THE USE OF DOGS TO DETECT NEW ZEALAND REPTILE SCENTS

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ABSTRACT

This study examined the ability of domestic dogs (*Canis familiaris*) to detect the scent of the Cook Strait tuatara (*Sphenodon punctatus*), Marlborough green gecko (*Naultinus manukanus*) and forest gecko (*Hoplodactylus granulatus*).

Handlers from two local dog training clubs with a total of 20 dogs participated in this study. The dogs' capacity to detect human and reptiles scents was evaluated in a series of trials. Each trial required the dogs to identify a different target scent, and consisted of nine replicate scent discrimination exercises. In the exercises the dogs were presented with a line of cloths. One or more of the cloths contained scent and the dogs were commanded to locate a specific scented cloth. Tuatara and gecko scats, sloughed skins and paper towels captive individuals had been sitting on were used to imbue the cloths with reptile scent.

The dogs were able to identify human, tuatara and gecko scents with average success rates of up to 96.3%, 93.7% and 86.7%, respectively. The dogs could detect fresh reptile scats, scats that had been exposed in native forest for two weeks and discriminate between several different reptile scents. The detection successes were significantly higher than would be expected if the dogs were selecting cloths at random ($p = 0.05$). The average results of each trial and the success rates of individual dogs were significantly different at both dog clubs ($p = 0.000$).

The results indicate that the methods used in this study are a good model for scent discrimination research, and dogs could be used to detect tuatara and gecko species for conservation work. Dogs may provide an alternative to the visual methods currently used to locate these reptiles.

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CHAPTER 1

INTRODUCTION

A tuatara-detection dog searching for a hidden tuatara (*Sphenodon punctatus*) on the edge of Pirongia Forest Park, Hamilton, New Zealand. Photo: Kara Goddard.

1.1 Introduction

The New Zealand archipelago is a continental fragment that split from the Gondwanan landmass approximately 80-60 million years ago (Chambers *et al.*, 2001). The fauna of New Zealand has therefore largely evolved in the absence of terrestrial mammalian predators, and consequently is characterised by such traits as gigantism, lack of defensive behaviour, longevity and low reproductive rates (Daugherty *et al.*, 1990b; Daugherty *et al.*, 1993). These features make many New Zealand species unique, but also vulnerable to disturbance and the introduction of novel predators (Daugherty *et al.*, 1993).

New Zealand reptiles have followed trends similar to other indigenous animals, and have declined in range and numbers due to the direct and indirect impacts of human arrival around 1,000 years ago (Daugherty *et al.*, 1993; Towns & Daugherty, 1994; Towns *et al.*, 2001). Tuatara are reptiles of international importance as the sole extant member of the order Sphenodontia (Cree & Butler, 1993). New Zealand's gecko fauna is also very significant in both its diversity and complete endemism (Daugherty *et al.*, 1994; Towns *et al.*, 2001). Since human colonisation of New Zealand, the introduction of mammalian predators and habitat modification, the tuatara has been reduced to only 0.5% of its former range and at least 32% of gecko species are restricted to offshore islands (Cree & Butler, 1993; Daugherty *et al.*, 1994). Both species of tuatara and 34 species of gecko are considered threatened by the New Zealand Department of Conservation (DoC) (Hitchmough, 2002).

Tuatara and geckos can be difficult to survey and capture because of their elusive, cryptic and often nocturnal natures (Robb, 1980; Cree *et al.*, 1995; Cassey & Ussher, 1999). Domestic dogs (*Canis familiaris*) have been used in New Zealand for over 100 years to locate threatened species for the purpose of conservation. The significant contribution dogs have made to many species' recovery programs has earned them recognition as valuable and efficient tools. This study aimed to examine the ability of dogs to detect tuatara and gecko scent, with the intention that successful results could be practically applied to assist in the conservation of these reptiles.

1.2 Thesis Organisation

This thesis has a chapter reviewing the literature on the use of detection-dogs, two research chapters and a final chapter of conclusions and suggestions for future research. The first research chapter examines the ability of dogs to detect tuatara scent; the second looks at dogs' capacity to detect gecko scent. References for all chapters are collated at the end of the thesis to avoid replication. Appendix 1 is a case study describing the training of a tuatara-detection dog; Appendices 2 and 3 provide dates of all the trials; and Appendices 4 and 5 detail information regarding the reptile samples used in the study.

CHAPTER 2

A REVIEW OF THE USE OF SCENT-DETECTION DOGS

A conservation dog searching for black-footed ferrets (*Mustela nigripes*) in a black-tailed prairie dog (*Cynomys ludovicianus*) burrow, Montana, United States. Photo: Aimee Hurt.

Domestic dogs have been closely associated with human beings for thousands of years (Clutton-Brock, 1995). Today, dogs are used by humans to perform a wide array of tasks. Dogs can detect a range of substances at concentrations 1,000-100,000,000 times less than humans can recognise (Neuhus, 1953; Becker *et al.*, 1957; Moulton *et al.*, 1960; cited in Thorne, 1995). The area of olfactory epithelium in dogs ranges from 18-150 cm^2 (Dodd and Squirrel, 1980; cited in Thorne, 1995), whereas humans have only 3 cm^2 (Albone, 1984). Dogs are employed frequently to search for things using their superior olfactory acuity.

The following sections of this chapter will look at how dogs are used to detect non-biological and biological materials, and the use of dogs in conservation, both internationally and in New Zealand.

2.1 Detection Dogs for Non-biological Scents

Specially trained dogs are used to detect a variety of non-biological substances. They help control the movement of contraband, identify dangerous chemicals and gather forensic evidence in criminal investigations. By locating dangerous substances by scent, often more accurately and reliably than equipment, detection dogs can reduce risks to human health and safety.

2.1.1 Drugs

Dogs are used to find illegal drugs including cocaine, heroin, methamphetamine and marijuana (Lorenzo *et al.*, 2003). They are routinely used to screen the millions of people and items crossing international borders through airports, ports and postal services (Adams & Johnson, 1994; Rouhi, 1997). Drug-detection dogs are also used by police, and are becoming common in workplaces as companies try to deter employees from using or selling illicit substances at work (Ritz, 1994).

2.1.2 Explosives

Explosives-detection dogs are now reputed to be the largest group of working scent-detection dogs in the world (Gazit & Terkel, 2003a). Trained dogs are considered by many to be the most reliable, versatile and cost efficient explosives-detectors (Furton & 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 & Myers, 2001).

There are over 100 million laid land mines around the world. These block access to productive land, curb economic growth and kill and maim people (McLean, 2001). Mine-detection dogs are used to search for buried land mines or to confirm that areas are free from mines (Phelan & Webb, 2003). They are trained to detect explosive chemicals and to recognise the scent of tripwires (Fjellanger, 2003; Hayter, 2003). Experts believe that the detection abilities of dogs are superior to all comparable artificial methods (Bach & McLean, 2003).

2.1.3 Accelerants

Accelerant-detection dogs are trained to locate the residual scent of flammable products commonly used as accelerants at fire scenes and to ignore the smell of pyrolysis products such as burned carpet or wood (Katz & Midkiff, 1998). Dogs are able to find vestiges of accelerants at fire scenes more quickly and precisely than humans (Kurz *et al.*, 1994). By using dogs that can accurately locate accelerants, fewer samples from a scene need to be submitted for analysis, improving the efficiency of investigations and saving time and money (Tindall & Lothridge, 1995; Katz & Midkiff, 1998).

Studies have tried to establish the thresholds of dogs for detecting accelerants and have found that they can detect extremely low volumes (5.0-0.005 μL) of potential accelerants, levels which are at or beyond the sensitivity of laboratory techniques and equipment (Kurz *et al.*, 1994; Tindall & Lothridge, 1995; Kurz *et al.*, 1996). Accelerant-detection dogs do occasionally falsely indicate the occurrence of accelerants, when in fact accelerants are absent and only pyrolysis products are present (Kurz *et al.*, 1994; Katz & Midkiff, 1998). However, this can also occur when using gas chromatography analysis of very small samples (1 μL or less) (Kurz *et al.*, 1996). When dogs are taught to ignore pyrolysis scents they show an improved ability to ignore background interference from non-target odours (Kurz *et al.*, 1994).

2.1.4 Contaminants

A study was carried out to see if dogs could be trained to identify areas contaminated with hazardous chemicals (Arner *et al.*, 1986). The study aimed to improve human safety by identifying the outer limits of a polluted area before dangerously high levels of toxins were encountered, and determine point sources for more efficient sampling (Arner *et al.*, 1986). Two dogs were trained to detect small quantities (0.1 g) of toluene, a hydrocarbon often found in gasoline storage tanks, and 2,4,6-trichlorophenol, a potential indicator of dioxins. A third dog was trained to detect 1,2,3-trichloropropane to levels of 0.1 g. Although only a small number of dogs was used and very limited tests were run, the results of the field trials indicate there is potential for using dogs for such purposes. The dogs were able to locate very small quantities of the chemicals over large distances where instruments had failed to detect them.

Organochlorine (OC) chemical residues have been found in beef exports from Australia. To manage OC contamination on farmland, a dog was trained to detect a range of OCs (aldrin, dieldrin, and DDT) at very low levels (1 part per million and less) in the soil (Crook, 2000). The dog identified point sources of OCs with sensitivity levels of up to 98.98%. Using the dog saved time and reduced the number of soil samples required to identify contaminated sites. The study's success has prompted training of at least one further OC-detection dog (Crook, 2000).

2.2 Detection Dogs for Biological Scents

Dogs are trained to detect a wide range of scents from biological sources. Their keen sense of smell is used to locate humans, detect medical conditions and find a range of other species.

2.2.1 Humans

Criminal identification

Dogs are able to differentiate between the odours of individual humans, irrespective of the body region (e.g. palm of hand, sole of foot, armpit) from which the odour was collected (Kalmus, 1955). Dogs can identify a person's scent even when mixed with the scent of another person or with strong smelling materials, and they can distinguish the individual odours of identical twins (Kalmus, 1955). Police in many countries use the acute discriminatory abilities of dogs for criminal identification. Matching the scent of a perpetrator on an object at a crime scene to the scent of a suspect is one of the most valuable tasks a police dog can perform, although 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.

Brisbin & Austad (1991) questioned the practice of using dogs for criminal identification and examined the ability of dogs to match odours from one part of a person's body to another. Some of their results were no better than what would be expected by random chance (57.9%), and they concluded either individual human odours were undetectable by dogs, or dogs trained with "standard methods" were not able to spontaneously recognise individual odour components of scents taken from different parts of the body. However, critics disagreed with Brisbin's & Austad's conclusions, on the basis that their study did not control for the dogs' confusion that arose due to differences between training and testing methods (Sommerville *et al.*, 1993). The dogs were originally trained to find their handlers' hand scent only, but were required to identify scents from a range of body parts from their handler and a stranger during the testing. Brisbin & Austad (1993) maintained this very specific training was deliberately designed to determine if the dogs would generalise odours from one body part to other body parts.

Schoon & De Bruin (1994) and Settle *et al.* (1994) performed experiments similar to Brisbin & Austad (1991) using Dutch police dogs and methods based on those used by police in Germany and the Netherlands, respectively. Their results indicated that with sufficient training police dogs are capable of matching scents from different parts of the same human body. Another study using bloodhounds trained to follow human scent trails, seems to confirm that dogs can be trained to generalise scent from different parts of an individual's body (Harvey & Harvey, 2003). In this study people walked through parkland, a university campus and busy urban centres; after 48 hours the dogs were cued with scent collected from various parts of the trail-setter's body and required to follow the trail. The dogs were able to complete the trails with an average success of 77.5%.

Search and rescue

One well-known use for dogs' olfactory capabilities is search and rescue work. Dogs have been used for search and rescue purposes for hundreds of years (Fenton, 1992). Trained dogs may be useful in a wide variety of situations, including searching for missing people, avalanche victims, possible survivors at disaster sites (such as earthquakes, floods and plane crashes) and drowning victims (Fenton, 1992; Hebard, 1993; American Rescue Dog Association, 2002).

Human remains

A specialist branch of search and rescue dogs is cadaver-detection dogs. These dogs are trained to find the generic scent of human decomposition (Lasseter *et al.*, 2003), and are used to locate the victims of crimes or accidents. Cadaver dogs are taught to find any possible trace of human corpses including bodies, skeletal remains and fluid and tissue remnants. These targets can be concealed on the surface, buried underground, or in water (Fenton, 1992; American Rescue Dog Association, 2002; Lasseter *et al.*, 2003).

Cadaver dogs are generally efficient and highly effective in the recovery of human remains (Komar, 1999; American Rescue Dog Association, 2002). Detection rates of cadaver dogs range from 30-81% in field trials; and as with all scent detection, the success of the dogs is very dependent on weather conditions (Komar, 1999; Lasseter *et al.*, 2003). Well-trained cadaver dogs can rapidly search large areas for human remains, saving a considerable amount time and human effort (Komar, 1999).

Medical conditions

There is anecdotal evidence of pet dogs detecting cancers in their owners. An often cited example is a woman whose dog constantly sniffed at a lesion on her leg, even through clothing, and eventually attempted to bite it off (Williams & Pembroke, 1989). On subsequent removal and histological examination the lesion was diagnosed as a malignant melanoma. Other accounts of dogs pawing and sniffing at cancerous sites, and evidence that cancerous cells produce volatile chemicals (Williams & Pembroke, 1989; Pickel *et al.*, 2004 and references therein), has prompted research into the possibility of using dogs to detect some cancers. There is now scientific evidence that shows dogs can detect melanoma and bladder cancers. Recent studies have described dogs trained to detect the odour of melanoma cells and urine from patients with bladder cancer, with accuracy levels of 100% and 41% respectively (Pickel *et al.*, 2001; Pickel *et al.*, 2004; Willis *et al.*, 2004).

There are many accounts of dogs predicting the onset of their owners' epileptic seizures (Edney, 1991). A survey carried out by Edney (1993) described the behaviour of 37 dogs that respond to their owners' epileptic events. Of these dogs, 56.8% displayed characteristic behaviours prior to a seizure and 67.6% 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 or staying beside their owners. Preliminary studies have successfully trained dogs to alert their owners to impending epileptic attacks (Strong *et al.*, 1999; Brown & Strong, 2001). In these studies dogs were able to consistently indicate to their owners that a seizure was imminent, with warning times ranging from 10-45 minutes. It has been suggested that dogs are able to detect scents exuded by their owners during the 'aura' phase of epilepsy, and sense electrical disturbances and behavioural changes (Edney, 1993).

More than a third of diabetic dog owners have reported that their dogs react to their hypoglycaemic attacks (Lim *et al.*, 1992; cited in Chen *et al.*, 2000). A published account of three case studies has 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, preventing the owner from leaving the house and barking. All the dogs were described as only resuming normal behaviours once their owners had eaten food to correct blood glucose concentrations. Two of the dogs also woke their owners when they lapsed into hypoglycaemia during the night, something glucose sensors are unable to do (Chen *et al.*, 2000). The mechanisms by which dogs detect changes in their owners' blood glucose levels are unknown, but it is suspected that the dogs recognise olfactory changes in their owner attributed to increased sweating, possibly combined with muscle tremors and behavioural changes (Chen *et al.*, 2000).

2.2.2 Cows in oestrus

Dogs can identify dairy cows that are in the oestrus phase of their sexual cycle by the scent of a range of body fluids, including vaginal fluid, urine, milk and blood plasma, with accuracies ranging from 77.8% to 99% (Kiddy *et al.*, 1978; Kiddy *et al.*, 1984). Dogs can also discriminate between the milk of pre-oestrous, oestrous and dioestrous cows (Hawk *et al.*, 1984).

2.2.3 Snakes

Dogs have been trained to find snakes for containment and border control purposes. Jack Russell terriers are used in Guam to search outward-bound cargo for brown tree snakes (*Boiga irregularis*), an introduced species that has caused considerable damage to the island's native fauna. To reduce the chances of accidental introduction of this pest elsewhere, cargo destined to susceptible locations are inspected by detector dogs trained to find brown tree snakes (Engeman *et al.*, 1998a; Engeman *et al.*, 1998b). These snake-detection dogs have an average location rate of 62% (Engeman *et al.*, 2002).

2.2.4 Insects

Dogs can be trained to find egg masses of gypsy moths (*Porthetria dispar* (L.)) (Wallner & Ellis, 1976). Most egg masses are laid close to the ground in leaf litter or debris and are particularly hard to find when in low numbers (Wallner & Ellis, 1976). Two dogs were evaluated at searching for egg masses in 0.01 ha plots of varying gypsy moth population densities. The dogs had a combined average detection rate of 73.2%, and the results showed a strong correlation between one dog's number of indications and egg mass density. Based on this, the authors suggested there is potential for calibrating and using a dog to estimate egg mass density by the number located within a specific time period.

One study examined the feasibility of using a dog to detect screwworms (*Cochliomyia hominivorax*), an obligate parasite which can kill warm-blooded animals and cause significant economic losses (Welch, 1990). A dog was trained to detect both screwworm pupae and screwworm-infested wounds on animals. The dog had an extremely high success rate (99.7%) at finding them, both on training objects (with exudate from infected wounds applied to them) and infected animals. Dogs could be used at quarantine and inspection stations to help prevent further spread or reintroductions of unwanted organisms (Welch, 1990).

Trained detector dogs can also 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 the preliminary results of a program aimed at using dogs to detect the red palm weevil. Two dogs were trained to respond to the secretions of infested trees and produced very high success rates in initial tests.

Subterranean termite damage and control are estimated to cost up to US$2 billion per annum in the United States alone (Culliney & Grace, 2000). Infestations are often impossible to detect visually and can cause significant damage before they are discovered (Brooks *et al.*, 2003). Termite-detection dogs trained to identify eastern subterranean termites (*Reticulitermes flavipes* (Kollar)) can locate them 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 devices, the results showed the dogs correctly identified 98% of artificially set-up infestations while the electronic device did not have a statistically significant detection level (Lewis *et al.*, 1997). However, the dogs also produced 28% false identifications (where there was no infestation), although this may be attributable to training techniques, which were not discussed (as reviewed in Brooks *et al.*, 2003).

