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The use of scent-detection dogs

Clare Browne[1], Kevin Stafford[2] and Robin Fordham[1]
[1] Ecology Group, Institute of Natural Resources, Massey University, Palmerston North, New Zealand
[2] Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand

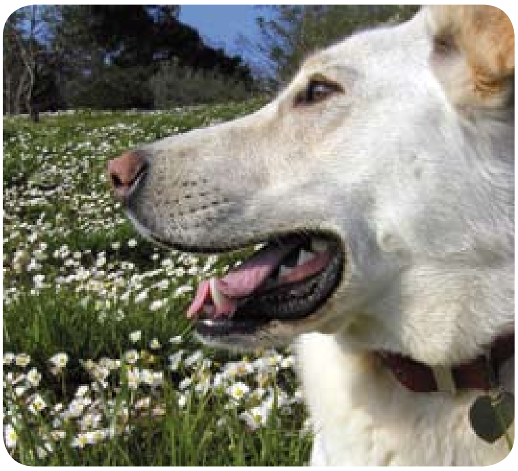
Domestic dogs (*Canis familiaris*) can detect substances at much lower concentrations than humans (Thorne, 1995) and their area of olfactory epithelium (18 to 150 cm^2 ; Dodd and Squirrel, 1980, cited in Thorne, 1995) is much greater than that of humans (3 cm^2; Albone, 1984). Dogs are used by humans to locate a range of substances because of their superior olfactory acuity. This paper reviews the use of scent-detection dogs to detect non-biological scents (explosives, chemical contaminants, illegal drugs) and biological scents (human odours, animal scents) and their role in conservation.

Detection dogs for non-biological scents

Dogs trained to detect explosives and land mines are now the largest group of working scent-detection dogs in the world (Gazit and Terkel, 2003). They are considered to be the most reliable, versatile and cost efficient explosives-detectors (Furton and Myers, 2001; Lorenzo *et al.*, 2003). The ability of dogs to locate their target scents while ignoring the many non-target scents encountered in their search environments (e.g., airports) is claimed to be better than that of instruments (Furton and Myers, 2001). There are over 100 million laid land mines around the world. They block access to productive land, curb economic growth, and kill and maim people (McLean, 2001). Mine-detection dogs search for buried land mines and are used to confirm that areas are free from mines (Phelan and Webb, 2003). They are trained to detect the explosive chemicals in land mines but also to recognise the scent of tripwires (Fjellanger, 2003; Hayter, 2003). Experts believe that the detection abilities of land mine-detection dogs are superior to all comparable methods (Bach and McLean, 2003).

Accelerant-detection dogs are trained to locate the residual scent of flammable products used as accelerants by arsonists and to ignore the smell of pyrolysis products such as burned carpet or wood (Katz and Midkiff, 1998). Dogs find vestiges of accelerants at fire scenes more quickly and precisely than humans (Kurz *et al.*, 1994). When dogs are used to locate accelerants, fewer samples from a scene need to be submitted for analysis, and this improves the efficiency of investigations and saves time and money (Tindall and Lothridge, 1995; Katz and Midkiff, 1998). Dogs can detect extremely low volumes (5.0 to 0.005μL) of accelerants, levels which are at or beyond the sensitivity of laboratory techniques and equipment (Kurz *et al.*, 1994; Tindall and Lothridge, 1995; Kurz *et al.*, 1996).

Dogs can be trained to identify areas contaminated with hazardous chemicals, such as toluene (Arner *et al.*, 1986). They are capable of locating very small (0.1g) quantities of these chemicals over large distances where instruments have failed to detect them. This improves human safety by identifying the outer limits of a polluted area before dangerously high levels of toxins are encountered and can determine point sources for more efficient sampling (Arner *et al.*, 1986). Organochlorine residues have been found in beef exports from Australia and dogs are now used routinely to detect aldrin, dieldrin, and DDT contamination on farmland. The level of contamination in the soil can be very low (1 part per million and less) (Crook, 2000) and trained dogs can identify point sources of organochlorines with sensitivity levels of up to 99%. Using dogs saves time and reduces the number of soil samples required to identify contaminated sites (Crook, 2000).



