Biodetection technology for rare plants

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Summary Detection of weeds by dogs as a part of eradication programmes is a relatively new concept, but is already being tested in Australia and the USA for a variety of applications. In preliminary work, we have demonstrated that dogs can discriminate a broad range of species and parts of plants amongst a variety of plant material. We have also explored the effects of temperature, relative humidity and detection distance in realistic search scenarios. Successful field searches have been conducted for heather (*Calluna vulgaris*), Darwin's barberry (*Berberis darwinii*) and spartina (*Spartina* sp.). Here, we report the results of this preliminary research, and point to future options for this valuable addition to the weed management toolbox.

Keywords Weeds, eradication, detection, sniffer dogs, olfactory sense, odour recognition.

INTRODUCTION

Biodetection systems for odour are increasingly being implemented on many fronts. For example, bees are used to detect explosives, drugs, fruit ripeness and human diseases; giant pouched rats (*Cricetomys* sp.) are being trained to detect landmines and tuberculosis; and dogs have long been used to support detection of drugs, buried people, landmines, concealed foodstuff and even whale dung!

Pest plants are one of the major challenges scientists and practitioners face in the effort to conserve natural environments. Such plants, usually introduced from other countries or localities, threaten to disrupt or entirely replace native ecosystems and are a key threat to endangered native plants (Reid 1998). Once established in an environment, these alien species are impossible to eradicate because of their abundance, density and the existence of long-lived banks of seeds in the soil. Nevertheless, finding and eliminating every single plant of a species can bring large economic and practical benefits when populations are small, newly established and amenable to eradication. In these circumstances, finding and destroying every individual plant is vital. At present, this is achieved by grid searching, in which observers traverse grid lines that may only be 5 m apart in dense bush (West 1996). Even with a grid search, some weeds are easier to find at certain times of the year, some are more distinguishable as adults and some as juveniles, while others are hard to find at any time.

Detector dogs have been used elsewhere for finding agricultural weeds (Hurt and Smith 2009). We tested the ability of dogs to discriminate different species of plants and to detect specific plants in the field. We also explored some environmental effects on the detection success of dogs.

MATERIALS AND METHODS

Two series of experiments were carried out in 2007, one in Dunedin, New Zealand (45°52'0"S, 170°22'1"E) and the other 15 km north of Hamilton, New Zealand (37°49'4"S, 175°11'19"E). In the Dunedin experiments, Storm, a young (3.5 months at the start) female fox terrier/border collie cross was trained to discriminate between a range of plant material (mostly leaves but including some flowering material) of different species hidden under inverted clay pots (Experiment 1). In Hamilton, Hoff, a 14-month old male German shepherd was trained to detect specimens of *Araujia sericifera* (moth plant) and to differentiate between those and other vegetation samples in plastic pottles with perforated lids arranged in a covered shed and then in a pasture (Experiment 2), and later to search for the weeds in their natural sites (Experiment 4).

In Experiment 1 (Dunedin), preliminary training involved increasing the choice array of pots from two to 10, and the number of plants in the array from one to 10, over a period of 3 months. Here we describe results from the stage at which Storm was searching 10 pots, as double blind trials were not conducted. A target was the species being searched for, and could occur up to four times (exemplars) in the array. A successful trial required that Storm find all exemplars of the target. Sitting beside the target was reinforced using a clicker as a secondary reinforcer, with small pieces of cheese or dried liver delivered occasionally as primary reinforcers.

A total of 19 species was used as targets (Table 1) and a total of 90 trials run. Up to four trials utilised the same array (i.e. the dog searched for up to four different plant species in that array, without the arrangement of exemplars in the array being changed).

In Experiment 2 (Hamilton), Hoff searched for leaf material of moth plant placed in plastic specimen jars (pottles) positioned in holes at 35 cm intervals in 100 cm wide boards fixed 50 cm above the ground, level with the dog's chest. Here, the dog initially sniffed a pottle containing the desired plant material and was then encouraged to sniff the others. Sitting beside the target was reinforced with verbal praise and a small piece of food. Later, plant samples, still in containers, were distributed in tall pasture for the dog to search under field conditions. As moth plant is an 'unwanted organism' in New Zealand and is also listed on the National Pest Plant Accord, dispensation was sought from and granted by MAFBiosecurity New Zealand to use the plant in this way.