2.2.5 Microorganisms

Some cyanobacteria species in commercial catfish ponds produce odorous compounds which accumulate in the flesh of the fish, resulting in an unpleasant flavour (Shelby *et al.*, 2004). The costs of rejecting such fish from processors are estimated to range from

US$15-23 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 1 μg/L with 79-93% accuracy and 10 ng/L with 37-49% success. Dogs may provide a practical method of alerting to off-flavours and provide a reliable alternative to expensive chemical analysis or the more commonly used 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. Superficial detection of microbial growth is extremely difficult (Kauhanen *et al.*, 2002). Kauhanen *et al.* (2002) tested the efficacy of dogs trained to find rot fungi, "typical building moulds" and bacteria. They found their two study dogs were able to locate 75% of hidden microbial growth samples.

2.3 Detection Dogs used for Conservation Internationally

The hunting instinct of dogs and their olfactory abilities have been exploited to locate certain species for the purpose of conservation. Trained dogs are used to help locate and monitor a number of mammals and birds internationally. These dogs provide alternative and comparatively unobtrusive methods for researchers and conservationists to conduct their studies. Using dogs can offer safer methods of studying potentially dangerous species, reduce certain sample collection biases and decrease the time spent searching for animals.

2.3.1 Scats

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-detection dogs is becoming increasingly popular due to the problems inherent in traditional methods of acquiring data on threatened species.

Using dogs to find scats is a non-invasive method of studying rare animal populations, which can increase sample numbers while reducing collection bias (Wasser *et al.*, 2004).

Mark-recapture techniques and attaching radio-tracking devices, for example, are invasive and potentially harmful to the animals (Long *et al.*, 2002). 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 & 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 & 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 & Wayne, 1997).

2.3.2 Bears

Dogs are used to locate bears in North America for management of game populations and conservation purposes. Although some bear populations are protected due to low numbers they are considered game animals throughout much of their North American range, and research and management are carried out to ensure viable numbers are maintained and human-bear conflicts are kept to a minimum (Vander Heyden & Meslow, 1999; Fecske *et al.*, 2002).

Dogs can be trained to discriminate between black bear (*Ursus americanus*) and grizzly bear (*Ursus arctos horribilis*) scats (Hurt *et al.*, 2000). This cannot be done by visual inspection, so dogs reduce the need for laboratory tests to differentiate between the species.

A study by Wasser *et al.* (2004) described the use of scat-detection dogs to assess the impacts of human disturbances on black bear and grizzly bear populations in Alberta, Canada. The dogs were trained to locate bear scats along transects within a 5,200 km^2 area. DNA was extracted from the collected scats to identify species. Grizzly bear scats were then further analysed to determine individual identities, and faecal hormones were examined as indicators of physiological stress and reproductive activity. Hair sampling of both bear species, and global positioning system (GPS) radio-tracking of grizzly bears only, were carried out concurrently with the scat sampling to compare the methods. The distributions of the bears as determined by scat sampling generally corresponded to those determined by hair sampling and radio-tracking (Wasser *et al.*, 2004). 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 are used to estimate North American black bear population densities using dogs trained to locate bear scent along transect routes (Akenson *et al.*, 2001). Surveying black bear populations with dogs has several advantages. Dogs can detect bears at sites within their normal home ranges, unlike attractants such as bait stations, which can cause an animal to change their foraging patterns and locations (biasing data); and the bears can be safely 'recaptured' without any physical handling (Akenson *et al.*, 2001).

2.3.3 Foxes

Dogs have been trained to find the scats of endangered San Joaquin kit foxes (*Voles macrotis mutica*) in California, United States. Using the dogs is a more efficient method than using humans to find enough scat samples for demographic and population studies to be carried out (Smith *et al.*, 2003). The dogs can also find kit fox latrines (areas where one or more individuals repeatedly defecate) (Ralls & Smith, 2004). Trained dogs are able to find up to four times more kit fox scats along transects than an experienced person (Smith & Ralls, 2001). In a study evaluating dogs' proficiency at finding scats, even the dogs' worst detection rate in difficult scenting conditions was as good as that of humans (Smith *et al.*, 2003).

Dogs searching for kit fox scats must distinguish them from scats of species such as coyotes (*Canis latrans*), skunk (*Mephitis mephitis*) and badger (*Taxidea taxus*); and have been found to be 100% correct in their species identification (Smith & Ralls, 2001; Smith *et al.*, 2003). The extremely accurate species identification abilities of scat-detection dogs could save researchers thousands of dollars. The cost of extracting DNA from faecal samples and using laboratory methods to determine species can cost up to US$50 per sample (D. Smith, personal communication, 2004).

Initial results of a study comparing the use of scat-detection dogs and DNA analysis with radio tracking and monitoring of a population of San Joaquin kit foxes in California, suggest both methods produce very similar information (Smith *et al.*, 2002). Individual fox locations were determined by DNA analysis of scats found by dog and handler teams along transect lines, which were then compared to fox locations indicated by radio tracking (Smith *et al.*, 2002). If the results continue to be comparable, using scat-detection dogs could provide a less invasive and more cost-effective alternative to studying such populations.

2.3.4 Ferrets

The endangered black-footed ferret (*Mustela nigripes*) has been reintroduced to a number of sites in North America in an effort to save it from extinction (Reindl *et al.*, 2004). Reindl *et al.* (2004) examined the potential of using detection-dogs to monitor black-footed ferrets at the reintroduction sites. Surveys using traditional methods (spotlighting) were done prior to two dogs searching the study locations. The dogs correctly confirmed ferret presence or absence in 84% of the test areas. The study indicated that dogs might provide an efficient alternative to current monitoring methods such as spotlighting and snow-tracking.

2.3.5 Tigers

Biologists studying the endangered Amur tiger (*Panther tigris altaica*) (formally known as the Siberian tiger) in Russia use dogs to identify individual tigers. The dogs identify the tigers by smelling urine and scat samples collected from forests 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. By recording the locations where scat and urine samples were collected, population numbers, distribution, movement and home range sizes can be calculated using mark-recapture analysis (L. Kerley, personal communication, 2004). Tigers new to the area can also be identified by this method (L. Kerley, personal communication, 2004). Two dogs used in this project have proved to have accuracy rates of 89% and 96% (Kerley, 2003). The dogs have also been able to identify tigers from blood samples, although blood is not typically presented as a scent sample (L. Kerley, personal communication, 2004).

2.3.6 Seals

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 & Gjertz, 1986; Smith, 1987; Furgal *et al.*, 1996). Dogs were trained to locate subnivean lairs and breathing holes on the ice shelf by scent. Dogs can detect breathing holes or lairs at distances of over 1.5 km, in drifted snow up to 2 m deep, and winds of up to 46 km/hour (Smith, 1987).

2.3.7 Birds

Dogs traditionally used for hunting game birds are now frequently employed to help carry out studies on threatened bird species. Locating birds in order to study them has been made far easier with the assistance of dogs. Yellow Rails (*Coturnicops noveboracensis*) are classified as a vulnerable species in Quebec (Robert & 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 & Laporte, 1997).

Management programs of rare avian species have also benefited from dogs' innate behaviours. Border collies, for example, have been 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 the geese originally inhabited 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 only four days (Shute, 1990).

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 in the United States. They found the dogs were significantly more efficient at detecting avian carcasses than humans, finding twice as many, even at very low carcass densities.

2.4 Detection Dogs used for Conservation in New Zealand

Although there is little published literature on conservation dogs being used in New Zealand, dogs have helped to locate and capture threatened species here since the 1800s.

The earliest use of dogs for conservation purposes in New Zealand is believed to be by Richard Henry, the first custodian of Resolution Island reserve in Fiordland. In the 1890s he used dogs to locate and capture kiwi (*Apteryx* spp.) and kakapo (*Strigops habroptilus*) on the mainland, and moved them to Resolution Island to protect them from introduced mammalian predators (Hill & Hill, 1987). Henry claimed that one of his dogs could detect kakapo scent from over 400 m away, and that the dog was so accurate it would find practically all the birds in an area during its first search (Hill & Hill, 1987).

The New Zealand Wildlife Service (now incorporated into DoC) used dogs in conservation programs to find kiwi, takahe, waterfowl and upland game-birds (Clegg, 1995). Kakapo conservation work continued to utilise dogs from the 1950s through to the 1980s (Reid, 1969; Merton, 1975; Best, 1979; 1980). Kakapo-detection dogs were considered to be essential tools for finding the critically endangered birds, and the dogs' skill at locating kakapo was cited as responsible for "a dramatic change in the fortunes of the [kakapo] program" (Best, 1980, p. 33).

Dogs now play a far wider role in New Zealand conservation (Browne & Stafford, 2003). There are two formal branches of conservation dogs: 'protected species dogs' and 'predator control dogs'. Protected species dogs are used to track, locate and capture protected native species in their natural environment (Table 2.1). Predator dogs are used in a similar capacity to search for introduced pest species (Table 2.1).

Table 2.1: Protected native species and introduced pest species that conservation dogs (protected species dogs and predator dogs) have been trained to locate.*

Protected species dogs' target species	Predator dogs' target species
Wood rose (*Dactylanthus taylorii*)	Possum (*Trichosurus vulpecula*)
Tuatara (*Sphenodon* spp.)	Wallaby (Diprotodontia) [+]
Gecko (*Naultinus* spp. and *Hoplodactylus* spp.)	Rat (*Rattus* spp.)
Skink (*Oligosoma* spp. and *Cyclodina* spp.)	Mouse (*Mus musculus*)
Kiwi (*Apteryx* spp.)	Cat (*Felis catus*)
Petrel (taiko) (*Pterodrama magentae*)	Mustelid (*Mustela* spp.)
Blue duck (*Hymenolaimus malacorhynchos*)	Deer (*Cervus* spp.) [+]
Brown teal (*Anas chlorotis*)	Goat (*Capra hircus*) [+]
Campbell Island teal (*Anas aucklandica nesiotis*)	Pig (*Sus scrofa*) [+]
Takahe (*Porphyrio mantelli*)	
Weka (*Gallirallus australis*)	
Snipe (*Coenocorypha aucklandica*)	
Black-fronted tern (*Sterna albostriata*)	
Kakapo (*Strigops habroptilus*)	

* J. Cheyne, personal communication, 2002.

[+] These pest species are not officially part of the predator dog program, although 'wild animal control dogs' are used to locate them.

2.4.1 Protected species dogs

Protected species dogs are used to locate a wide range of species, and have contributed significantly to the conservation of some New Zealand animals. Reliable kiwi-detection dogs, for example, are considered to be essential to kiwi field research because the birds are so difficult to locate (Colbourne, 1992). Dogs are used during the day when the birds are sleeping in underground burrows or dense vegetation, and at night while they are actively foraging (Colbourne, 1992; McLennan & Potter, 1993).

Conservation dogs can significantly reduce the amount of time spent searching for a target species. For example, there is one dog in New Zealand trained to detect the endangered wood rose, the world's only terrestrial bat-pollinated flower (Daugherty *et al.*, 1993). The handler of this dog states that by using the dog, time spent searching for the plant is reduced from up to one hour to a maximum of 10 minutes per plant (G. Atkins, personal communication, 2002).

Many protected species management programs in New Zealand would have been impractical and very difficult to implement without using dogs (Browne & Stafford, 2003). The co-ordinator of the Department of Conservation's National Conservation Dog Program, John Cheyne, has many years experience working with conservation dogs. He believes "kakapo may well be extinct by now if it wasn't for the use of trained dogs in locating them. Kiwi conservation is probably 20 years advanced because of the use of dogs" (personal communication, 2002).

2.4.2 Predator dogs

Predator dogs contribute to the conservation of New Zealand species through helping to reduce the impacts of introduced pests. Dogs can be particularly useful in eradicating surviving individuals after other methods (i.e. aerial poisoning) have reduced predator populations to low numbers (Cowan, 1992; Caley & Ottley, 1995).

Wild animal control dogs are used to locate a number of pest species that are outside the scope of the predator dog program (Table 2.1).

2.5 Studies with Similar Methods

Many studies have aimed to quantify dogs' olfactory discriminatory abilities. This section examines the methodology of research that has tested the ability of dogs in experimental situations.

2.5.1 Detection dogs for non-biological scents

Accelerants

A series of experiments by Kurz *et al.* (1994) compared the ability of dogs to detect accelerants with traditional laboratory techniques. They used two Labradors trained by

Police, which received regular training, testing and annual recertification. Measured amounts of potential accelerants (gasoline, kerosene and isopars) were added to continuous linear strips of burned and unburned carpet and wood. The dogs were led along the strips at least three times and indicated by sitting when they detected an accelerant.

Tindall & Lothridge (1995) also evaluated canine accelerant detection teams. They tested a total of 39 dogs, 39 handlers and 10 trainers in a series of tests designed to examine different aspects of accelerant detection. The dogs were required to indicate the location of various types and amounts of accelerants placed inside lines of five to 10 cans or on pieces of wood. The dogs had to make their selection from amongst common pyrolysis products and/or controls.

Kurz *et al.* (1996) ran a series of experiments to examine the effects of background interference on the accelerant detection abilities of both dogs and laboratory techn..,
They used 34 trained accelerant detection dogs from all over the United States; and followed an experimental protocol very similar that used by Tindall & Lothridge (1995).

2.5.2 Detection dogs for biological scents

Humans

Kalmus (1955) investigated the ability of dogs to discriminate human odours, in particular, identical twins. Part of the study involved retrieval exercises, in which two Alsatian bitches trained for 'show' purposes were used. The methods were similar to the standard show protocol. A dog was presented with a line of several handkerchiefs, one of which contained the armpit odour of a specific person. That person then held the dog's muzzle with their hands, and the dog was told to retrieve the matching handkerchief. In the initial tests, the dogs were required to identify the correct handkerchief from amongst other handkerchiefs containing no scent, or the armpit scent of other people. The experiments involving twins were performed in a similar fashion, and the dogs were ultimately required to locate a handkerchief containing the odour of a specific twin from amongst handkerchiefs scented by the second twin and members of the twins' immediate family.

A study by Brisbin & Austad (1991) tried to evaluate the ability of dogs to identify individual human odours. They used three dogs that were trained to distinguish human scent. The dogs had all reached the American Kennel Club's (AKC) 'utility dog' level of competence. This title generally requires at least six months to one year of training. They were all trained and handled by the same person. Brisbin and Austad's methods followed a protocol similar to the AKC competitive scent discrimination task. This exercise involves 10 'scent articles' (five made of leather, five metal) presented to a dog in a straight line. The dog is required to retrieve the one leather and the one metal article scented from the palm of its handler's hand (the other eight articles being scented from the palm of the judge's hand).

The ability of Dutch police dogs to match scents from different parts of the human body was investigated by Schoon & De Bruin (1994). Six Dutch police dogs were used, varying in age and sex, although all were shepherd breeds (German, Malinois, or mixed). The dogs were trained to perform scent discrimination tasks and certified as human scent tracking dogs. The experimental procedure involved volunteers holding stainless steel tubes in either their hands, crooks of elbows, or pockets, to impart their scent to the tubes. The dogs were given a tube to smell, scented by a specific person, which they then had to match to one of six tubes laid in a row inside the training room, one of which was scented by the same person although not necessarily from the same part of their body.

Settle *et al.* (1994) attempted to quantify the success rates of dogs identifying human scent under similar working conditions to those of police dogs in Germany and the Netherlands. They used male handlers and dogs from a police dog training school as their subjects. The dogs were trained prior to and during the testing period. All trials were performed in an indoor training room at the school. Scent samples from over 700 individuals were collected on small cotton cloths. In the first series of experiments, seven dogs were presented with a cloth containing their target odour and were required to match it to another cloth scented by the same person, from amongst five cloths scented by other people. In the second group of trials, three dogs were asked to match a cloth scented by various parts of the body to a steel tube containing that same person's hand scent, from amongst five tubes containing other people's hand scent.

Schoon (1996) performed a series of experiments evaluating the design of four different scent discrimination tasks. Eight shepherd dogs (German, Malinois, Dutch and cross-breeds) of varying age and sex were used. All of the dogs had been trained to meet Dutch police human scent tracking standards. The experiments were carried out over an eight-month period, with each dog performing a maximum of two experiments per test-day. They were conducted at sites familiar to the dogs (outdoor and indoor areas) under normal working conditions. Volunteers held stainless steel tubes in their hands to collect scent. Up to 14 tubes were laid on the ground in two rows. The dogs were given a 'sample tube' to smell and were then required to retrieve the matching tube from amongst other scented tubes.

Another scent discrimination study by Schoon (1997) followed an odd-even paradigm. Four Malinois shepherds were used; three were without scent training prior to the study and one was a certified police dog. All the dogs were trained for the purposes of this experiment over approximately one year. Training and experiments were conducted in an indoor area that was cleaned regularly. The dogs were given human scent on either a stainless steel tube or another object. They were trained to approach a platform where two tubes were fixed (controlled by a hidden observer); one tube had an odour, and the other was blank. An 'even' trial was when the two scents matched, and the dogs were trained to respond to this by retrieving the scented tube. An 'odd' trial was when the two scents did not match, and the dogs were then required to retrieve the blank tube instead, ignoring the scented one. If they attempted to make an incorrect selection, the observer did not release the tubes, not allowing the dogs to pick up the tubes (which was a form of reward).

Medical conditions

Pickel *et al.* (2004) used two dogs to identify melanoma tissue samples. One dog was a trained police dog and certified for bomb detection work, and both dogs held multiple AKC obedience and utility titles. The dogs were initially trained to identify the scent of melanoma tissues. The testing began once the dogs' proficiency in the training exercises was judged to be "near perfect". In the first series of tests, a melanoma tissue sample was placed in one part of a long 'scent box' divided into 10 distinct compartments. Zero or one to nine of the other compartments held objects that a dog would commonly encounter in a medical setting (e.g. gauze, latex gloves, etc.). The dogs were led along the box and were required to locate the melanoma sample. The second series of tests involved both dogs inspecting human beings. Healthy volunteers had variable numbers of adhesive bandages attached to their bodies, one of which contained a melanoma tissue sample. The dogs were encouraged to inspect each bandage and indicate the presence of the melanoma tissue. The third and final test used actual patients with suspected melanoma. Numerous adhesive bandages were placed on the patients' skin, including over the area suspected to be cancerous. The dogs searched the patients for melanoma tissue.