Dogs have amazing capacities to detect scents.

Author for Correspondence:
Clare Browne
Ecology Group
Institute of Natural Resources
Massey University
Palmerston North
New Zealand
Tel: +64 6 355 9235
Email: clare_browne@yahoo.co.nz

Dogs are used by customs services to find illegal drugs including cocaine, heroin, methamphetamine and marijuana (Lorenzo *et al.*, 2003) and are used routinely to screen the millions of people and items crossing international borders through airports, seaports and by post (Adams and Johnson, 1994; Rouhi, 1997). Drug-detection dogs are also used by police and in schools and workplaces to detect and deter the use and trading of illicit substances (Ritz, 1994).

Detection dogs for biological scents

Human scents

Dogs are able to identify an individual's scent even when it is mixed with the scent of another person or with other strong smelling substances (Kalmus, 1955). Police in some countries use dogs to identify criminals by matching the scent of a perpetrator at a crime scene to the scent of a suspect. To some police forces this is the

Clare Browne's dog Apple sniffs a dead tuatara, a reptile used in training.

most valuable task a police dog can perform but it is controversial (Schoon, 1997). Because the information provided by dogs in 'scent identification line-ups' is used as evidence in court (Schoon, 1996), its reliability has been investigated in several studies. Results indicate that, with sufficient training, dogs are capable of matching scents from different parts of the same human body (Schoon and De Bruin, 1994; Settle et al., 1994). In addition, dogs can follow trails of human scent through busy urban centres 48 hours after they were laid with 77.5% average success (Harvey and Harvey, 2003).

Dogs trained for search and rescue are used to search for missing people, avalanche victims, survivors at disaster sites (such as earthquakes, floods and plane crashes) and drowned persons (Fenton, 1992; Hebard, 1993). Cadaver-detection dogs are trained to find decomposing human bodies (Lasseter *et al.*, 2003) and are used to locate the victims of misadventure. Cadaver dogs are trained to find traces of human corpses, such as skeletal remains or fluid and tissue remnants, on the surface, buried underground, or in water (Fenton, 1992; Lasseter *et al.*, 2003). Cadaver dogs can rapidly search large areas for human remains, saving a considerable amount of human time and effort (Komar, 1999). Detection rates of cadaver dogs range from 30% to 81% in field trials (Komar, 1999; Lasseter *et al.*, 2003).

Scent detection dogs can aid in the diagnosis of some types of cancer. They can detect the odour of melanoma cells and that of urine from people with bladder cancer, with accuracy levels of 100% and 41%, respectively (Pickel *et al.*, 2001; Pickel *et al.,* 2004; Willis *et al.,* 2004). Cancerous cells may produce volatile chemicals, enabling their detection by dogs (Pickel *et al.,* 2004). Edney (1993) described the behaviour of 37 dogs that responded to their owners' epileptic events. Of these dogs, 57% displayed characteristic behaviours prior to a seizure and 68% performed similar behaviours during a seizure. Activities of the dogs prior to the onset of a human seizure were predominantly attention-seeking such as barking, jumping up and becoming overly attentive; while the behaviour of the dogs reacting during their owners' seizures were mainly described as protective, including sitting and staying beside their owners. Dogs trained to alert their owners to impending epileptic attacks were able to consistently indicate to their owners that a seizure was imminent, with warning times ranging from 10 to 45 minutes (Strong *et al.*, 1999; Brown and Strong, 2001). It has been suggested that dogs are able to detect scents exuded by their owners before the epileptic fit and sense behavioural changes in their owners at this time (Edney, 1993).