In all experiments in both Dunedin and Hamilton, the plant material used was fresh (almost always less than 24 h old). Care was taken to ensure that no cross-contamination of odour took place and the position of plant material within the array was randomised.

In Experiment 3, in Dunedin in 2007, Storm was tested for her ability to find small pieces of cheese hidden 10 to 50 m apart along bush tracks in native or exotic deciduous forest. Here, detection rate and detection distance were tested under field conditions, and the effects of temperature (at ground and 1.5 m) and relative humidity (at 1.5 m) on detection success were monitored.

Experiment 4 was carried out in 2009. A young female German shepherd, Freya, was tested for her ability to find plants of three weed species (heather, *Calluna vulgaris*; Darwin's barberry, *Berberis darwinii*; spartina *Spartina* sp.) in the environments in which they occur. Freya was first trained to detect all three species under controlled conditions, using the same techniques as in the 2007 Hamilton trials. She was then taken into the field in appropriate localities (Pureora Forest – *c.* 38°31'S, 175°33'E – for heather and Darwin's barberry; Firth of Thames – *c.* 37°13'S, 175°29'E – for spartina), where she sniffed a target plant and then searched marked plots. For heather, four 10 m^2 plots were each searched for 5 min early in the morning of 3 June 2009, when there was a ground frost of −6°C. For Darwin's barberry, four different 10 m^2 plots were searched for 5 min each later the same morning. Positive identifications were recorded and after Freya had completed her searches, two observers counted the plants in the same plots. Four separate visits were made to the spartina site and a total of 24 searches were made on plots of between 20 and 50 m^2, with each individual search lasting 15 min. Again two observers counted plants in the plots after the dog had finished her search. Dispensation was sought from and granted by MAFBiosecurity New Zealand to use heather and Darwin's barberry as they are 'unwanted organisms' in New Zealand and also listed on the National Pest Plant Accord.

RESULTS

In most cases in Experiment 1, Storm found the target plant on the first exposure to that plant. A few species were difficult for her on the first encounter (e.g. *Hebe salicifolia*), but Storm found all species reliably by the third or fourth encounter. The average success for all targets over all trials was 88% and, for 11 of the 19

Table 1. Species tested in Experiment 1 in Dunedin.

Botanical name	Common name	Botanical name	Common name
Achillea millefolium	yarrow	*Rheum sativum*	rhubarb
Calystegia silvatica	'convolvulus'	*Rosmarinus officinalis*	Rosemary
Dactylis glomerata	cocksfoot	*Rumex* sp.	dock
Diplotaxis tenuifolia	rocket	*Salvia officinalis*	sage
Fuchsia sp.	fuchsia	*Salvia officinalis**	pizza sage (a cultivar of sage?)
Jacobaea vulgaris	ragwort	*Sonchus oleraceus*	sow thistle
Hebe salicifolia	hebe	*Sophora* sp.	kowhai
*Helichrysum augustifolium**	'curry plant'	*Syzygium maire*	maire
Lupinus polyphyllus	lupin	*Tagetes* sp.	marigold
Melissa officinalis	lemon balm	*Taraxacum officinale*	dandelion
Petroselinum crispum	parsley	*Tropaeolum majus*	nasturtium
Pinus sp.	pine	*Tropaeolum speciosum*	Chilean flame creeper
Pyrus sp.	pear		

*Indicates uncertainty over correct botanical name.

species tested, success rate was 100%. In early trials, dock (leaves) was confused with marigold (flowers), producing consistent false alarms on one when the other was the target. Reliable discrimination was obtained after several trials.

In Experiment 2, the dog had no trouble detecting the target species (moth plant – *Araujia sericifera*). Over the training period, about 30 different types of (unspecified) plant material were introduced to the search area, and the dog was clearly able to distinguish moth plant from all other odours.

In the field, distractions from stock, people and dogs from neighbouring properties were easily overcome. Training conditions included frost, high winds, heavy rain and still, warm afternoons. On frosty mornings, the dog detected every target accurately and at distances of up to 10 m (detection distance was not recorded consistently in this study). High winds did not affect the results greatly, providing the dog was working into the wind. The dog did not detect the target odour in heavy rain, unless he was almost on top of it.