Willis *et al.* (2004) examined dogs' ability to detect human bladder cancer. Six dogs were trained for seven months to discriminate urine from patients with bladder cancer from non-cancerous urine samples. None of the dogs had previous scent training experience. The dogs were evaluated on their ability to discriminate between urine samples on filter paper in Petri dishes. One sample was from a patient with bladder cancer, the six remaining samples were from healthy controls.

Cows in oestrus

Hawk *et al.* (1984) trained dogs to discriminate between oestrous-related odours in cows' milk. Nine milk samples were adsorbed onto cottons balls, placed in perforated containers and arranged into a line along the ground. Two to six dogs were used in several experiments. The dogs were led along the line and required to indicate the location of the target odour.

Kiddy *et al.* (1978; 1984) also used dogs to detect oestrus-related odours. They used four and six dogs respectively, to discriminate between a variety of body fluid samples taken from cows in oestrus and dioestrus. The dogs were required to discriminate between samples in methods very similar to those used in the study by Hawk *et al.* (1984).

Insects

Brooks *et al.* (2003) studied the ability of dogs to detect live termites in several different scenarios. Experienced dog trainers taught six dogs (one German shepherd and five beagles) to locate eastern subterranean termites. The testing was carried out over several months, and twice-daily training sessions were maintained throughout this period. A line of five PVC containers was set up on the ground, and the dogs were required to indicate the presence of termites in one or more of the containers by digging, or to display no response in the absence of the termites.

Microorganisms

The possibility of using dogs to detect off-flavour compounds in commercial catfish ponds was investigated by Shelby *et al.* (2004). Six dogs were trained daily for six months, and three dogs were subsequently selected for evaluation. The dogs were presented with a line of five boxes, each holding a sample of pond water. The dogs were trained to sit beside the one sample that contained the off-flavour compounds.

2.5.3 Detection dogs used for conservation internationally

Bears

The ability of trained dogs to distinguish between grizzly bear and black bear scats was tested in an artificial environment by Hurt *et al.* (2000). Three dogs were used, two of which had completed part of a narcotics-detection training program, the other had no prior scent training. The training and testing was carried out in indoor facilities, using a scent box with distinct compartments, each containing a scent. The dogs were trained to sniff the compartments and identify grizzly bear scats. They were tested on their ability to locate one grizzly bear scat from amongst four black bear scats, and to give no response when presented with five black bear scats only.

Foxes

Smith *et al.* (2003) performed a simple scent discrimination experiment as part of a larger study examining the detection and accuracy rates of dogs trained to find endangered San Joaquin kit fox scats. Four dogs of different breeds were trained to identify kit fox scats (one had also previously been trained to detect kit fox scats in the field). The trials were all conducted at a dog training facility, using a scent box with a series of compartments containing odours. In each trial the scent box contained either one kit fox scat and four red fox (*Vulpes vulpes*) scats, or five red fox scats. The dogs were tested to see if they could discriminate between red and kit fox scats, and if they could ignore red fox scats in the absence of kit fox scats. The dogs were trained to sit beside the kit fox scat once they had located it.

Tigers

Kerley (2003) examined the accuracy of two dogs trained to identify individual Amur tigers. The dogs were tested over a period of 12 days in an indoor facility. Tiger scats collected from the forest were placed into jars. The dogs were required to sniff the scats contained in a 'start' jar and then proceed to sniffing a circle of jars. They were trained to then sit in front of the jar that contained the same tiger scent as the start jar.

2.5.4 Detection dogs used for conservation in New Zealand

No other studies have assessed the ability of New Zealand conservation dogs in an experimental situation.

CHAPTER 3

THE ABILITY OF DOGS TO DETECT TUATARA SCENT

A tuatara (*Sphenodon punctatus*) in the forest on Stephens Island, New Zealand. Photo: Dr Paddy Ryan.

3.1 Introduction

Tuatara (*Sphenodon* spp.) are endemic New Zealand reptiles, and the sole extant members of the order Sphenodontia (Daugherty *et al.*, 1993). Sphenodontids were once widely distributed, and fossil remains have been found in Africa, Europe and North America (Cree & Butler, 1993). Many species of Sphenodontids existed alongside dinosaurs, but all except the tuatara became extinct approximately 60 million years ago (Gaze, 2001). As the only surviving Sphenodontids, tuatara are considered to be of "exceptional international importance to the evolutionary history of reptiles" (Cree & Butler, 1993, p. 1).

Two species of tuatara are currently recognised, one of which comprises two subspecies. Northern tuatara (*Sphenodon punctatus punctatus*) inhabits offshore islands from the Bay of Plenty northwards; Cook Strait tuatara (*S. punctatus*) populates Stephens Island and the Trio Islands in the Marlborough Sounds; and Brothers Island tuatara (*S. guntheri*) is found only on the tiny (4 ha) Brothers Island in the Marlborough Sounds (Daugherty *et al.*, 1990a; Gaze, 2001; Hay *et al.*, 2003). Most of the research on tuatara has been carried out on the Stephens Island population.

3.1.1 Tuatara biology

Tuatara are New Zealand's largest terrestrial reptiles, with adults ranging in snout-vent length (SVL) from 170-250 mm and weighing 300-1,000 g (Cree, 1994; Gaze, 2001). They have a variety of colourations including brown, black, green, pink or rust with patterning (Thompson *et al.*, 1992). Adult males are larger and have bigger crest spines than adult females, and females have a more 'pear-shaped' abdomen (Cree *et al.*, 1995).

Superficially, tuatara appear similar to their sister taxon, squamates (Thompson & Daugherty, 1998). They have analogous functional adaptations and exhibit behaviours similar to squamates in certain social contexts (Gillingham *et al.*, 1995). Despite this, there are several features that distinguish Sphenodontids from all other reptiles including a unique dentition and specialised jaw movement, a diapsid skull, uncinate processes on the ribs and the absence of a male copulatory organ (Cree & Butler, 1993).

Tuatara have been described as cryophilic reptiles (Thompson & Daugherty, 1998). They remain active with body temperatures as low as 5.2 °C when most lizards would be inactive (Thompson & Daugherty, 1998), and body temperatures as high as 27.2 °C have been recorded (Cree, 1994). Although primarily nocturnal (Cree *et al.*, 1995), tuatara bask in sunlight during the day (Walls, 1983; Cree, 1994). Tuatara are less active during cold months but emerge from their burrows on warm winter evenings (Walls, 1981), and are more conspicuous during damp weather (Walls, 1983).

Tuatara live in underground burrows, which are usually dug by seabirds, although they also dig their own burrows (Cree & Butler, 1993; Ussher, 1999). Males on Stephens Island defend territories which average 15.7 m^2 in the forest and 86.7 m^2 in paddocks, and females occupy home ranges about half this size (defending only a small area of about 2 m radius around their burrows) (Gillingham *et al.*, 1995). Newman (1987) found the distances between recaptures of adult Stephens Island tuatara over a number of years were a maximum of 10.8 m (cited in Cree *et al.*, 1995), indicating high site fidelity.

The upper limits of tuatara longevity are yet to be determined (Cree, 1994) but they are believed to live for more than 70 years (Daugherty *et al.*, 1993). Tuatara reach sexual maturity at approximately 11-13 years (Castanet *et al.*, 1988; cited in Cree, 1994) and females can still be reproductively active at 55 years (Newman *et al.*, 1994). Tuatara do not reproduce annually. Although females can breed every second year (Newman *et al.*, 1994), they have an average nesting rate of about once every four to five years (Cree, 1994). Females nest in open areas that have higher soil temperatures than under a forest canopy, laying an average of 8.6 eggs in underground tunnels (Thompson *et al.*, 1996). Competition for nest sites has been observed on Stephens Island. Aggressive interactions sometimes result in tail loss, and females will often excavate another female's eggs while digging their own nest (Nelson *et al.*, 2004). Temperature-dependent sex determination has been established in tuatara. The pivotal temperature is between 21 and 22 °C, with a bias towards females produced in eggs artificially incubated at 18 and 21 °C, and towards males at 22 °C (Nelson *et al.*, 2004).

Tuatara are opportunistic foragers, feeding on invertebrates (mainly beetles), other reptiles (including juvenile tuatara), seabird eggs and chicks and carrion (Walls, 1981;

Gaston & Scofield, 1995). Walls (1981) established that movement was important in evoking a predatory response in tuatara. However, there are data that suggest tuatara do respond to chemical cues. Tuatara feed on motionless items (e.g. eggs and carrion), and selectively bite in reaction to prey chemicals (Walls, 1981; Cooper *et al.*, 2001). The vomeronasal chambers in tuatara do not open via ducts into the oral cavity as they do in squamates (Parson, 1970; cited in Gillingham *et al.*, 1995), and they have a lower density of vomeronasal chemoreceptor cells (Gabe & Saint Girons, 1976; cited in Cooper *et al.*, 2001). This, and the fact that tuatara have not been observed to use tongue-flicking as a means of mediating feeding or social behaviour, suggests that vomerolfaction is not essential in chemical discrimination for tuatara (Gillingham *et al.*, 1995; Cooper *et al.*, 2001). Olfaction has been proposed as the most likely sense involved in tuatara chemoreception (Walls, 1981; Cooper *et al.*, 2001).

Evolving in isolation from mammalian predators (Daugherty *et al.*, 1994), tuatara have few natural predators. The Australasian harrier (*Circus approximans*), New Zealand falcon (*Falco novaeseelandiae*), kingfisher (*Halcyon sancta vagans*) and possibly the Southern black-backed gull (*Larus dominicanus*) and morepork (*Ninox novaeseelandiae*) will feed on tuatara (Cree & Butler, 1993; Gaze, 2001). The extinct adzebill (*Aptornis otidiformis*) and New Zealand raven (*Corvus antipodum*) may also have preyed on tuatara (Holdaway, 1989; cited in Cree & Butler, 1993).

3.1.2 Current status of tuatara in New Zealand

Tuatara were originally distributed over most of New Zealand (Newman, 1877; Cree & Butler, 1993) but are now absent from the mainland and only remain on 36 islands off the coast of New Zealand. The two species currently inhabit 0.5% or less of the geographic range they occupied prior to human arrival (Cree & Butler, 1993). Although tuatara have been fully protected by New Zealand legislation since 1895, 25% of the known populations have become extinct in the past 100 years (Daugherty *et al.*, 1990a). Cree & Butler (1993) predicted that if those trends persisted, 12-23% of the remaining populations were likely to die out within the next 50 years.

Extinction of tuatara on mainland New Zealand was primarily caused by the arrival of humans, the introduction of predatory mammals and habitat modification (Cree *et al.*, 1995). Introduced rats, Norway rats (*Rattus norvegicus*), ship rats (*Rattus rattus*) and Polynesian rats or kiore (*Rattus exulans*) in particular, are thought to have had a detrimental impact on tuatara survival (Newman, 1988; Cree & Butler, 1993; Cree *et al.*, 1995). The small size of most of the islands that hold tuatara means that the potential risks to these populations posed by the introduction of predators, habitat destruction (e.g. by fire) and poaching are amplified (Cree & Butler, 1993).

The New Zealand Department of Conservation produces 'recovery plans' that compile the research carried out on threatened species and develop long-term management strategies aimed at halting and reversing the species' decline. The most recent tuatara recovery plan produced by DoC estimated the northern tuatara populations total at approximately 10,000 animals; the Cook Strait populations 45,000; and Brothers Island 400 individuals (Gaze, 2001). The New Zealand Threat Classification System produced by DoC categorises taxa according to the level of threat of extinction they face (Molloy *et al.*, 2002). Within this classification system, northern tuatara are described as 'sparse', Cook Strait tuatara as 'range restricted' and Brothers Island tuatara as 'nationally endangered' (Hitchmough, 2002). The International Union for Conservation of Nature and Natural Resources (IUCN) 2003 Red List describes *S. punctatus* as 'low risk' (grouping the northern and Cook Strait subspecies together) and Brothers Island tuatara as 'vulnerable' (IUCN, 2003).

3.1.3 Management of tuatara

The Department of Conservation's long-term goal for tuatara is to maintain genetic diversity by restoring existing populations to their natural levels and establishing new populations throughout the pre-human range of tuatara (Gaze, 2001). Raising public awareness of tuatara conservation is also an objective. A number of 'actions' have been outlined by DoC to help affect this, including monitoring trends in tuatara populations and surveying islands that may hold currently unknown relict populations (Gaze, 2001).

To date, most research on tuatara has used simple observations along transects or catch per unit effort methods (i.e. the number of tuatara captured per person per hour searching) to capture and monitor tuatara and to provide crude indices of relative abundance (Walls, 1983; Thompson *et al.*, 1992; Newman *et al.*, 1994; Cree *et al.*, 1995; Hay *et al.*, 2003). These methods have inherent problems that account for many undetected individuals, particularly juveniles. These problems include the cryptic behaviour of tuatara, the difficulty of accessing their habitat and the learned avoidance of spotlights (Walls, 1983; Cree *et al.*, 1995; Nelson *et al.*, 2002). Also, due to their burrowing nature, only the proportion of tuatara above ground will be available for visual sampling methods (Cassey & Ussher, 1999). Systematically searching burrows for occupant tuatara is time consuming and can destroy their habitat (Cassey & Ussher, 1999).

The tuatara recovery plan has identified the need to establish practical alternative methods to census tuatara and monitor populations (Gaze, 2001). The use of dogs trained to detect tuatara may provide an alternative method. The powerful olfactory abilities of dogs could be a distinct advantage when searching for a burrowing, nocturnal, cryptic species such as tuatara. By relying on olfaction rather than visual cues dogs are more likely to find hidden individuals. Dogs can access habitat that humans cannot. Dogs could search burrows without causing damage or significantly disturbing occupants, thereby all members of a population potentially become available for sampling. By exploiting dogs' advanced sense of smell, tuatara populations could potentially be surveyed more effectively and more efficiently.

Dogs have potential to be significant tuatara conservation tools. This study aims to investigate whether dogs can detect tuatara scent in a variety of situations.

3.2 Methods

A number of dogs from a local dog-training club were used for this study. The dogs had been trained to perform scent discrimination exercises for competitive obedience work, and the experimental design of this study closely followed the protocol of these exercises. Seven trials were held, each with a different target scent the dogs were required to identify. The target scent in the first two trials was human scent, and the remaining five trials used tuatara (*S. punctatus*) scent.

3.2.1 Dogs

Purchasing and training a large number of dogs for this research would have been too time-consuming and was not financially feasible. Instead, the study subjects were sourced from a local dog-training club, the Tararua Allbreeds Dog Training Club (TADTC). Members of the club train their dogs for competitive obedience work, which can include scent discrimination tests where the dogs are required to find specific scents. Such competitive scent work is standardised across New Zealand according to the New Zealand Kennel Club (NZKC) Dog Training Regulations (New Zealand Kennel Club (Inc.), 2005); therefore dogs from any NZKC approved competitive obedience dog club in New Zealand trained to perform scent exercises, are trained according to the same standard protocol.

Eight handlers with nine dogs from the club voluntarily participated in the study (Table 3.1). The dogs differed in breed, sex, age and their previous level of training. The NZKC has an ability-based ranking system for their competitive obedience work, with categories 'special beginners', 'novice', 'test A', 'test B' and 'test C', in order of increasing competence (requirements to meet these categories are described in New Zealand Kennel Club (Inc.), 2005). Most of the dogs used in this study were at the novice level of obedience training. Dogs are not required to compete in scent discrimination exercises until they reach the test A category, so many of the dogs in this study were trained beyond novice level, some specifically for this research. None of the dogs was trained solely for scent discrimination.

Table 3.1: The dogs that participated in this study from the Tararua Allbreeds Dog Training Club. The dogs received various levels of obedience training, including scent discrimination training, prior to this study.

Dog	Breed	Sex	Age (years)	Level of training*	Scent training prior to study	Scents used in prior training
1	Labrador retriever	Bitch	2	Novice	3 days	Human, horse, bull, possum, rabbit, cockatoo
2	Rottweiler	Dog	10	Test B	7-8 years	Human
3	Kelpie / border collie x	Dog	4	Test B	2 years	Human
4+	German shepherd	Bitch	2.5	Novice	6 months	Human
5	Labrador retriever	Spayed Bitch	4	Novice	3 days	Human, horse, bull, possum, rabbit, cockatoo
6	Labrador retriever	Neutered Dog	10	Test B	5 years	Human, horse, bull, possum, rabbit, cockatoo
7	Golden retriever	Bitch	8.75	Novice	3 weeks	Human
8+	German shepherd / Staffordshire terrier x	Spayed Bitch	6	Novice	8 months	Human
9	Dalmatian	Bitch	6	Novice	2 weeks	Human

* The level of obedience training the dogs received prior to the start of this study. The New Zealand Kennel Club categories include 'special beginners', 'novice', 'test A', 'test B' and 'test C', in order of increasing competence.

+ The same handler owned both of these dogs.

3.2.2 Study location

Most of the trials were conducted under normal obedience training and working conditions for the handlers and dogs at the club's training grounds located in Longburn, 2.5 km south west of Palmerston North, New Zealand. The training grounds consisted of two asphalt areas, each 36 × 42 m and enclosed by 1.7 m high wire mesh fencing (Figure 3.1). Floodlights were used to light the grounds at night during winter months.

Figure 3.1: Tararua Allbreeds Dog Training Club grounds. Photo: Clare Browne.

For the convenience of the dog handlers the scent exercises were held once a week on the same night as the club met, after the general obedience classes had finished. A range of dog obedience classes was taught at the club, and approximately 30 dogs trained on the grounds each week before the exercises. When handlers missed club sessions and had several scent exercises to catch up on, some exercises were conducted at the handlers' homes.