More than a third of people with diabetes reported that their dogs react to their hypoglycaemic attacks (Lim *et al.*, 1992; cited in Chen *et al.*, 2000). Three case studies described dogs detecting a hypoglycaemic attack before their owners had noticed any symptoms (Chen *et al.*, 2000). The dogs displayed a range of abnormal behaviours prior to and during their owners' hypoglycaemia, including running and hiding, barking and preventing the owner from leaving the house. None of the dogs described resumed normal behaviours until their owners had eaten food to correct blood glucose concentrations. The mechanisms by which dogs detect changes in human blood glucose levels are unknown, but it is suspected that the dogs recognise olfactory changes attributed to increased sweating, possibly combined with muscle tremors and behavioural changes (Chen *et al.,* 2000).

Animal scents

Dogs are used for biosecurity purposes in a variety of circumstances, including containment and border control. Dogs are used in Guam, for example, to search outward-bound cargo for brown tree snakes (*Boiga irregularis*) and prevent accidental introduction of this pest elsewhere (Engeman *et al.*, 1998a; Engeman *et al.*, 1998b). These snake-detection dogs have an average location rate of 62% (Engeman *et al.*, 2002).

Dogs can locate insects that damage plants. The red palm weevil (*Rhynchophorus ferrugineus*) can inflict severe damage on date palms (*Phoenix dactylifera* L.), the most important fruit crop in the Middle East (Nakash *et al.*, 2000). Affected trees are extremely difficult to find, but can be saved if identified in the early stages of infestation (Nakash *et al.*, 2000). Nakash *et al.* (2000) reported that two dogs were trained to respond to the secretions of infested trees and produced very high success rates in initial tests. Dogs can also be trained to detect the egg masses of gypsy moths (*Porthetria dispar L.*) which are laid close to the ground in leaf litter or debris and are particularly hard to find (Wallner and Ellis, 1976). Two dogs evaluated at searching for egg masses had a combined average detection rate of 73%, with the results showing a strong correlation between one dog's number of indications and egg mass density (Wallner and Ellis, 1976). There is potential for calibrating and using a dog to estimate egg mass density by the number located within a specific time period.

In the USA subterranean termite damage and control are estimated to cost up to US$2 billion per annum (Culliney and Grace, 2000). Early infestations are often impossible to detect visually and can cause significant damage before they are discovered (Brooks *et al.*, 2003). Trained termite-detection dogs can locate eastern subterranean termites (*Reticulitermes flavipes* Kollar) with average success rates of over 95%, and can discriminate between termites, other insects (ants and cockroaches) and termite-damaged wood (Brooks *et al.*, 2003). When the ability of dogs to detect western subterranean termites (*Reticulitermes hesperus* Banks) was compared with electronic odour detection devices, the dogs correctly identified 98% of artificially set-up infestations while the electronic device had a low detection rate (Lewis *et al.*, 1997). However, the dogs also produced 28% false positives, where there was no infestation, although this may be attributable to training techniques (Brooks *et al.*, 2003).

Screwworms (*Cochliomyia hominivorax*) are obligate parasites that can kill warm-blooded animals and cause significant economic losses (Welch, 1990). A dog trained to detect both screwworm pupae and screwworm-infested wounds on animals had an extremely high success rate (99.7%) at finding them (Welch, 1990).

Dogs may even be used to detect microorganisms. Some cyanobacteria species in commercial catfish ponds produce odorous compounds which accumulate in the flesh of the fish, causing an unpleasant flavour (Shelby *et al.*, 2004). The cost of rejecting affected fish ranges from $15 to 23 million annually for catfish producers in the United States (Hanson, 2003; cited in Shelby *et al.*, 2004). Shelby *et al.* (2004) showed that dogs could identify the two most common 'off-flavours', 2-methylisoborneol and geosmin, in pond water samples with high levels of accuracy. Three dogs detected the off-flavours at levels of 1μg/L with 79% to 93% accuracy and 10ng/L with 37% to 49% success. Trained dogs are a practical method of detecting off-flavours and are a reliable alternative to chemical analysis or human taste-testers (Shelby *et al.*, 2004). Microbial growth in buildings can have detrimental effects on human health and cause costly deterioration of construction materials. The initial detection of microbial growth is extremely difficult and Kauhanen *et al.* (2002) tested the efficacy of dogs trained to find rot fungi, typical building moulds and bacteria. They found that their two study dogs were able to locate 75% of hidden microbial growth samples.