In Experiment 3, 38 trials were run between 6 March and 15 May 2007 to investigate the effects of environmental conditions on field searching. The proportion of cheese pieces found in a trial increased significantly with increasing temperature at ground level ($R^2 = 0.13$, $F_{1,38} = 5.68$, $P = 0.02$, Figure 1; results were similar for temperature at 1.5 m). The median distance at which the dog detected the cheese increased with increasing temperature but the relationship was not significant. For relative humidity, no significant relationships were found between proportion of cheese pieces found and detection distance. Very little wind was encountered in the bush environment, and no analysis of wind was attempted.

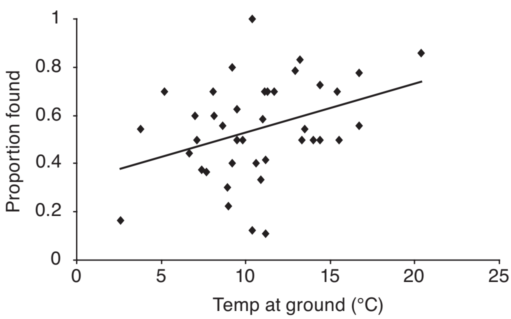

Figure 1. Relationship between proportion of cheese pieces found in each trial, and temperature at ground level, for a dog searching on bush tracks.

In Experiment 4, the ability of Freya to find plants of three weeds (*Berberis darwinii*, *Calluna vulgaris*, *Spartina* sp.) growing in their 'natural' environments was tested. After 40 to 50 days of training, the dog could identify material of each of the three species after being allowed to sniff a sample. The trainer believed that spartina was the easiest plant for the dog to detect, and Darwin's barberry the most difficult.

When searching for heather, Freya gave five positive indications in the four plots she searched; the two observers found 10 plants. A search conducted on a large 20 m^2 patch of heather containing about 300 plants caused Freya to become disorientated, probably due to odour saturation. With Darwin's barberry, four separate areas were searched and Freya gave a total of 38 positive indications; the two observers estimated 300 plants in the four plots. Plants in the search area had been controlled the previous year so the dog was searching for re-growth and new seedlings. The plants tended to occur in clusters and although the dog's indication rate was low relative to the number of plants, she was indicating groups or clusters. On one occasion the dog found a seedling only 2 cm in height with two leaves and hidden by fallen leaves. She moved the leaves aside with her nose to indicate this plant.

For spartina, visits were made on four separate occasions, and several areas were searched at each visit. The number of plants found in these areas on each visit is shown in Table 2. Freya seemed to have greater success on later visits, however, she consistently indicated fewer plants than those recorded by observers.

Table 2. Plants found by Freya and by observers.

Area No.	1	2	3	4
Freya	30	65	48	55
Observers	140	150	125	75

DISCUSSION

Experiments 1 and 2 showed convincingly that dogs can be trained to detect and distinguish between odours of different plant species. Furthermore, the field work indicated that dogs are capable of detecting plants under field conditions. Storm detected all 19 species with which she was challenged, in many cases immediately, suggesting that most plants will be detectable by an appropriately trained dog. The match-to-sample protocol used here (often used in dog training, where the dogs have to select the correct one out of a number of alternatives to match the odour of a sample), produces a versatile dog that can be quickly switched from one plant species to another, and it may be that specialist dogs trained for one species are rarely or never needed. The question of whether dogs or people provide the most effective detection capacity for individual species will always depend on the particular conditions in which searches are proposed, and it is most likely that both working together will give the best outcome.

Finding the right dog can be difficult. Forty dogs were evaluated in the search for Freya for Experiment 4. However, while it is likely that key behavioural attributes predict greater success, equally important are training style and versatility, and breed choice is an additional key component of success (GICHD 2001). Only 2 dogs were trialled for Experiment 1, and the rejected dog (a 3 year-old Labrador) was possibly too old to undertake such a retraining programme.

Goodwin *et al.* (2008) also experienced the issue of odour saturation when the dog is overwhelmed by the large number of plants, and becomes confused. One obvious difficulty is finding individual plants when the plants grow in clumps. Goodwin *et al.* (2008) found, in their 2006 field trials, that an average of 92% of the knapweed was detected by three dogs working individually, while humans found 76%. Our results were not as conclusive, which indicates that the measurement of detection success must take into account the pattern of distribution of the weed.

We conclude that dogs have the potential to provide an excellent additional tool in the search for either remnant weed plants after eradication, or for cryptic endangered species.

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