3.2.3 Experimental protocol

Preparation of equipment

Two hundred cloths were prepared in accordance with the NZKC specifications for scent discrimination cloths (New Zealand Kennel Club (Inc.), 2005). The cloths were 18 × 18 cm, and made from four different coloured cotton sheets (pink, beige, blue and dark grey). After each use the cloths were washed in a washing machine, without detergent, to remove any debris, and then wrapped in small tin foil pouches and sterilised in an autoclave at 117 °C for 20 minutes. Disposable latex gloves were used to handle all cloths after they had been autoclaved. The cloths were hung on a line using sterilised pegs, and dried in direct sunlight whenever possible.

'Neutral' cloths (sterile cloths not impregnated with scent) were stored in airtight Glad Snaplock® plastic bags until their use. 'Target' and 'decoy' cloths (cloths impregnated with scent) were prepared with one of three sources of tuatara scent: scats, sloughed skins or paper towels that captive tuatara had been sitting on for several days within their enclosures (Figure 3.2). (If the tuatara had urinated, defecated or shed any skin while sitting on the paper towels, the towels may have contained not only the scent of gland secretions, but the scent of urine, scats and skins as well.) Target and decoy cloths were prepared by placing either one tuatara scat (average length = 1.4 cm), a piece of tuatara skin (sections of what had been a nearly entire sloughed skin, average size = 10 cm^2) or one paper towel (21 × 23 cm) between two sterile cloths. The cloths were folded around the item and sealed in a jar for 48 hours prior to the scent exercises. Due to limited supplies of tuatara skin, the pieces had to be re-used on at least three occasions. The jars (container LBS33558, LabServ, Biolab Ltd., Auckland, New Zealand) were 500 mL

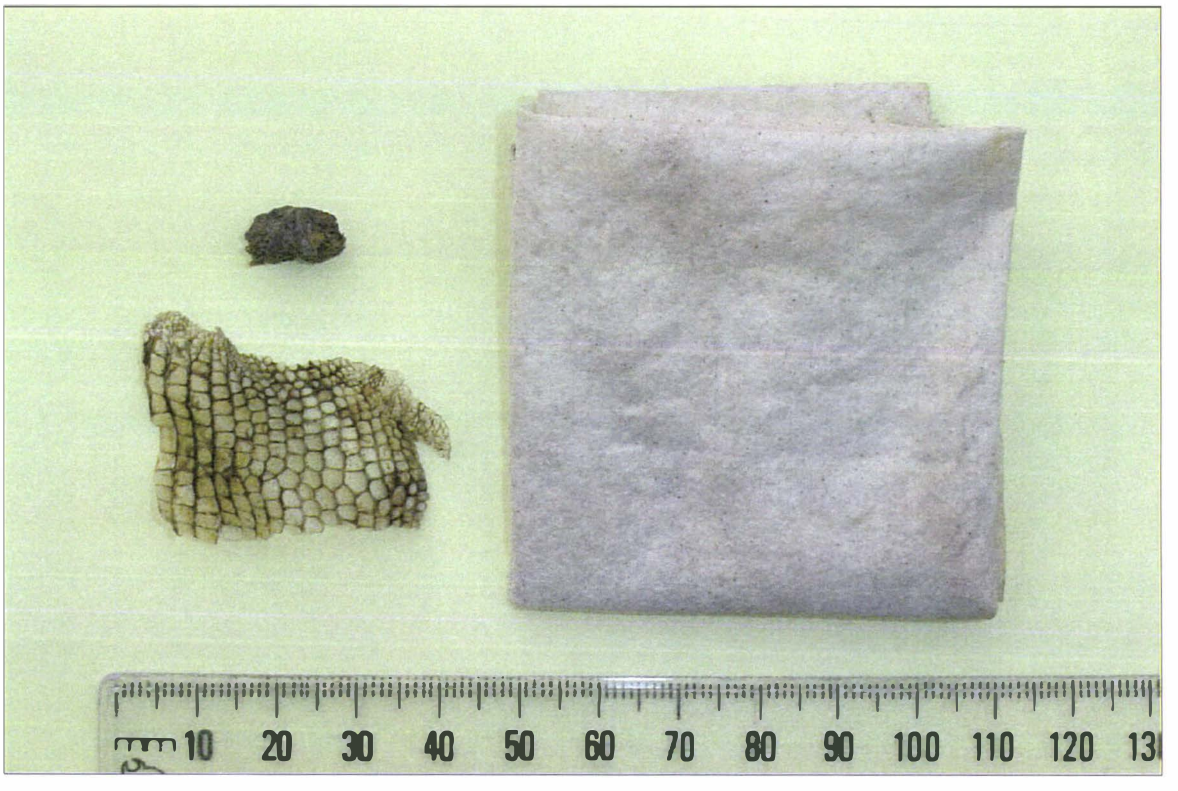

Figure 3.2: Examples of the tuatara samples used to scent target and decoy cloths. A tuatara scat is on the upper left, a piece of tuatara skin is on the lower left, and a tuatara-scented paper towel (folded) is on the right. Photo: Clare Browne.

capacity, made of polycarbonate with polypropylene screw caps. Each jar and lid was sterilised in boiling water for up to one minute before use, and was used only once. Immediately prior to the scent exercises, the tuatara sample was removed and the cloths resealed in the jar ready for use. Latex gloves were used to handle the cloths and jars during their preparation and cleaning. Metal tongs were used to handle all cloths during the scent exercises and these were autoclaved after each use. Tuatara samples were received from Victoria University of Wellington, Wellington; Nga Manu Nature Reserve, Waikanae; and Wellington Zoo, Wellington. Each person who collected a sample completed a form stating the species of the animal from which the sample came, the animal's sex, the date and time of collection, a brief description of the animal's habitat and diet and the estimated age of the sample. Most of the samples were received from Nga Manu Nature Reserve, so in order to use samples from the same tuatara population (and therefore the same diet and environment) for each dog, only these samples were used (see Appendix 4 for information regarding these samples). The tuatara samples were handled with latex gloves or sterile metal forceps. The samples were kept at -20 °C from the date they were received until they were required for use, when they were defrosted at room temperature. Freezing the samples follows the methodology of similar studies (Hawk *et al.*, 1984; Kiddy *et al.*, 1984; Hurt *et al.*, 2000; Pickel *et al.*, 2004; Willis *et al.*, 2004).

Small rocks were used to hold the cloths in place during the scent exercises. These rocks were sterilised in boiling water for up to one minute and dried in direct sunlight when possible.

Protocol of the scent exercises

Scent exercises were based on NZKC scent discrimination tasks (as outlined in New Zealand Kennel Club (Inc.), 2005) that the study dogs were familiar with, the main exception being that no time limit was imposed on the dogs. A straight line of eight cloths was placed on the ground. The cloths were 0.6-1 m apart, and each held in position by a rock. In the simplest exercise, seven neutral cloths were placed on the ground. The eighth cloth was taken from a sealed jar containing two target cloths. One of the target cloths was given to the dog's handler, who positioned themselves and their dog facing away from the line of cloths, while an observer placed the second target cloth in the line amongst the neutral cloths. The handler and dog were then allowed to turn and face the line of cloths and the dog was encouraged to smell and/or taste the target cloth (Figure 3.3). The handler gave the dog the command to go and identify the matching target cloth from the line of cloths. It did this by sniffing along the line of cloths (Figure 3.4), retrieving the target cloth (Figure 3.5) and presenting it to their handler (Figure 3.6). The handlers were asked not to give any verbal commands to the dog that could indicate the location of the target cloth. The results of the exercise and behaviour of the dog were recorded.

Decoy cloths were also added in some exercises. These cloths were impregnated with a different tuatara scent to the target cloths. The decoy cloths were placed in the line of neutral cloths as an added distraction for the dogs and to ensure that the dogs were not selecting the one cloth in the line that smelt different to the other neutral cloths.

After each dog completed a scent exercise the target cloths were replaced. The neutral and decoy cloths were also replaced if a dog had mouthed (picked up, bitten or licked) them. To minimise distraction from other scents, where possible the lines were set up in areas where the least number of dogs had been training in the obedience classes held beforehand. If a dog urinated or defecated on or near the scent area, the line of cloths was moved at least 2 m away to avoid distracting successive dogs.

Three lines of cloths were set up each evening the club met and all dogs performed one scent exercise at each of the three lines. Two volunteers, usually post-graduate and under-graduate Zoology and Ecology students from Massey University, Palmerston North, assisted each week, so there was one observer stationed at each line of cloths. Each person helped for a minimum of one complete scent trial. The observers carefully watched and recorded the behaviour of the dogs and handlers during the exercises, noting if the dogs 'succeeded' or 'failed' the events. The handlers were asked to tell the observers if their dogs were unwell or on medication, and this information was documented in case it influenced the results. The weather conditions (e.g. temperature, rain and wind) were also noted because of the effect they can have on scent dispersal (Gutzwiller, 1990; Harvey & Harvey, 2003; Lasseter *et al.*, 2003; Wasser *et al.*, 2004).

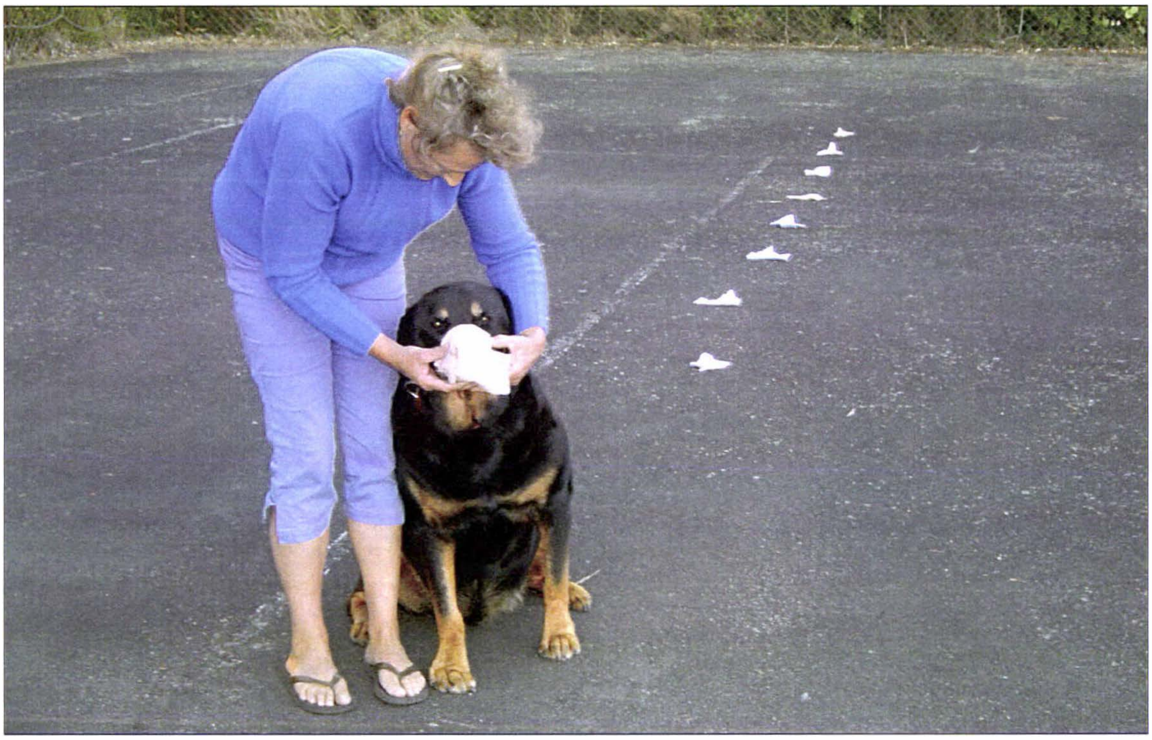

Figure 3.3: Dog 2 being encouraged to smell one of a pair of target cloths. The second target cloth has been placed in the line. Photo: Clare Browne.

Figure 3.4: Dog 5 sniffing along the line of cloths, searching for the target cloth. Photo: Clare Browne.

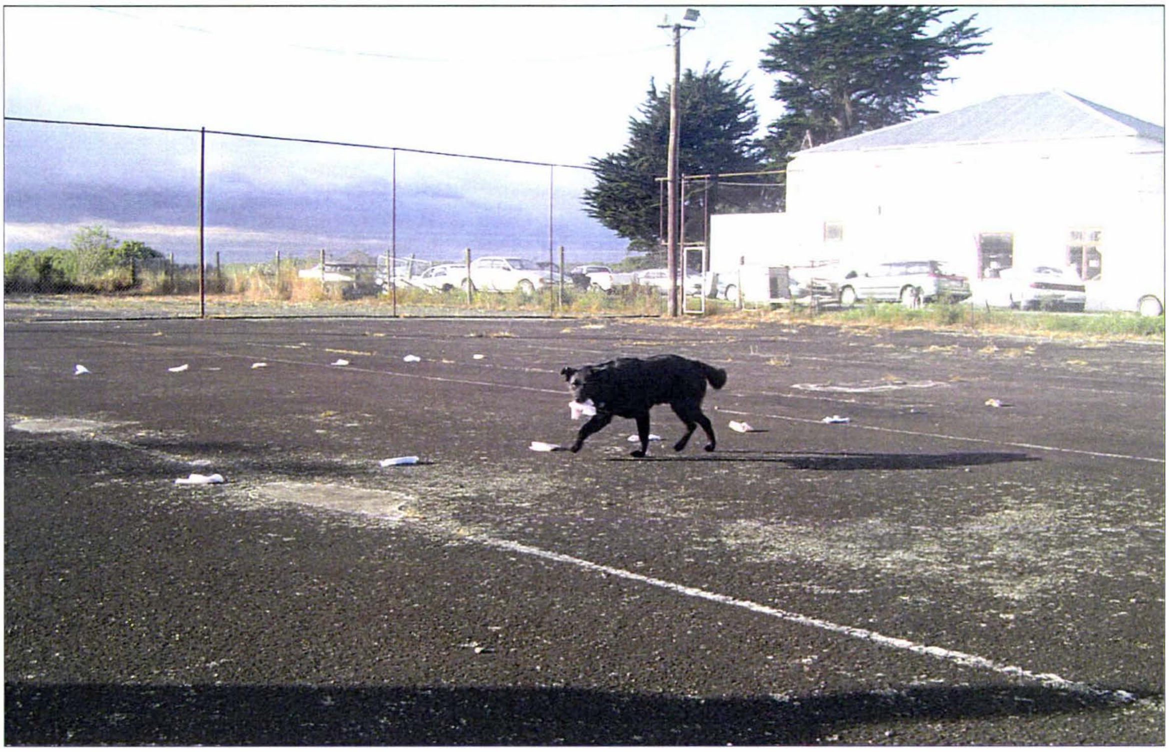

Figure 3.5: Dog 3 retrieving the target cloth. Photo: Clare Browne.

Figure 3.6: Dog 5 presenting the target cloth to its handler. Photo: Barbara Just.

A scent exercise was defined as successful when the target cloth was the first cloth to be retrieved and brought all of the way back to the handler. If a dog picked up an incorrect cloth and dropped it before returning to the handler, and then correctly retrieved the target cloth, this was still a success. If the target cloth was not the first cloth retrieved by the dog, or if the dog did not retrieve any cloths, the exercise was classed as a fail. An exception to this was when a dog ran enthusiastically to the first cloth they encountered and retrieved it. If the dog had not ventured further along the line of cloths than the first one (so had not had the opportunity to smell any of the other cloths), the dog was sent out again; if it then correctly scented along the line and retrieved the target cloth this was deemed to be a success.

The target cloths were placed semi-randomly along the line of cloths, the only restraint being that they were never placed first in the line. Random numbers were generated using the random function on a scientific calculator (Casio, fx-82W), and the first three numbers between two and eight were selected as the positions for the target cloths along the three lines of cloths that were set up each week.

Because the supply of tuatara resources was limited, dogs that performed below an arbitrarily prescribed level were withdrawn from the study. A dog that frequently failed more than one of three scent exercises was considered unreliable, so dogs consistently achieving an average success of less than 66.7% were omitted from further trials.

3.2.4 Experimental designs

Seven scent trials were run at the club, each requiring the dogs to identify a different target scent. Each trial consisted of nine replicates of the same scent exercise. All trials were planned to run over three consecutive weeks, with each dog doing three replicates per week (on the night the club met for regular training).

All of the trials followed the same basic protocol. Trials 1 and 2 were designed to provide a cursory indication of the dogs' ability.

Trial 1 – Handlers' scent

In Trial 1 the target cloths were scented with the dogs' own handler's scent. All dogs had been previously trained to find their handler's scent, so this was considered the easiest possible exercise for the dogs to perform. Immediately before each exercise the handler rubbed two sterile cloths on their hands, face, neck, or back. The dogs had to identify the cloth scented by their handler from amongst seven neutral cloths.

Trial 2 – Unfamiliar people's scent

In Trial 2 people who were unfamiliar to the dogs scented the target cloths. Although finding an unfamiliar person's scent was a novel task for many of the dogs that had limited scent training, they were still being presented with human scent. People from Massey University, Palmerston North, who had no association with any of the dogs, carried one pair of sterile cloths with them for the length of their working day on the day of the scent exercises. One of these target cloths was placed amongst seven neutral cloths.

Trial 3 – Tuatara-scented paper towels

The target cloths in Trial 3 were prepared with tuatara-scented paper towels. The paper towels were damp, so often during this trial the cloths were damp also (although attempts were made to dry them by airing them). The dogs were required to identify one target cloth from amongst seven neutral cloths.

Trial 4 – Tuatara scats

Tuatara scats were used to scent the target cloths in Trial 4. One scat-scented target cloth was randomly placed amongst seven neutral cloths.

Trial 5 – Tuatara skins

Trial 5 required the dogs to detect target cloths that had been scented with a piece of tuatara skin. One target cloth was positioned amongst seven neutral cloths.

Trial 6 – All three tuatara scents (paper towels, scats and skins)

This trial was designed to be more difficult for the dogs, and involved all three types of tuatara scent. One type of tuatara scent was the dogs' target scent (on the target cloths), and the other two types were impregnated on decoy cloths. Because the tuatara-scented paper towels may have contained more than just the scent of glandular secretions, tuatara-scented paper towels were not used as a target scent in this trial.