Apple at work in the New Zealand countryside.

Dogs can identify dairy cows that are in oestrus from the scent of vaginal fluid, urine, milk and blood plasma, with accuracies ranging from 78% to 99% (Kiddy *et al.*, 1978; Kiddy *et al.*, 1984). Dogs can also discriminate between the milk of cows in pre-oestrus, oestrus and dioestrus (Hawk *et al.*, 1984).

Detection dogs used for conservation

Dogs are used to locate and monitor a number of endangered mammals and birds and are a comparatively unobtrusive method for researchers and conservationists to use when studying rare species. Dogs can offer safer methods of studying potentially dangerous animals, reduce some sample collection biases and decrease the time spent searching for animals. It is often difficult to collect information on endangered species due to their low densities and the large, remote areas they commonly inhabit. The use of scat (animal droppings)-detection dogs is becoming increasingly popular in many countries due to the problems inherent in traditional methods of researching threatened species. Mark-recapture techniques and attaching radio-tracking devices, for example, are invasive and potentially harmful to the animals (Long et al., 2002). Using dogs to find scats is a non-invasive method of studying rare animal populations, and it can increase sample numbers while reducing collection bias (Wasser et al., 2004). The information that can be extracted from scats is comparable to data provided by traditional methods.

Applying molecular techniques to scats provides information on the species, sex, individual identity, diet and parasitology of animals (Kohn and Wayne, 1997; Mills *et al.*, 2000). Reproductive and stress hormones from scats can indicate reproductive productivity and impacts of disturbance on physiological condition (Wasser *et al.*, 2000; Wasser *et al.*, 2004). By systematically sampling scats over a large geographic area, population characteristics such as sex ratio, relatedness, habitat and home ranges may be estimated (Kohn and Wayne, 1997; Kohn *et al.*, 1999; Wasser *et al.*, 2004). Scats may provide more information and be a more accessible source of DNA than materials such as hair, skin, feathers, nails, bones, or saliva (Kohn and Wayne, 1997). The distribution of animals determined by dog-assisted scat sampling has been found to correspond well with methods such as hair sampling and GPS radio-tracking (Wasser *et al.*, 2004).

Dogs are used to locate bears in North America for management of game populations and conservation purposes. A study by Wasser *et al.* (2004) described the use of scat-detection dogs to assess the impacts of human disturbances on black bear (*Ursus americanus*) and grizzly bear (*Ursus arctos horribilis*) populations in Canada. The dogs were trained to locate bear scats along transects within a 5,200km2 area and DNA was extracted from the scats to determine species and individual identities. By using scat-detection dogs, Wasser et al. (2004) were able to effectively and non-invasively identify land use patterns for both black and grizzly bears. Mark-recapture methods, using dogs trained to locate bear scent along transect routes, are also used to estimate bear population in North America (Akenson *et al.*, 2001); and dogs can be trained to discriminate between black and grizzly bear scats, reducing the need for laboratory tests (Hurt *et al.,* 2000).

Dogs trained to find the scats of endangered San Joaquin kit foxes (*Vulpes macrotis mutica*) in the US are more efficient than humans at finding scats for demographic and population studies (Smith et al., 2003). Trained dogs are able to find up to four times more kit fox scats along transects than an experienced person, and even the dogs' worst detection rate in difficult scenting conditions was as good as that of humans (Smith and Ralls, 2001; Smith et al., 2003). Dogs searching for kit fox scats must distinguish them from coyote (*Canis latrans),* skunk (*Mephitis mephitis*) and badger (*Taxidea taxus*) scats, and have been found to be 100% correct in their species identification (Smith and Ralls, 2001; Smith *et al.*, 2003). Kit fox latrines (areas where one or more individuals repeatedly defaecate) can also be found by dogs (Ralls and Smith, 2004). As the cost of extracting DNA from faecal samples and using laboratory methods to determine species is expensive, this extremely accurate species identification ability of scat-detection dogs saves thousands of dollars.

