimated timeframe
Programme proposal completed	1–2 weeks
Programme proposal accepted	1 week
Search for a suitable dog	1–8 weeks
Complete initial dog training	3 months
Train dog on first response organism	6–8 weeks
Dog ready for field trial	1 week
Dog approved for response work	1 week
Train dog on additional response organism(s)	As required

The second phase is a six to eight week organism specific training programme that is aimed to get the dog to recognise and indicate the scent of *B. cretica*. This is achieved firstly in a controlled environment (training facility) and then in the field (yet to be completed):

1. Exposing the dog to *B. cretica* scent,
2. Rewarding the dog (with food or toys) on acknowledgement of *B. cretica* scent,
3. Carry out search exercises and reward the dog when it finds the *B. cretica* scent,
4. Get the dog to find *B. cretica* scent and continue to do so with acknowledgement reward only.

Once the trainer is confident the dog has completed the first steps to the desired level in a controlled environment, the dog will be taken out to the field where steps 3 and 4 will be repeated.

The **digital recognition software** analysis starts by putting an image through an initial filter to highlight possible edge points (Figure 2).

Next, a colour-sensitive snake to seek the edge of the leaf in colour space and a vegetative index were developed. In colour images each pixel has three components, red, green and blue – each defined by one byte. Each colour can be represented by a vector of these components. By selecting appropriate ratios discrimination against all non *B. cretica* colours was achieved. This approach declares most areas of the image to be out of bounds and therefore saves processing time. Following this first discrimination step, a mathematically complex discrimination in colour space

Figure 2. Application of the initial filter to highlight possible edge points.

was applied to yield those points that might plausibly lie on the edge of a *B. cretica* leaf.

Several challenges are apparent when considering the very specific problem of recognising a plant such as *B. cretica*; leaves vary in shape, they are generally presented against a cluttered background, their colour varies, they can be in any orientation, many will be obscured and lighting will be very variable. However, since it is the function of leaves to acquire light, the assumption was made that many of them will present as orthogonal to possible sight lines. Thus an aerial drone scanning the vegetation might capture many leaves in this desirable configuration.

RESULTS

Abseiling has allowed 6.5 km of previously unsearchable cliff face to be searched and delimited. A total of 380 plants were found and treated during the 2011/12 season compared to 324 during the 2012/13 season. However, 1087 *B. cretica* were found during the 2013/14 season with all size classes found during all three seasons (Figure 3).

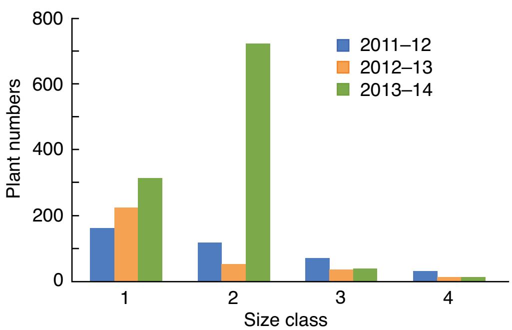

Figure 3. Number of *B. cretica* plants and size class found by abseiling from 2011/12–2013/14.

The **development of a detector dog** is underway (at time of writing); however more results will be available for the presentation at the conference in September 2014.

The **digital recognition software** has generated positive initial results in terms of being able to discriminate between *B. cretica* leaves (Figure 4) and leaves of other species (Figure 5).

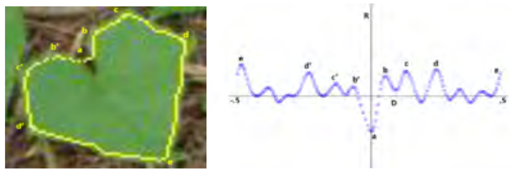

Figure 4. Plot of a *B. cretica* leaf; rotation per pixel (R) versus normalised distance (D).

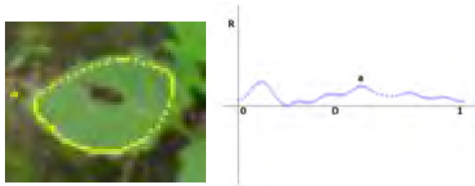

Figure 5. Plot of a non- *B. cretica* leaf; rotation per pixel (R) versus normalised distance (D).

The next step is to formalise algorithms for image identification on the basis of these curves, a task which is not anticipated to be difficult. The much more challenging improvement will be to recognise one leaf super-imposed on another and to acquire the edge points.

DISCUSSION

The abseiling delimiting survey was completed during 2010/11 to ascertain the full extent of the infestation on the very steep or vertical cliff faces. All *B. cretica* found during the survey were treated.

The exceptionally high number of *B. cretica* found during the 2013/14 season although unusual to the previous seasons is not alarming. This high number is expected to be due to the drier than normal weather in the previous year followed by a warm wet spring. It is expected that the number of plants found and treated by abseiling will follow a similar trend to the ground based search and steadily reduce each season.

Having the capability to deploy a detector dog in the field with a sense of smell approximately 250,000 times greater than a human to search for *B. cretica* is greatly advantageous to the success of the eradication attempt. The potential value of a detector dog is high; as now the density of *B. cretica* plants has decreased to levels requiring significantly more human search effort per plant, however it is expected the dogs will considerably enhance search efficiency.

To further increase the efficiency of the digital recognition software, a bird's eye view should see leaves from each *B. cretica* plant, particularly if it is visited by field staff several times during the season. The deployment of ultralight, radio-streaming cameras and GPS modules on an unmanned aerial vehicle (UAV) is the next step once the software is completed. Initial results suggest this technology holds promise for inspection of *B. cretica* and presumably other plants as well.

Although in the early stages of development (with the exception of abseiling) these innovative techniques not only have great potential to assist the eradication of *B. cretica* but also other weed species. Despite the advancements we have made with developing these innovative techniques it is important to work closely and cooperate with managers and people on the ground to further find new solutions to eradication attempts. Initially these techniques began as ideas and it is this engagement of thought that drove the innovation. The importance of this paper is therefore two-fold; not only within the methods and results but also in the wider sense, to broaden our thoughts, approaches and realm of possibilities when considering eradication attempts.

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