The dogs were placed randomly in two groups: one searching for scat-scented target cloths, the other searching for skin-scented target cloths. The dogs were split into the groups by listing them alphabetically and assigning each of them a random number generated by the random number function on a calculator. The dogs numbered 0-4 comprised one group and the dogs numbered 5-9 comprised the second group. The two decoy cloths were scented with the two non-target tuatara scents. For instance, the dogs with scats as their target scent had to identify the target cloth from amongst one decoy cloth scented with tuatara skin, another decoy cloth scented with paper towels and five neutral cloths. The cloths were arranged so that the decoy cloths were encountered along the line before the target cloth. The first three random numbers between two and eight generated by a calculator were selected for the positions of the two decoy cloths and the target cloth. The decoy cloths were randomly assigned the first two of the three positions, while the target cloth was assigned the position furthest along the line. This was done so the dogs had to smell the decoy cloths before the target cloth and therefore had to make a choice between several scented and neutral cloths.

Trial 7 – Weathered tuatara scats

Trial 7 was designed to be a practical test of the dogs' abilities. Tuatara scats were left under young planted native forest at Massey University, Palmerston North, for two weeks before being used to scent the target cloths (Figure 3.7). This trial provided scats in a weathered condition, such as could be encountered by dogs in the field. The scats were contained in a small pouch made of plastic netting (mesh width 3 × 4 mm), so were exposed to moisture, ultraviolet light, wind and animals (Figure 3.8). Rainfall,

Figure 3.7: The tuatara scats were placed in this young planted native forest. Photo: Clare Browne.

Figure 3.8: Tuatara scats sitting in the forest (in the pouch on the right), with rain gauge and high/low thermometer. Photo: Clare Browne.

temperature (minimum and maximum) and sunlight hours were recorded daily during the period the scats were in the forest because of the influence these factors could have on the strength of the scats' scent.

Decoy cloths were also prepared using soil and leaf litter from the area immediately surrounding the spot where the scats had been placed in the forest. The dogs were required to identify the one target cloth from among one decoy cloth and six neutral cloths. Again, the cloths were organised within the line so that the dogs encountered the decoy cloth before the target cloth.

3.2.5 Statistical analysis

The number of possible selections the dogs could make in each scent exercise was considered to be equal to the total number of cloths they were presented with (eight). If they were retrieving cloths at random, a success rate of 12.5% (one in eight) would be expected. Over nine repetitions of the same scent exercise (i.e. a standard trial) an average success of over 34.6% would be statistically significant from chance (95% confidence interval, $p = 0.05$). Over 12 exercises, an average success of 31.6% would be significant (95% confidence interval, $p = 0.05$).

Differences between dogs

The overall difference between the successes of individual dogs was tested using chi-square analysis. The analysis was performed including the results of all the dogs, and excluding the results of Dogs 7 and 9. Percentages of success were calculated per trial per dog.

No analysis was done to investigate potential differences between breeds of dog because the samples sizes were too small.

Differences between trials

Binary logistic regression was used to test for differences between the results of all the trials. This was examined in two ways; the response variable in both analyses was the proportion of individual dogs' success. The first analysis used 'dog' (success or failure) as the response variable versus 'dog' and 'trial number' as the predictors. In this analysis both of the predictor variables were fitted as factors. Based on these results, a second analysis was performed, in which the influence of the dogs was excluded.

Evidence of learning

Binary logistic regression was used to test for evidence of the dogs learning over the course of the study. The proportion of the individual dogs' success was used as the response variable in all analyses.

The first analyses tested if there was a difference between the success of the dogs in Trials 1 and 2 as compared to their success in Trials 3-7. This was done in two ways. The first analysis used 'dog' (success or failure) as the response variable versus 'dog' and 'Trials 1 and 2 results compared to Trials 3-7 results' as the predictors; both of the predictor variables were also fitted as factors. In the second analysis, the dogs were removed from the model. On the basis of the results from these analyses, Trials 1 and 2 results were excluded in further analysis for learning.

Only two dogs (numbers 2 and 3) did not complete some scent exercises in sequential date order (see Appendix 2 for details). However, Dog 2 was 100% successful throughout the study, and Dog 3 performed only six exercises out of order; these were considered negligible, so these data were not reorganised into date order for analysis. To test for a linear trend in Trials 3-7, which would occur if the dogs were learning (i.e. their success increasing over time), the success of the dogs across Trials 3-7 was examined. The analysis used 'dog' as the response variable versus 'dog' and 'Trials 3-7 results' as the predictors. 'Dog' was the only predictor variable fitted as a factor.

Failed scent exercises

No statistical comparison was made between the reasons why dogs failed scent exercises because the sample sizes in each category of failure were too small.

Minitab® Release 14 statistical software was used to perform the chi-square and binary logistic regression analyses. Significance was accepted in all statistical tests when $p < 0.05$.

3.3 Results

The trials were carried out between 3 December 2002 and 25 November 2003 (see Appendix 2 for a timetable). The overall success of the dogs at retrieving the target cloths differed for each trial; for example, average success was greater in Trial 4 than Trial 5 (Table 3.2). Variation in the performance of individual dogs became apparent as the study progressed (Table 3.2). Four dogs (numbers 1, 6, 7 and 9) were withdrawn from the study at various stages either at their handler's request or because of poor performance (Table 3.2).

The results in Table 3.2 show that the average success rates of the dogs in the trials are significantly higher than would be expected by random selection of cloths (random selection = 34.6% for nine scent exercises; 31.6% for 12 exercises) (95% confidence interval, $p = 0.05$).

Table 3.2: The success of all dogs in the seven different scent trials at the Tararua Allbreeds Dog Training Club. The dogs were required to identify a different target scent in each trial. The results are calculated as the average percent correct.

Dog	Trial 1 Handler	Trial 2 Unfamiliar people	Trial 3 Tuatara paper towels	Trial 4 Tuatara scats	Trial 5 Tuatara skins	Trial 6 All 3 tuatara scents	Trial 7 Weathered scats	Average
1	100	100	66.7	77.8	66.7	-	-	82.2
2	100	100	100	100	100	100	100	100
3	100	100	83.3	100	100	88.9	77.8	92.9
4	100	100	100	100	88.9	88.9	88.9	95.2
5	88.9	77.8	66.7	100	88.9	88.9	77.8	84.1
6	100	100	41.7	88.9	66.7	55.6	-	75.5
7	88.9	55.6	-	-	-	-	-	72.3
8	100	88.9	75	88.9	100	77.8	100	90.1
9	88.9	-	-	-	-	-	-	88.9
Average	96.3	90.3	76.2	93.7	87.3	83.4	88.9	

- Dogs withdrawn from the study.

3.3.1 Differences between dogs, between trials and evidence of learning

Differences between dogs

Most dogs showed some variation in their success across trials (Table 3.2). Three dogs (numbers 2, 3 and 4) had consistently high success rates throughout the study, while the success of the other dogs was less reliable and tended to vary between trials.

The difference between the overall successes of individual dogs was statistically significant ($\chi^2 = 32.275$, DF = 8, $p = 0.000$). In this analysis however, two expected cell counts were lower than 5, which may make the chi-square approximation unreliable. These low cell counts are attributable to the results of Dogs 7 and 9, which were withdrawn from the study after Trial 2 and Trial 1, respectively. When these dogs' results were excluded from analysis the difference between the remaining dogs' successes was still significant ($\chi^2 = 29.280$, DF = 6, $p = 0.000$).

Differences between trials

When the results of all the trials were compared, including the success of the individual dogs, there was a statistically significant difference between the trials (G = 69.732, DF = 14, $p = 0.000$). The dogs' success was included in this first analysis because there was a significant difference between the successes of individual dogs. This needed to be taken into account when comparing the trials to each other. However, the variation between dogs contributed to the significance of the analysis, so the analysis was run a second time without including dogs. There were significant differences between the results of each trial (G = 19.656, DF = 6, $p = 0.003$).

Evidence of learning

There was a statistically significant difference between the success of the dogs in Trials 1 and 2, as compared to Trials 3-7 (G = 55.436, DF = 9, $p = 0.000$). The average success of the dogs was higher in Trials 1 and 2. A significant difference between the results of

Trials 1 and 2 as compared to the results of Trials 3-7 was still produced when the dogs were removed from the model ($G = 7.358$, $DF = 1$, $p = 0.007$).

When the results of Trials 3-7 were examined for a linear trend the overall model was significant, but this was due to the already-established significant difference between the dogs. The 'Trials 3-7 results' variable was not significant ($p = 0.680$), indicating no evidence of the dogs learning over the course of these trials.

3.3.2 Trial 1 – Handlers' scent

The dogs were very successful in Trial 1. The target cloth was correctly identified in an average of 96.3% of the scent exercises; success rates for individual dogs ranged from 88.9% to 100% (Table 3.3).

Table 3.3: Trial 1 results. The target cloths were scented with the dogs' own handler's scent. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total correct	Percent correct
	1	2	3	4	5	6	7	8	9		
1	1	1	1	1	1	1	1	1	1	9	100
2	1	1	1	1	1	1	1	1	1	9	100
3	1	1	1	1	1	1	1	1	1	9	100
4	1	1	1	1	1	1	1	1	1	9	100
5	0	1	1	1	1	1	1	1	1	8	88.9
6	1	1	1	1	1	1	1	1	1	9	100
7	1	1	1	0	1	1	1	1	1	8	88.9
8	1	1	1	1	1	1	1	1	1	9	100
9	1	1	1	1	0	1	1	1	1	8	88.9
Total	8	9	9	8	8	9	9	9	9	78	96.3

Trial 1 ran from 3 December 2002 until 4 March 2003 (the club suspended its regular classes from 18 December 2003 until 20 January 2003). Most of the dog handlers did not regularly attend club training nights during this trial and subsequently did not perform the scent exercises over three consecutive weeks as planned. When a handler missed several club nights and had a number of exercises to catch up on, some of the dogs would perform extra exercises on one night if their handler thought it was within the dog's capabilities. In such cases, the dogs would generally do three exercises, have a break, and then complete the remaining exercises. Dog 2's scent exercises 7-9 were held on the same evening as its exercises 1-3 for Trial 2. Dog 4's handler did not attend club training for one week, so in order to catch up on scent exercises, its final three exercises for Trial 1 were held on an evening (other than club training night) at a local school near the handler's house. Dog 9 was withdrawn from the study after the completion of Trial 1.

Throughout Trial 1 the weather was warm and settled. The evening when Dogs 1, 2, 3, 5, 8 and 9 performed exercises 1-3 and Dog 6 performed exercises 4-6 was quite windy. No rain or windy conditions were experienced on any other evenings that the exercises were held.

3.3.3 Trial 2 – Unfamiliar people's scent

The dogs achieved a high rate of success in Trial 2, with an average of 90.3% correct choices, ranging from 55.6% to 100% for individual dogs (Table 3.4).

Table 3.4: Trial 2 results. The target cloths were scented with unfamiliar people's scent. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
1	1	1	1	1	1	1	1	1	1	9	100
2	1	1	1	1	1	1	1	1	1	9	100
3	1	1	1	1	1	1	1	1	1	9	100
4	1	1	1	1	1	1	1	1	1	9	100
5	1	1	1	1	0	0	1	1	1	7	77.8
6	1	1	1	1	1	1	1	1	1	9	100
7	1	1	0	0	1	0	1	1	0	5	55.6
8	1	1	1	0	1	1	1	1	1	8	88.9
Total	8	8	7	6	7	6	8	8	7	65	90.3

Trial 2 began on 25 February and ran until 1 April 2003. Dog 2's handler started the trial one week late, and Dog 7's handler missed three weeks of club training nights, causing the trial to run for an extended number of weeks. Dog 2 completed exercises 7-9 on the same night as it performed exercises 1-3 of Trial 3. Dog 7 was withdrawn from the study at the end of Trial 2.

Dog 8 developed a fungal infection during the second week of Trial 2, and was treated with antibiotics in week 3.

The evenings when the scent exercises were performed for this trial were dry and without wind.

3.3.4 Trial 3 – Tuatara-scented paper towels

The lowest average success of the study (76.2%) was produced in Trial 3; success of individual dogs ranged from 41.7% to 100% (Table 3.5).

Table 3.5: Trial 3 results. The target cloths were scented with tuatara-scented paper towels. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Week 4			Total correct	Percent correct
	1	2	3	4	5	6	7	8	9	10	11	12		
1	1	1	1	1	0	1	0	0	0	1	1	1	8	66.7
2	1	1	1	1	1	1	1	1	1	1	1	1	12	100
3	1	1	1	1	1	0	1	1	1	1	1	0	10	83.3
4	1	1	1	1	1	1	1	1	1	1	1	1	12	100
5	0	1	0	1	0	0	1	1	1	1	1	1	8	66.7
6	1	1	0	0	0	0	0	1	0	0	1	1	5	41.7
8	0	1	0	1	1	0	1	1	1	1	1	1	9	75
Total	5	7	4	6	4	3	5	6	5	6	7	6	64	76.2

This trial ran from 18 March until 10 June 2003. A new group of dog obedience classes started on the same evening as this trial began. The majority of the dogs appeared uncharacteristically distracted on the first night of the trial, taking very long times to complete the scent exercises and sniffing the surrounding ground extensively. This was attributed to the club grounds being heavily scented by unfamiliar dogs, so the trial was extended for an extra week in case any undue disturbance was reflected in the results. The handlers of Dogs 1 and 5 were absent from club training nights for a prolonged period of time, resulting in the trial running for several weeks longer than anticipated. Dog 3 completed exercises 7-12 on the same evening.

Dog 3 was on antibiotics during week 2. Dog 8 was taking prednisone, a steroid medication, for its continuing infection throughout the entire trial.

The weather continued to be consistently dry and calm on the evenings the scent exercises were held throughout Trial 3.

3.3.5 Trial 4 – Tuatara scats

Of all the tuatara scents used in the study, the dogs were the most successful at locating scats. The dogs selected the correct cloth 93.7% of the time, ranging from 77.8% to 100% (Table 3.6).

Table 3.6: Trial 4 results. The target cloths were scented with tuatara scats. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
1	0	0	1	1	1	1	1	1	1	7	77.8
2	1	1	1	1	1	1	1	1	1	9	100
3	1	1	1	1	1	1	1	1	1	9	100
4	1	1	1	1	1	1	1	1	1	9	100
5	1	1	1	1	1	1	1	1	1	9	100
6	1	1	0	1	1	1	1	1	1	8	88.9
8	1	1	1	0	1	1	1	1	1	8	88.9
Total	6	6	6	6	7	7	7	7	7	59	93.7

Trial 4 started on 13 May and finished on 29 August 2003. By this stage there were several weeks of overlap between the start and finish dates of consecutive scent trials, due to some dog handlers not attending club training nights on numerous occasions. Dog 1 and Dog 5 started Trial 4 several weeks later than most of the other dogs, so in order to catch up they both completed their final three exercises of the trial at Dog 5's handler's house. Dog 2 carried out exercises 1-6 at its handler's house. Dog 2 also performed exercises 7-9 of Trial 4 on the same evening as exercises 1-6 of Trial 5.

Dog 1 became pregnant a few days prior to starting Trial 4. Dog 5 had minor surgery in between week 2 and week 3 of the trial. Dog 8 continued to take steroids for weeks 1 and 2 of this trial.

The weather conditions during Trial 4 were slightly variable. On the evenings that Dogs 1 and 5 performed exercises 1-6 and Dogs 4 and 8 performed exercises 7-9, there was a slight breeze, and it had rained during the day and the ground remained very damp. All other nights were calm and dry.

3.3.6 Trial 5 – Tuatara skins

The dogs correctly selected the tuatara skin-scented target cloths in 55 of 63 exercises (87.3%); success rates of individual dogs ranged from 66.7% to 100% (Table 3.7).

Table 3.7: Trial 5 results. The target cloths were scented with tuatara skins. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
1	1	1	1	1	0	0	1	0	1	6	66.7
2	1	1	1	1	1	1	1	1	1	9	100
3	1	1	1	1	1	1	1	1	1	9	100
4	1	1	1	1	1	0	1	1	1	8	88.9
5	1	1	1	1	0	1	1	1	1	8	88.9
6	1	1	0	0	0	1	1	1	1	6	66.7
8	1	1	1	1	1	1	1	1	1	9	100
Total	7	7	6	6	4	5	7	6	7	55	87.3

Trial 5 ran from 8 August until 14 October 2003. Dog 1's success at the scent exercises was noticeably decreasing. Dog 2 completed the final three exercises of this trial two and a half months after the other dogs had finished. This was due to its handler not attending club training sessions and the inconvenience of setting up Trial 5 exercises while Trial 6 was running (the experimental protocols of these two trials were slightly different). Dog 2 performed exercises 7-9 of Trial 5 on the same evening as exercises 4-6 of Trial 7. Dog 1 was withdrawn from further trials at the end of this trial.

Dog 4 was on heat during the first two weeks of Trial 5. Its behaviour during this time was slightly different: it appeared less focused on the scent exercises and was more easily distracted.

Week 2 of Trial 5 was the only damp evening of the trial, when it rained lightly. The weather conditions during the rest of the trial were very cold, but dry and windless.

3.3.7 Trial 6 – All three tuatara scents (paper towels, scats and skins)

Although this trial was designed to be a more difficult test of the dogs' discriminatory abilities, a very high overall average success of 83.4% was achieved; individual dogs' success ranged from 55.6% to 100% (Table 3.8).

Of the nine failed scent exercises in Trial 6, five (55.6%) of them were due to the dogs retrieving the decoy cloths instead of the target cloths (Table 3.8). Dogs trying to locate scat-scented target cloths incorrectly retrieved skin-scented decoy cloths on two occasions. Dogs searching for skin-scented target cloths retrieved scat-scented decoy cloths during two exercises, and both decoys (scat- and paper towel-scented cloths) during another. During two additional failed scent exercises, both the scat- and skin-scented decoy cloths were heavily mouthed by dogs, but not retrieved.