Biologists studying the endangered amur tiger (*Panther tigris altaica*) in Russia use dogs to identify individual tigers. The dogs identify the tigers by smelling the collected urine and scat samples and matching them to a reference collection of known tigers (L. Kerley, personal communication, 2004). The movements of individual tigers are monitored using a combination of observation, conventional tracking and the dog-identified scats (Kerley, 2003). However, information on the population dynamics of the tigers can be obtained by using the dogs alone. Tigers new to the area can also be identified by this method (L. Kerley, personal communication, 2004) and two dogs used in this project have proved to have accuracy rates of 89% and 96% (Kerley, 2003).

Trained dogs assist researchers studying ringed seals (*Phoca hispida*) in the North American Arctic. Dogs have been relied on to locate these seals in a number of studies, which assessed the impacts of human activity and industry on the seals, examined possible links between lair characteristics and predation success, and obtained measures of territory size (Lydersen and Gjertz, 1986; Smith, 1987; Furgal *et al.,* 1996). Specially trained dogs can locate, by scent, subnivean (beneath the snow) lairs and breathing holes on the ice shelf at distances over 1.5km, through drifted snow up to 2m deep, and in winds of up to 46 km/hour (Smith, 1987).

Dogs traditionally used for hunting game birds are now frequently employed to locate birds and help carry out studies on threatened species. Yellow rails (*Coturnicops noveboracensis*), for example, are classified as a vulnerable species in Quebec (Robert and Laporte, 1997). Because their patchy, localised distribution makes them extremely difficult to locate, study, or catch, dogs have been used to find their nests during research projects (Robert and Laporte, 1997).

Management programs of rare avian species have also benefited from dogs' innate behaviour. Border collies, for example, were used to help capture endangered aleutian canada geese (*Branta canadensis leucopareia*) in Alaska for relocation to predator-free islands (Shute, 1990). The terrain of the island inhabited by the geese made catching them extremely dangerous for humans, and many researchers and geese sustained injuries. The use of dogs not only made the exercise much safer, but also much more efficient. Scientists took three weeks to catch 120 geese; two dogs were able to round up 143 in four days (Shute, 1990).

Dogs have been used in New Zealand for more than a 100 years to locate a number of endangered species, such as blue duck (*Hymenolaimus malacorhynchos*), kiwi (*Apteryx spp.*) and kakapo (*Strigops habroptilus*) (Browne, 2005). Reliable kiwi-detection dogs are considered essential to kiwi field research because the birds are so difficult to locate (Colbourne, 1992).

Surveys of bird carcasses can be used to estimate mortality caused by disease, poisoning or pollution (Homan *et al.,* 2001). Quick recovery of carcasses before decomposition or scavenging takes place is important to obtain accurate population estimates. Homan *et al.* (2001) compared the searching efficiency of humans and dogs looking for house sparrow (*Passer domesticus*) carcasses amongst vegetation. They found that dogs were significantly more efficient at detecting avian carcasses than humans, finding twice as many, even at very low carcass densities.

Summary

Dogs are reliable and efficient scent-detectors. Numerous studies have established dogs' proficiency at locating an extremely wide range of scents. Trained dogs can significantly reduce the amount of time spent searching for a target object, chemical or species. Often more sensitive, reliable and practical than electronic scent-detection devices, dogs are also easy and cheap to train and put into action. Scent-detection dogs make a significant contribution to the conservation programmes of many endangered species. In the future we can expect to see dogs involved more widely in chemical detection, conservation and disease diagnosis, both human and veterinary. The major restriction to the use of trained scent-detection dogs appears to be human imagination.

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