Table 3.8: Trial 6 results. The target cloths were scented with either tuatara scats or skins. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise, D indicates a failed scent exercise when a decoy cloth was retrieved instead of the target cloth.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
2	1	1	1	1	1	1	1	1	1	9	100
3	0	1	1	1	1	1	1	1	1	8	88.9
4	D	1	1	1	1	1	1	1	1	8	88.9
5	1	1	1	1	D	1	1	1	1	8	88.9
6	D	0	1	1	0	1	1	1	D	5	55.6
8	1	1	1	1	1	D	1	1	0	7	77.8
Total	3	5	6	6	4	5	6	6	4	45	83.4

The dogs searching for scat-scented target cloths identified them in an average of 88.9% of the exercises, ranging from 77.8% to 100% (Table 3.9). The dogs with skin-scented target cloths made an average of 77.8% correct selections, ranging from 55.6% to 88.9% (Table 3.9).

Table 3.9: Trial 6 results, showing the two groups the dogs were split into. The target cloths were scented with either tuatara scats or skins. The results are calculated as the average percent correct.

Dog	Target scent	
	Scats	Skins
2	100	
3		88.9
4	88.9	
5		88.9
6		55.6
8	77.8	
Average	88.9	77.8

Trial 6 was held from 5 August until 2 December 2003. All of the dogs began this trial on the same night and most finished within three consecutive weeks. However, Dog 3's handler was preparing for competitive scent work and took a break from the study for three months. Dog 3 finished exercises 4-9 on the same evening, three months after the other dogs had completed the trial. Dogs 2 and 5 completed exercises 4-9 of Trial 6 on one evening. Dog 6 was withdrawn from the study at the end of Trial 6.

Weather conditions during Trial 6 were generally dry with little wind. The grounds were damp one evening (week 3 for Dogs 4, 5, 6 and 8), and there was a slight breeze.

3.3.8 Trial 7 – Weathered tuatara scats

The dogs had a high average success of 88.9% (ranging from 77.8% to 100%) at finding tuatara scats that had been exposed for two weeks to natural conditions in native forest (Table 3.10).

None of the failed scent exercises in Trial 7 were the result of the dogs selecting the decoy cloths.

Table 3.10: Trial 7 results. The target cloths were scented with weathered tuatara scats. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
2	1	1	1	1	1	1	1	1	1	9	100
3	1	1	1	0	1	1	0	1	1	7	77.8
4	1	1	1	1	1	1	1	1	0	8	88.9
5	0	1	1	1	0	1	1	1	1	7	77.8
8	1	1	1	1	1	1	1	1	1	9	100
Total	5	6	6	5	5	6	5	6	5	40	88.9

This final trial was held from 7 October until 25 November 2003. The five remaining dogs all started and finished the trial within a few weeks of each other. Dog 2 performed exercises 4-6 on the same night as it completed the final three exercises for Trial 5. Dogs 3 and 5 completed exercises 1-6 on the same evening.

On all of the evenings that Trial 7 was held the weather was dry and slightly windy.

The average temperature that the scats were exposed to in the forest was 11.6 °C, and ranged from 0-22 °C (Figure 3.9). The average amount of rainfall received in the specific area where the scats were placed was 3.6 mm, and ranged from 0-20.5 mm for any given 24 hour period (Figure 3.9).

3.3.9 Failed scent exercises

There were a total of 56 failed scent exercises across all seven trials (Figure 3.10). In 29 (51.8%) failed exercises, the dogs selected wrong (non-target) cloths rather than not selecting any cloth at all, five (8.9%) of these were decoy cloth selections. Nine (16.1%) incorrect cloth selections were due to no selection being made, and the reasons for 18 (32.1%) failed exercises were unknown (Figure 3.10). Some dogs (in particular numbers 3 and 6) were more likely to retrieve an incorrect cloth than return to their owner without a cloth.

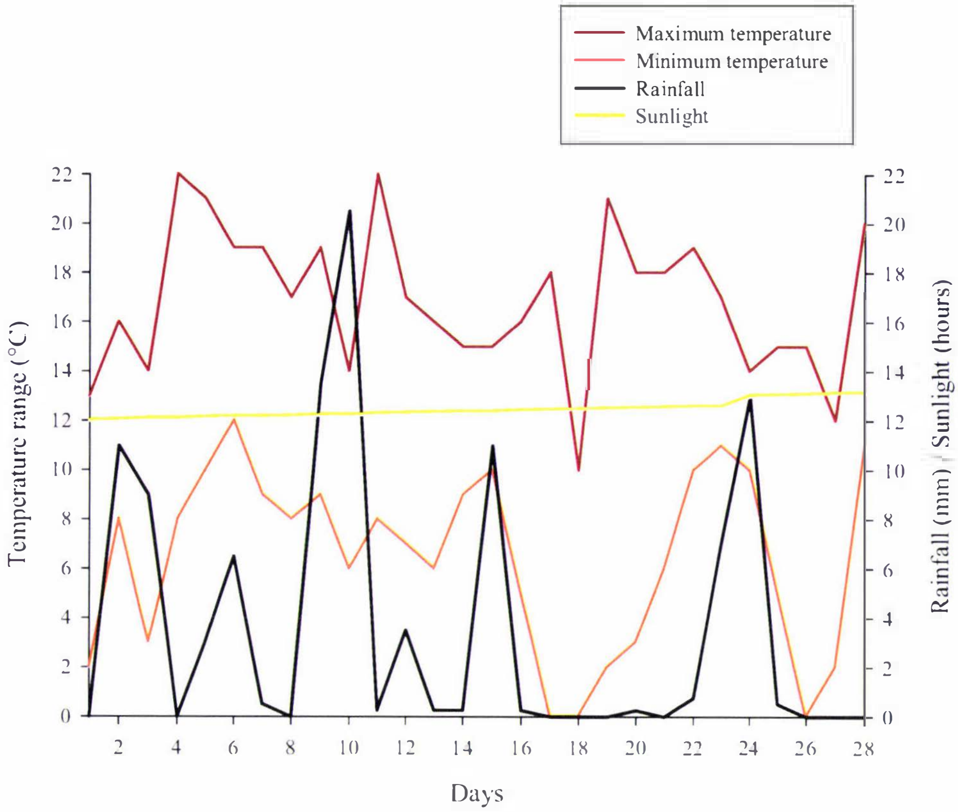

Figure 3.9: The temperature range, amount of rainfall and sunlight hours the tuatara scats were exposed to in young planted native forest between 20 September and 18 October 2003.

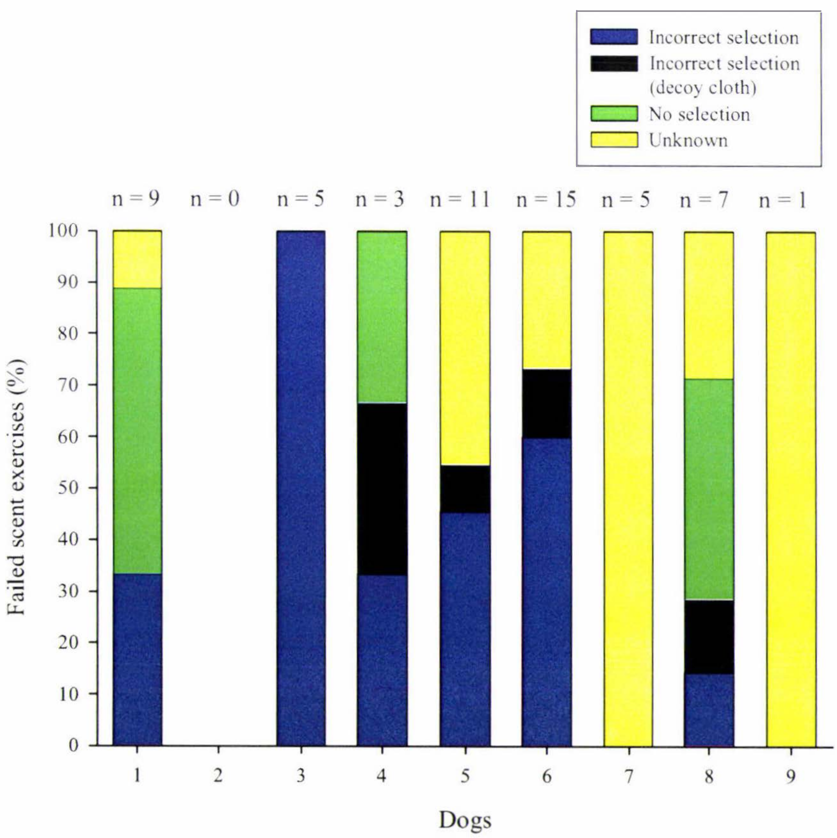

Figure 3.10: Causes of failed scent exercises for each dog, across all scent trials. n = total number of failed exercises.

3.3.10 Dog behaviour during scent exercises

The observers recorded the behaviour of the dogs during each scent exercise. The dogs commonly exhibited a number of behaviours, such as:

- Picking up an incorrect cloth, dropping it immediately, then locating and retrieving the target cloth.
- Picking up an incorrect cloth, continuing along the line carrying the cloth until reaching the target cloth, dropping the incorrect cloth and retrieving the target cloth.
- Retrieving the first cloth encountered. When commanded to find the target scent a second time, searching the whole line of cloths and retrieving the target cloth immediately. (Because some dogs showed this behaviour often the target cloth was never positioned first in the line.)
- Retrieving any cloth hastily (not necessarily the first one), apparently not sniffing or making any real effort to locate the target cloth.
- Continuing past the target cloth, although their body language suggested they recognised the scent, and retrieving an incorrect cloth.
- Refusing to search along the line of cloths, apparently uninterested in the task or being disobedient.
- Distracted behaviour, such as urination, defecation, attention directed at other dogs, people or noises, taking a very long time to perform the exercise.
- Mouthing several cloths, sometimes all cloths, in the line.
- Retrieving cloths and jars of cloths from other lines.

3.4 Discussion

The outstanding finding of this research is that dogs can detect tuatara (*S. punctatus*) scent. The dogs used in this study were trained to perform only very basic scent discrimination exercises and were not specifically trained to detect tuatara scent. However, they were able to identify various tuatara scents with high levels of success, including the scent of tuatara scats that had been exposed to the elements in native forest for two weeks. The dogs were able to distinguish tuatara scents from neutral scents and were also able to discriminate between several types of tuatara scent.

There were aspects of the methodology in this study that may have affected the results and could potentially be improved. Individual variation between dogs, the unavoidable influence of the handlers on their dogs and uncontrollable variables such as the weather, may all have influenced the results to some extent.

3.4.1 Limitations of the methodology

Each scent exercise was not strictly an independent event and this needs to be kept in mind when interpreting the results of statistical tests. The sample population of dogs was not randomly selected which means the results cannot necessarily be extrapolated to all dogs

The tuatara samples were frozen and thawed prior to target and decoy cloth preparation and it was presumed the odoriferous compounds within the tuatara scents remained stable. Although this may not be the case, it was the only practical way to store the samples. Similar studies have stored biological samples in the same way, with seemingly no effect (Hawk *et al.*, 1984; Kiddy *et al.*, 1984; Hurt *et al.*, 2000; Pickel *et al.*, 2004; Shelby *et al.*, 2004; Willis *et al.*, 2004). Hawk *et al.* (1984) found that the ability of dogs to detect milk from oestrus cows was not affected by repeated freezing and thawing of the milk samples.

Reusing tuatara skin samples due to their scarcity may have affected results. Certain pieces may have had an inherently stronger scent depending on how many glands they contained, and the more volatile chemicals within the skin may have deteriorated over time with re-use. These factors may have contributed to the relatively low average detection rate achieved in Trial 3 when skin was the target scent. Also, the target cloths were sometimes damp during this trial, which may have affected the dogs' willingness to retrieve the correct cloth. However, the dogs' behaviour during this trial did not suggest a reluctance to retrieve the target cloths (personal observation).

As the scats were exposed to mixed weather conditions in Trial 7, the strength of the scats' odour could have varied. Variation in odour could have been reflected in the results if some dogs were searching for target cloths that smelt disproportionately weak or strong.

The practice of drying the autoclaved cloths in sunlight could have allowed extraneous odours from the environment to contaminate the cloths. Groups of cloths that were sterilised then dried together (and absorbed the same odours), were used for each trial (as target, decoy and neutral cloths) in an attempt to negate the effects of this by standardising the scent of the cloths. Overall this potential source of error was probably slight.

Some degree of observer bias may have been introduced since different observers were used throughout the study. Due to the length of the study period, having numerous observers, each for short periods of time, was the only way to ensure willing volunteers. Recording detailed descriptions of the dogs' behaviour during each scent exercise was designed to help counter any potential observer bias, and the retrieval was an easily recognisable, unambiguous indication that the dogs had made a cloth selection. Video recording the scent exercises for later analysis by just one observer may have eliminated any possible element of observer bias.

Environmental factors such as temperature, rainfall and wind were subjectively noted, but could have been quantitatively measured to assess any possible impact they had on the dogs' success.

A trial testing the dogs' ability to discriminate between reptile species (i.e. tuatara, gecko and skink) would have been of value, but was not feasible due to lack of time and limited supplies of reptile scent samples. Although not rigorously tested, three dogs trained to detect tuatara (*Sphenodon* spp.), geckos (*Naultinus* spp. and *Hoplodactylus* spp.) and skinks (*Oligosoma* spp. and *Cyclodina* spp.) respectively, have shown the ability to successfully discriminate between the three reptiles (see Appendix 1 for further information).

The tuatara samples used to scent the target and decoy cloths came from tuatara differing in sex and age; however, the samples were often mixed or from animals whose sex or age was unknown (see Appendix 4 for details). Because of this, there were insufficient sample sizes to test the ability of the dogs to discriminate between either sex or age.

Some comparable studies have included tests where the target scent is absent (Hurt *et al.*, 2000; Brooks *et al.*, 2003; Smith *et al.*, 2003). A well-trained detection dog should not respond with a 'false positive' when the target scent is absent. However, the point of this study was to ascertain whether dogs could detect a variety of tuatara scents, and the trials were designed to test the dogs within the limits of their training. Most of the dogs had only basic scent discrimination training, and in their obedience scent work they are never put in a situation where the target scent is absent. For these reasons, and because such a test was not planned at the start of the study, a trial in which the target scent was absent was not held. However, it would be a valuable exercise for a purpose-trained tuatara-detection dog.

3.4.2 The ability of the dogs to detect tuatara scent

The dogs used in this study were able to detect tuatara scent with high average rates of success, ranging from 76.2% for tuatara-scented paper towels to 93.7% for scats. Current visual search methods are inefficient and ill-suited to the cryptic and burrowing habits of tuatara (Cassey & Ussher, 1999). The need for a more practical way to monitor tuatara populations has been identified in the tuatara recovery plan (Gaze, 2001). Although these results were achieved in an experimental situation and alternate sources of scent were substituted for live tuatara, the implication of such high detection rates is that dogs may complement existing search methods or provide an alternative means of locating tuatara.

Tuatara do feed on motionless items, implying they use olfaction to locate them (Walls, 1981; Cooper *et al.*, 2001), and their predominantly nocturnal nature suggests their sense of smell could be reasonably well developed, similar to geckos (see Schwenk, 1993). However, there is scant additional literature on tuatara chemical communication, so it is not known if tuatara produce chemical signals that could be exploited by dogs. To date, there have been no other scientific studies assessing the ability of dogs to detect tuatara. There is currently only one dog in New Zealand being trained to detect live tuatara in the field (see Appendix 1 for details).

3.4.3 The dogs' previous training

The dogs were not individually assessed for their suitability; although Trials 1 and 2 were designed to give a very basic indication of the dogs' aptitude at the most simple of scent discrimination exercises, the dogs' performance in these trials were not reflective of their success in subsequent trials. The sample of dogs was not randomly selected; they were all sourced from a local dog obedience club, and chosen solely on the basis of availability. The results show that some dogs consistently achieved higher rates of success at the scent exercises than others, however the overall average results are still very good. These findings imply that a purposely selected and trained dog could potentially detect tuatara with extremely high rates of success.

Despite the fact that the dogs were not trained to detect tuatara scent, they were able to do so very accurately. Most of the dogs were trained to detect only human scent, specifically, their own handlers' odour. Three dogs had done some very limited training using scent from a horse (*Equus caballus*), bull (*Bos taurus*), possum (*Trichosurus vulpecula*), rabbit (*Oryctolagus* spp.) and cockatoo (*Cacatua* spp.). The dogs' levels of experience ranged from years of competitive scent work (i.e. Dogs 2, 3 and 6), to being taught the protocol of the scent exercises just before Trial 1 began (i.e. Dogs 1, 5, 7 and 9). Time spent training for scent discrimination work prior to this study seemed to have little influence on the success rates of the dogs. Although the dog that achieved the highest average success rate (Dog 2) did have the most experience, no relationship between training time and success was reflected in the other dogs. Dog 4, for example, had only six months of scent training prior to this study, but achieved a much higher average success rate than Dog 6, which had five years experience.

The dogs encountered tuatara scent for the first time in Trials 3-7. Similar research has suggested that familiarity with a scent achieves a higher detection rate by dogs (Schoon & De Bruin, 1994; Kurz *et al.*, 1996; Komar, 1999; Hurt *et al.*, 2000), yet most of the dogs in this study consistently identified the tuatara scents with average success rates significantly higher than random. However, there was a significant difference between the results of Trials 1 and 2, when human scent was used as the target scent, and Trials 3-7, when tuatara scents were used. Because of this difference, the results of Trials 1 and 2 were excluded when searching for evidence of the dogs learning (and thus improving their success rates) throughout the study. There was no evidence of the dogs learning over the course of the tuatara trials.

The results of this study compare favourably with other research that has assessed dogs' abilities to detect biological scents using similar methods (Table 3.11). In all other comparable studies, a select group of dogs was either trained prior to the study (i.e. police dogs) or trained to detect a target scent specifically for the project. Once the dogs were trained, their proficiency was evaluated. In some studies, training persisted throughout the testing period (Settle *et al.*, 1994; Brooks *et al.*, 2003; Pickel *et al.*, 2004). This is in contrast to the dogs used in this study; some of dogs received only rudimentary scent training prior to the study, and the target scent was completely novel to all dogs.

Table 3.11: Comparison of this study with other assessments of the ability of dogs to detect biological scents. All studies tested the dogs in experimental situations, using similar methods.

Study	Number of dogs	Target scent	Average success (%)
This study	**3-9**	**Tuatara**	**76.2-93.7**
Brooks *et al.*, 2003	6	Termites	95.9-96.7
Hurt *et al.*, 2000	3	Grizzly bear scat	75
Kerley, 2003	2	Tiger scat	92.5
Schoon, 1996	8	Human	31-58
Settle *et al.*, 1994	3-7	Human	80-85
Smith *et al.*, 2003	4	Kit fox scat	67-100
Willis *et al.*, 2004	6	Bladder cancer	41

Most studies evaluating detection-dog proficiency have small sample sizes (Table 3.11), mainly because the training time and costs involved can be considerable. Accordingly, this study used volunteers whose dogs already had some basic scent discrimination skills. The trade-off from this choice, however, was the potential lack of suitability of some subjects.

3.4.4 Detection of weathered tuatara scats

The dogs were able to identify the scent of scats placed in native forest for two weeks in an average of 88.9% of the scent exercises. The cool temperatures and the amount of rainfall to which these scats were subjected are probably not reflective of the conditions tuatara scats would generally be exposed to. At the time of year when the scats in this study were placed in the forest (early spring, September and October) tuatara naturally produce no or very little faecal material, whereas tuatara consuming food during summer months will generally defecate within four days (L. Hazley, personal communication, 2003). The high rainfall experienced during this time may have caused excessive deterioration of the scats used in this study. In the wild, warmer temperatures during summer months may also boost bacterial activity within the scats, increasing the amount and dispersion of scent from the scats (Wasser *et al.*, 2004). Dogs trained to detect scats in the field, working in summer months when tuatara are most active, would therefore probably encounter scats that were fresher, that had less exposure to rainfall and temperature variation and that were producing more volatile chemicals. The finding that the dogs could very accurately identify the deteriorated scats used in this study suggests that dogs could successfully detect scats in the field.

Several studies have shown that scat-detection dogs can readily locate endangered species' scats (Hurt *et al.*, 2000; Kerley, 2003; Smith *et al.*, 2003; Wasser *et al.*, 2004). Dogs are also used to discriminate a target species' scats from non-target scats; and DNA and hormones can be extracted from the scats dogs have found (Hurt *et al.*, 2000; Wasser *et al.*, 2000; Smith & Ralls, 2001; Smith *et al.*, 2003; Wasser *et al.*, 2004). The New Zealand Department of Conservation has recognised that a simple technique for surveying and monitoring tuatara is yet to be developed, and states "changes in habitat or potential changes in those factors most likely to cause a decline (weeds, pests, revegetation or modification owing to muttonbirding visits) are easier to detect and manage than tuatara populations themselves" (Gaze, 2001, p. 18). Scat-detection dogs can also be useful in determining the presence or absence of rare or endangered species outside their known range (Smith *et al.*, 2003). A 'moderate' priority has been assigned by DoC to the surveying of islands likely to hold unknown relict tuatara populations (Gaze, 2001). Although no work has yet been done on extracting DNA or hormones from tuatara scats, it has been proposed several times by researchers as worth investigating as a source of mitochondrial DNA and other information. Analysis of tuatara scats found by dogs could potentially provide valuable information gained in a much less invasive manner than traditional methods. Using tuatara scat-detection dogs could result in reduced disturbance to the tuatara, less habitat destruction and potentially be a more efficient method of data collection than those methods currently used.

3.4.5 Accurate scent discrimination

The dogs clearly showed that they were able to detect all three tuatara scents in Trial 3, 4 and 5. However, in these trials the dogs were required to identify the target cloth from amongst seven neutral cloths, so it was possible that they were simply selecting the one cloth that had a different scent to the other cloths. Decoy cloths were added in Trials 6 and 7 with the aim of ensuring the dogs were specifically detecting the target tuatara scent. The high average success rates in Trials 6 and 7 (83.4% and 88.9% respectively) showed the dogs were correctly discriminating between the scents.

The incorrect selection of decoy cloths in five (55.6%) of the nine failed scent exercises in Trial 6 indicates that although tuatara scents are distinguishable by dogs, the scents are probably very similar. It is extremely unlikely that any cross-contamination occurred between cloths leading to misidentification in the failed exercises. All tuatara samples and cloths were handled with clean gloves during preparation; and although during the scent exercises only one pair of tongs was used at each line of cloths to handle all the cloths, any potential contamination from the tongs would have been negligible compared to the amount of scent contained on each cloth.

These results indicate that dogs can be trained to detect tuatara scents with a high degree of specificity. If a dog was adequately trained to locate tuatara scats, for example, it could accurately identify them and discriminate between other tuatara scents, such as sloughed skins.

3.4.6 Limitations of the dogs

Some dogs performed significantly better than others, and certain individuals clearly had more aptitude for scent discrimination work. For example, Dog 2 maintained 100% success throughout the entire study, and Dogs 3 and 4 consistently achieved average success rates at a minimum of 77.8%. In contrast, Dog 6's performance fluctuated between 100% success in Trials 1 and 2 and a low of 41.7% in Trial 3. Although most of the dogs were reasonably consistent, occasionally one dog's performance had a disproportionate impact on the total average success in certain trials. For instance, Dog 6's results were at least 20% lower than all other dogs in Trials 3 and 6, which reduced the overall average success in those trials by over five percent. The results of the trials have been reported and discussed in terms of their total average success rates (pooling all the dogs' results), however, these averages are unlikely to be particularly useful for making comparison between the scents. Due to the inconsistencies between the dogs' performances and considering some dogs were withdrawn from the study at various stages, the average success for each trial is more of a measure of individual dogs' performances than a measure of how difficult each scent is to detect by dogs.

Throughout the study there were instances where dogs that were normally consistently successful failed several consecutive scent exercises. In Trial 3 for example, Dog 1 failed all three exercises in the third week and Dog 5 failed two out of three exercises in the first and second weeks; both of these dogs passed almost every other exercise in this trial. Dogs performing repetitive scent exercises can become bored, leading to a lowered success rate (Kerley, 2003; Smith *et al.*, 2003). The numbers of exercises on any night were limited to three in an attempt to negate this possibility, although some dogs did perform more than three when they had exercises to catch up with no obvious effects on their success. Failures that appear to be linked may be due to a multitude of reasons, including the motivation of the dog and the mood of the handler.

Physiological factors may explain other failed scent exercises. During the study, Dog 1 became pregnant; Dog 3 took antibiotics for one week; Dog 4 came into heat, and its behaviour was noticeably different; Dog 6 had minor surgery; and Dog 8 had a fungal infection that lasted almost three months, requiring treatment with antibiotics for one week and steroid medication for six weeks of scent exercises. Although the performance of Dogs 1, 3 and 6 did not conspicuously change during this time, the success of Dogs 4 and 8 may have been affected. Dog 4 failed a scent exercise for the first time while on heat. The period in which Dog 8 was unwell corresponded with most of its failures. Steroids can increase the detection thresholds of scents in dogs (Ezeh *et al.*, 1992), which may explain the decrease in Dog 8's success while unwell and taking steroid medication.

The individual variation shown between the dogs used in this study is noteworthy, because it illustrates the importance of selecting dogs with the correct temperament and aptitude for such work.

3.4.7 Handler influences

Some of the handlers became emotionally involved in the outcome of the scent exercises. They wanted their dogs to have high success rates, and were commonly disappointed or became frustrated if their dogs failed to identify the target cloths. The mood and motivation of the handlers may have affected their dogs' performance. Settle *et al.* (1994) noted the performance of most dogs in their human-scent discrimination tasks started to deteriorate as the handlers became emotionally involved in the outcome of the testing. Insufficient training, handler error and varying handler motivation are commonly cited as reducing detection efficiency (Tindall & Lothridge, 1995; Schoon, 1996; Komar, 1999; Smith *et al.*, 2003; Wasser *et al.*, 2004).

Using the club grounds as the testing area, although convenient, was not ideal from an experimental point of view. Due to the layout of the club grounds, handlers not actively participating in a scent exercise were able to observe other dog and handler teams completing their exercises, so were able to see the position of the target cloth along the line of cloths. The trials were, therefore, not strictly blind; if handlers knew the position of the target cloth, there was potential for them to consciously or subconsciously influence the dogs' cloth selection. This was minimised by the handlers being requested not to issue verbal commands that could indicate the location of the target cloth, and by the handlers' position in relation to the line of cloths. Human social cues such as pointing gestures, body position, head orientation and direction of gaze can assist dogs in problem solving situations (Hare & Tomasello, 1999; Soproni *et al.*, 2001; 2002; Virányi *et al.*, 2004). Positioned directly in front of the cloths, which were arranged in a straight line moving away from them, the handlers were not able to easily direct the dogs to any particular cloth using inconspicuous physical cues that dogs may have recognised as directive signals, such as gaze or body position. The dogs also worked independently of their handlers, moving away from them as they walked along the line of cloths, although on occasion dogs did make their cloth selection as they returned along the line towards the handler. Using a portable screen to shield non-participating handlers from observing the exercises could have prevented the handlers seeing the location of the target cloths, thus enabling the trials to be completely blind.

When Dogs 3, 4, 5 and 6 failed a scent exercise they were more likely to retrieve non-target cloths than to return to their handler without a cloth. This tendency to retrieve, irrespective of accuracy, could be partly explained by the handlers rewarding the dogs when they correctly completed the exercises. Handlers would use either food rewards or play (usually with the retrieved cloth) as a positive reinforcer, according to individual preference. Negative reinforcement (withholding positive reinforcement) or punishment (verbal reprimands) was applied when a dog made an incorrect retrieval. When cloths were used as a reinforcer, some dogs may have been unable to separate the exercise from the reward, and perceived the line of cloths as eight potential reinforcers. This problem has been identified in a similar study (Schoon, 1996). Most dogs are highly motivated by social interactions, and quickly learn to behave in certain ways to evoke a specific reaction from their handler (O'Farrell, 1987). The dogs often seemed to haphazardly retrieve any cloth, often the first cloth they encountered, in an effort to please their handler (personal observation). Another possible explanation for such frequent incorrect retrievals by particular dogs could be to evoke positive reinforcement or to avoid negative reinforcement or verbal punishment.

Some handlers did not attend club training evenings every week and therefore did not complete each trial with their dogs over three successive weeks; there were delays of up to several months before some trials were completed (see Appendix 2). This did not cause any noticeable impact on the dogs' success. Some studies have found interruptions have caused a decrease in the dogs' accuracy (Settle *et al.*, 1994; Kauhanen *et al.*, 2002). A tuatara-detection dog would probably only be used to search for tuatara during the warmer months of the year when the reptiles are most active. Maintaining regular training throughout the year is standard practice; however, realistically there may be periods when training is not possible (see Appendix 1 for an example).

3.4.8 Uncontrolled variables

There were many uncontrollable variables that may have impacted on the dogs' success throughout the study. The dispersal of scent particles and the concentration of odour are strongly influenced by wind, moisture and temperature (Gutzwiller, 1990; Harvey & Harvey, 2003; Lasseter *et al.*, 2003; Wasser *et al.*, 2004). The weather remained reasonably consistent throughout the study. The scent exercises were held on very few wet or very windy evenings, and there was no clear pattern between the dogs' success and the weather conditions. There were also continual distractions, such as other dogs and people. Trial 3, for example, was extended for one week because a new group of dog obedience classes began on the same night and the dogs were extremely distracted by the scent of many new dogs. There appeared to be no detectable difference in the results however, so the trials were not extended on subsequent nights of new classes. Many similar studies have used controlled, indoor facilities in which to carry out their testing (Schoon & De Bruin, 1994; Settle *et al.*, 1994; Kerley, 2003).

In summary, the results show that dogs can reliably detect tuatara scent. This indicates that using dogs is a viable alternative method of locating tuatara for conservation work.

CHAPTER 4

THE ABILITY OF DOGS TO DETECT GECKO SCENT

A Marlborough green gecko (*Naultinus manukanus*) on Stephens Island, New Zealand. Photo: Dr Paddy Ryan.

4.1 Introduction

New Zealand's lizard fauna, with its unusual diversity, is as equally significant as the tuatara (Towns *et al.*, 2001). When compared to fauna in other temperate regions on a unit per area basis, the species richness of lizards in New Zealand is very high (Daugherty *et al.*, 1990b). New Zealand has approximately 78 species of lizards, including 32 undescribed taxa, and two taxa are believed to be extinct (Hitchmough *et al.*, 2004). As well as notable taxonomic diversity, all native lizards are endemic to New Zealand (Daugherty *et al.*, 1994). Lizards have traditionally been considered relatively recent arrivals in New Zealand (Towns *et al.*, 2001 and references therein), however genetic studies suggest that they have been evolving *in situ* for at least 20 million years and perhaps far longer (Daugherty *et al.*, 1993).

Within the order squamata (snakes and lizards) New Zealand has two families of lizards: gekkonidae (geckos) and scincidae (skinks). The gekkonidae family consists of the genera *Naultinus* (nine species, one of which is undescribed) and *Hoplodactylus* (31 species, 21 of which are undescribed and one believed to be extinct) (Hitchmough *et al.*, 2004). Geckos are one of the most ecologically diverse components of the vertebrate fauna in New Zealand (Chambers *et al.*, 2001). They are distributed throughout the North and South Islands, although some species are mainly restricted to offshore islands (Towns *et al.*, 1985; Gill & Whitaker, 1996). New Zealand geckos are found in a wide range of environments inhabiting coastal vegetation and cliffs, farmland, gardens, scrub, forest and alpine areas (Gill, 1986; Gill & Whitaker, 1996).

4.1.1 Gecko biology

Geckos can slough the outer layers of their skin, either whole or in pieces (Gill & Whitaker, 1996). The species of gecko, availability of food and time of year will affect the frequency of this shedding (Robb, 1980). Most geckos will slough every six to eight weeks in summer, and less often or not at all during winter (Robb, 1980). The eyelids of geckos are fused, and their eyes are covered by an immovable spectacle which they clean with their tongue (Robb, 1980; Gill & Whitaker, 1996; Pianka & Vitt, 2003). The spectacle is sloughed with the rest of the skin and replaced during each moult (Pianka & Vitt, 2003).

Almost all species of geckos have autotomising tails (Pianka & Vitt, 2003). The movement of the severed tail distracts predators so the lizard can escape (Pianka & Vitt, 2003 and references therein). The toe pads on gecko feet are made up of millions of very fine, hooked setae, which are designed to cling to almost any substrate including smooth and vertical surfaces (Pianka & Vitt, 2003). In contrast to most reptiles, geckos can vocalise (Robb, 1980). New Zealand geckos make a range of noises, including chattering, chirping and croaking sounds (Gill & Whitaker, 1996). Several species of nocturnal geckos, including *Hoplodactylus* spp., remain active at very low temperatures, e.g. 11-15 °C (Pianka & Vitt, 2003). New Zealand geckos are believed to be relatively long-lived; repeated surveys of a *H. maculatus* population found individuals that were estimated to be at least 36 years old (Bannock *et al.*, 1999).

Male geckos can be identified by a pair of swellings at the base of their tails containing the hemipenes (Robb, 1980). Males also have an area of pre-anal pores anterior to the vent and femoral pores on the underside of the hind legs; although these pores can be present on female geckos, they are less conspicuous and in smaller numbers (Robb, 1980).

All New Zealand geckos are viviparous (Cree, 1994). Of the more than 800 species of gecko in the world, only New Zealand geckos and at least one New Caledonian species give birth to live young (Cree, 1994; Gill & Whitaker, 1996). New Zealand geckos normally give birth to twins, however, they have low annual rates of reproduction (Cree, 1994; Gill & Whitaker, 1996). Relatively few studies have been done, but several *Naultinus* and *Hoplodactylus* species have annual reproductive outputs of up to two offspring per female per year, and species in regions with lower seasonal temperatures have biennial reproduction, producing only 0.85 young annually (Cree, 1994 and references therein; Cree & Guillette, 1995). This less-than-annual reproduction is not known in any gecko species outside New Zealand; many geckos in tropical and subtropical regions have several clutches each year (Cree, 1994).

New Zealand geckos are omnivorous. Their diet predominantly consists of arthropods (particularly insects and spiders), but they will feed seasonally on fruit and nectar (Gill & Whitaker, 1996). Both *Naultinus* and *Hoplodactylus* species have been observed feeding on the fruits and nectar from a variety of plants, including pohutukawa (*Metrosideros* *excelsa*), southern rata (*M. umbellata*), ngaio (*Myoporum laetum*), flax (*Phormium tenax*), hebe (*Hebe bollonsii*), cabbage tree (*Cordyline australis*), mawhai (*Sicyos australis*) and manuka (*Leptospermum scoparium*) (Whitaker, 1987 and references therein). Geckos could potentially be important as agents of seed dispersal and pollination for some plants as seeds are often ingested whole and remain viable after passing through their gut and large amounts of pollen are often carried on their bodies (Whitaker, 1987; Wotton, 2002).

Squamates have three well-developed chemical sensory systems, suggesting that chemical cues are an important means of communication to these reptiles (Schwenk, 1995; cited in Pianka & Vitt, 2003). They have a nasal olfactory system, a gustatory system and a vomeronasal system (Pianka & Vitt, 2003). Lizards pick up less-volatile and non-airborne chemicals on their tongues and bring them into their mouth, passing them over the ducts leading to the olfactory and vomeronasal systems (Pianka & Vitt, 2003). The chemical sensory systems in lizards enables them to identify species, sex, sexual receptivity, social status and individual identity (Pianka & Vitt, 2003).

Chemoreception mediates many aspects of gecko behaviour, and olfaction is possibly more developed in gekkonids than in any other squamate (Schwenk, 1993). Although little or no available research has looked specifically at the chemosensory abilities of New Zealand geckos, there has been much work done on exotic species. Glands within gecko skin, femoral pores and around the cloacal region produce pheromones used for chemical signalling (Pianka & Vitt, 2003). Actions such as chin-rubbing or wiping cloacal regions on substrates may deposit pheromones with the purpose of communicating with conspecifics (Cooper & Steele, 1997). Studies have found that by using chemosensory cues, various gecko species are able to recognise their own scent, discriminate conspecific sex, detect food and distinguish prey odours (Schwenk, 1993; Carpenter & Duvall, 1995; Dial & Schwenk, 1996; Cooper & Steele, 1997; Downes & Adams, 2001; Regalado, 2003). Keen olfactory acuity is ideally suited to the predominantly nocturnal nature of most gecko species (Schwenk, 1993).

The natural predators of New Zealand geckos are other reptiles (including tuatara) and birds such as the Australasian harrier, kingfisher and red-billed gull (*Larus novaehollandiae*) (Walls, 1981; Towns & Daugherty, 1994; East & Daugherty, 1995).

Naultinus

Geckos in the genus *Naultinus* are diurnal unlike most geckos (Gill & Whitaker, 1996; Pianka & Vitt, 2003). All species are green and they cannot alter their skin colour (Gill & Whitaker, 1996). Their toes are slender, and they have long, tapering, prehensile tails with adhesive pads suited to grasping and climbing through foliage (Robb, 1980; Gill & Whitaker, 1996; Pianka & Vitt, 2003).

Scent of the Marlborough green gecko (*N. manukanus*) was used in this study. These geckos are found only in the Marlborough region (including offshore islands) of the South Island (Gill & Whitaker, 1996). Marlborough green geckos grow up to 68 mm SVL, and they rarely shed their tails (Gill & Whitaker, 1996). The species is green with a pale under-surface, and the soles of their feet are a yellowish colour (Robb, 1980). Their mouth is blue-tinged, with a pink tongue (Towns, 1985; Gill & Whitaker, 1996). They have enlarged scales on the dorsal surface of their head, and scales that form an irregular dorso-lateral line (Towns, 1985; Gill, 1986). Marlborough green geckos are arboreal lizards that live in forest and scrub, mainly in manuka and kanuka (*Kunzea ericoides*) bushes, where they forage for invertebrates (Robb, 1980; Gill & Whitaker, 1996). The breeding season is between June and October, with live young produced the following March or April (Gill & Whitaker, 1996).

Hoplodactylus

The species belonging to *Hoplodactylus* are generally nocturnal, although some will emerge during the day to sun bask (Robb, 1980; Gill & Whitaker, 1996). They are grey-brown, and their colouration can change in intensity (Gill & Whitaker, 1996). Most *Hoplodactylus* geckos have wide toe pads to hold to smooth surfaces (Gill & Whitaker, 1996).

Forest gecko (*H. granulatus*) scent was also used in this study. Forest geckos are distributed throughout most parts of New Zealand, including some large offshore islands (Gill & Whitaker, 1996). They reach up to 89 mm SVL, and are described as one of the most vocal New Zealand gecko species (Robb, 1980; Gill & Whitaker, 1996). Their body colour is variable, mainly in shades of grey and brown, with patches and patterns in black, white and yellowish colours (Robb, 1980; Gill & Whitaker, 1996). They have distinctive white lines from their eyes to their ears (Gill & Whitaker, 1996). The lining of their mouth is yellow or orange, and their tongue is yellow (Towns, 1985; Gill & Whitaker, 1996). The pads on their toes are only slightly widened, and the soles of their feet are yellow (Gill & Whitaker, 1996). Forest geckos are arboreal, living in forest and scrub up to altitudes of 1,400 m (Gill & Whitaker, 1996). They forage in vegetation at night and unless basking in the sun, these geckos will seek cover in crevices or under loose bark on trees during the day (Gill, 1986; Gill & Whitaker, 1996). They give birth to their young from December to March (Gill & Whitaker, 1996).

4.1.2 Current status of geckos in New Zealand

There is no indication of restrictions to gecko distribution prior to human arrival in New Zealand (Towns & Daugherty, 1994). Since that time however, two species of gecko have disappeared from the North Island (Towns & Daugherty, 1994). Using standard IUCN criteria, Daugherty *et al.* (1994) assessed the distribution and status of known New Zealand lizard species. They described 32% of gecko species as rare and 32% as being largely confined to offshore islands (all species were within the *Hoplodactylus* genus). Lizards only became protected under the Wildlife Act of 1981 (Daugherty *et al.*, 1994).

Habitat modification and introduced mammals are cited as responsible for the now-fragmented and restricted distribution of many reptiles, including geckos (Towns *et al.*, 1985; Daugherty *et al.*, 1994; Towns & Daugherty, 1994). Neither terrestrial nor arboreal species of gecko are safe from introduced predators such as ship rats and mustelids (*Mustela* spp.) (Towns & Daugherty, 1994).

Thirty-four species of gecko are listed as threatened in the New Zealand Threat Classification System lists, nine within *Naultinus* and 25 within *Hoplodactylus*. This system describes six *Naultinus* species as being in 'gradual decline' and three as 'sparse' (Hitchmough, 2002). Three species of *Hoplodactylus* are 'nationally critical' (with only one known population for each), four are in 'gradual decline', eight are 'sparse', six are 'range restricted' and four species are 'data deficient' (Hitchmough, 2002). Marlborough green geckos are one of the species described as sparse and forest geckos are not threatened.

4.1.3 Management of geckos

The Department of Conservation has not produced recovery plans for any New Zealand geckos, although they are currently working towards drafting a plan that will cover all threatened gecko species. The recovery plan will identify specific management goals and ways to achieve them, meanwhile the Wildlife Act (1981) continues to legislate for the protection of geckos.

Current methods of surveying and catching geckos include observations from fixed points or along transects during the day and night (using spotlights); searching within crevices, retreats, under logs and in vegetation, capturing them by hand; and pitfall trapping (Walls, 1983; Whitaker, 1987; Thompson *et al.*, 1992; East & Daugherty, 1995; Wotton, 2002; Wilson & Cree, 2003). Many species of gecko are cryptic and well camouflaged in their habitats and can therefore be difficult to identify (Robb, 1980). Visual methods of searching may fail to locate many members of a gecko population, either due to difficulty distinguishing them from their immediate environment, or if they are hidden from sight in inaccessible places.

Using dogs trained to locate geckos may complement the existing visual search techniques. Due to the relatively small size of geckos, dogs may only be useful in locating them in a limited capacity. However, the propensity of geckos to defecate in and near their retreats (Whitaker, 1987) may increase their scent in these areas. The extensive nature of gecko chemical communication may also aid dogs, particularly if New Zealand geckos deposit pheromones on substrates within their home ranges as has been documented for exotic species (Cooper & Steele, 1997). Dogs have a powerful sense of smell and may be able to exploit the chemical signals produced by geckos. Employing a dog trained to detect geckos could potentially lead to more efficient methods of surveying gecko populations.

Gecko-detection dogs have the potential to contribute to the conservation of New Zealand gecko species. This study will examine whether dogs can detect gecko scent in a range of circumstances.

4.2 Methods

This study followed the methods outlined in Chapter 3 (section 3.2), with two distinctions. Firstly, a group of dogs from a different local dog-training club was used. Secondly, the target scent in Trials 1 and 2 was again human scent, but was gecko (Marlborough green gecko and forest gecko) scent in Trials 3-7.

4.2.1 Dogs

The dogs used in this study were sourced from the Feilding Dog Training Club. Members of this club train their dogs for both competitive obedience and agility work, so their dogs are commonly trained to perform scent discrimination exercises.

Thirteen dogs took part in this research (Table 4.1). Two of these dogs (numbers 4 and 8) were also members of the TADTC, and completed trials at both clubs (Tables 3.1 and 4.1). The dogs were a mixture of breed, sex and age, and varied in their level of training prior to this study. Most of the dogs were at the novice or test A level of obedience training (as defined in New Zealand Kennel Club (Inc.), 2005). None of the dogs was trained exclusively for scent discrimination work.

Table 4.1: The dogs that participated in this study from the Feilding Dog Training Club. The dogs received various levels of obedience and agility training, including scent discrimination training, prior to this study.

Dog	Breed	Sex	Age (years)	Level of Training*	Scent training prior to study	Scents used in prior training
4^{α}	German shepherd	Bitch	2.5	Novice	6 months	Human
8^{α}	German shepherd / Staffordshire terrier x	Spayed Bitch	6	Novice	8 months	Human
10	Border collie / Smithfield x	Neutered Dog	3	Novice	3 weeks	Human
11	English springer spaniel	Spayed Bitch	6	Novice	2 months	Human
12^{β}	Flat-coated retriever	Spayed Bitch	7	Test A	3 years	Human
13^{χ}	Golden retriever	Spayed Bitch	6	Test A	1 year	Human
14	German shepherd	Spayed Bitch	9	Test B	2 years	Human
15	Border collie / Siberian husky x	Dog	1.5	Novice	6 months	Human
16^{χ}	Flat-coated retriever	Spayed Bitch	3.5	Novice	6 weeks	Human
17^{δ}	American Staffordshire terrier	Dog	6.5	Test A	1 year	Human
18^{β}	Flat-coated retriever	Neutered Dog	3	Test A	2 years	Human
19	German shepherd	Dog	5	Test A	2 months	Human
20^{δ}	Boxer	Neutered Dog	3.5	Special Beginners	6 months	Human

* The level of obedience training the dogs received prior to the start of this study. The New Zealand Kennel Club categories include 'special beginners', 'novice', 'test A', 'test B' and 'test C', in order of increasing competence.

$^{\alpha\,\beta\,\chi\,\delta}$ The same handler owned both of these dogs.

4.2.2 Study location

Most of the trials were held at the club training grounds located in Feilding, 11 km north of Palmerston North, New Zealand. The club grounds were a large grassed area 54.4 ×

55.5 m, enclosed by 2.5 m high hedging (Figure 4.1). Floodlights were used to light the area during winter.

The scent exercises were run on the same evenings as the club met for training, one night per week. They were held under normal training and working conditions for the dogs and handlers, after the general obedience classes had finished. Approximately 30 dogs were trained at the club in a range of obedience classes each week before the exercises commenced. If handlers were absent from club meetings, the missed scent exercises were held elsewhere at the handlers' convenience.

4.2.3 Experimental protocol

For details of how the equipment was prepared see Chapter 3 (section 3.2.3). However, for these trials the target and decoy cloths were prepared with one of three sources of Marlborough green gecko or forest gecko scent: scats, sloughed skins, or paper towels that captive gecko had been sitting on for several days within their enclosures (the paper towels may also have contained the scent of scats and skins) (Figure 4.2). Gecko samples were received from Victoria University of Wellington, Wellington; Otorohanga Kiwi House and Native Bird Park, Otorohanga; and private breeders Roger and Barbara Watkins and Heather Barton, New Plymouth. All of the Marlborough green gecko samples came from Victoria University of Wellington. The Watkins supplied the majority of the forest gecko samples, and so that samples from the same gecko population (with the same diet and environment) were used for each dog, only samples from these breeders were used (see Appendix 5 for details of the samples used in this study).

The average length of the Marlborough green gecko scat samples was 0.95 cm, the skins were cut in half longitudinally and were an average length of 14.1 cm and the paper towels were 23 × 23 cm. Due to limited resources, the Marlborough green gecko skins were re-used at least three times. The forest gecko scats were an average length of 1.2 cm.

The scent exercises followed the protocol explained in Chapter 3 (see section 3.2.3). The handlers positioned their dogs facing away from the line of cloths, while one of a pair of target cloths was placed in the line (Figure 4.3). The second target cloth was given to the dog to smell, and the dog was required to sniff along the line (Figure 4.4) and retrieve the target cloth (Figure 4.5).

Figure 4.1: Feilding Dog Training Club grounds. Photo: Clare Browne.

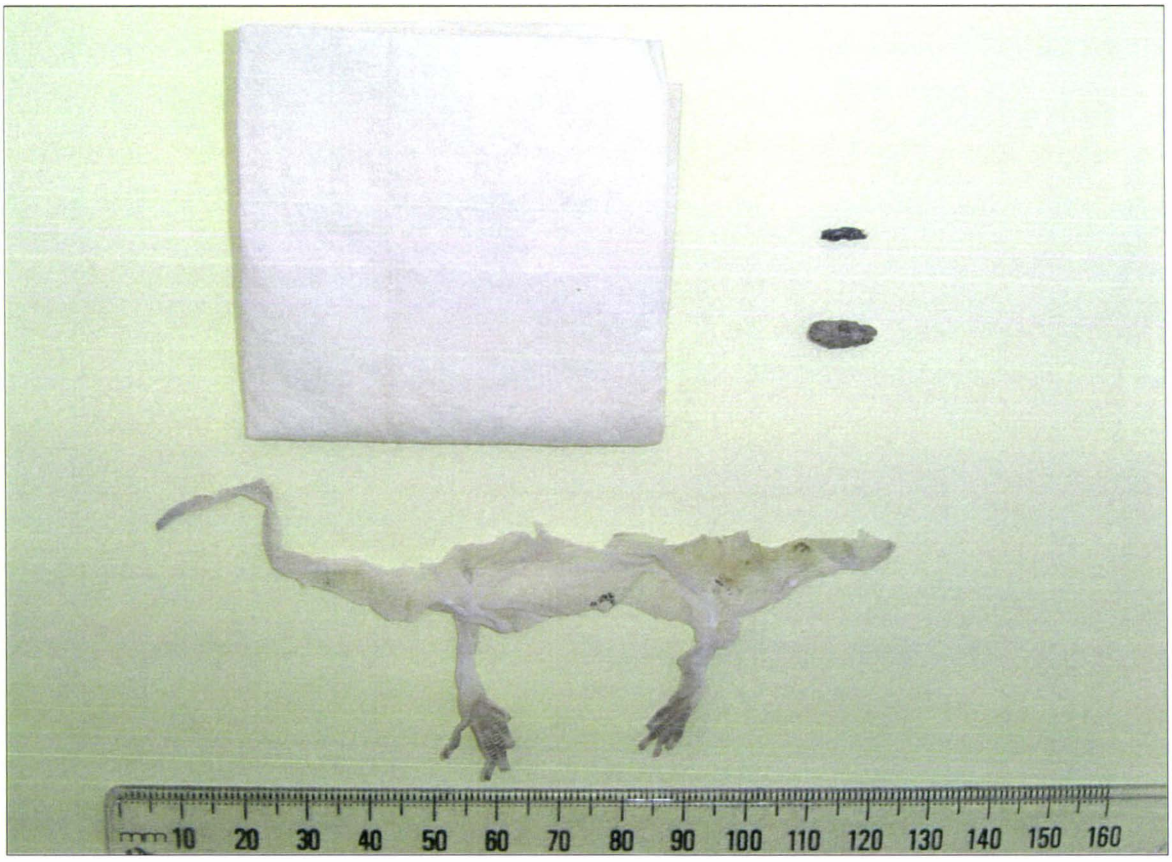

Figure 4.2: Examples of the gecko samples used to scent target and decoy cloths. A Marlborough green gecko-scented paper towel (folded) is on the upper left, half of a Marlborough green gecko skin is along the bottom, a Marlborough green gecko scat is on the upper right, and a forest gecko scat is on the lower right. Photo: Clare Browne.

Figure 4.3: Dog 12 and its handler facing away from the line of cloths while one of a pair of target cloths is placed in the line. Photo: Louise June.

Figure 4.4: Dog 4 sniffing along the line of cloths, searching for the target cloth. Photo: Louise June.

Figure 4.5: Dog 15 retrieving the target cloth. Photo: Louise June.

4.2.4 Experimental designs

Seven scent trials were held at the club, each with a different target scent the dogs were required to identify. Each trial consisted of nine replicate scent exercises, and was intended to run over three consecutive weeks. Marlborough green gecko scent was used in five trials and forest gecko scent was used in one.

The dogs were randomly split into two or three groups in some trials as described in Chapter 3 (section 3.2.4).

Trial 1 – Handlers' scent

The target cloths were scented with the dogs' handler's scent. One of these target cloths was randomly placed amongst seven neutral cloths.

This trial was run for only one week because based on previous experience at the TADTC, this was sufficient to give an indication of each dogs' ability at this most basic of levels.

Trial 2 – Unfamiliar people's scent

People from Massey University, Palmerston North, who were unfamiliar to the dogs scented the target cloths in Trial 2. The dogs had to identify the target cloth from amongst seven neutral cloths.

Trial 3 – Marlborough green gecko-scented paper towels, scats or skins

The dogs were split into three groups, each searching for differently scented target cloths. One group's targets cloths were prepared with Marlborough green gecko-scented paper towels, one with Marlborough green gecko scats and one with Marlborough green gecko skins. The dogs were required to locate one target cloth from amongst seven neutral cloths.

Trial 4 – Marlborough green gecko scats or skins

The dogs were split into two groups for Trial 4. The dogs that had been searching for target cloths scented with Marlborough green gecko scats in Trial 3 were now searching for target cloths scented with Marlborough green gecko skins, and vice versa. The dogs that had paper towel-scented target cloths in Trial 3 were randomly split between the two new groups in Trial 4. One target cloth was placed amongst seven neutral cloths.

Trial 5 – All three Marlborough green gecko scents (paper towels, scats and skins)

This trial involved all three types of Marlborough green gecko scent. One type of gecko scent was the dogs' target scent (on the target cloths), and the other two scented decoy cloths. The dogs were split into two groups: one with scat-scented target cloths and the other with skin-scented target cloths. The two decoy cloths were scented with the two non-target gecko scents. For example, the dogs with scat-scented target cloths had to identify the target cloth from amongst one skin-scented decoy cloth, a paper towel-scented decoy cloth and five neutral cloths. Gecko-scented paper towels were not used as a target scent in this trial. The line of cloths was ordered so that the dogs encountered the decoy cloths before the target cloths (see Chapter 3, section 3.2.4).

Trial 6 – Two gecko species' scats

In Trial 6 the dogs were required to discriminate between the scats of two different species: Marlborough green gecko and forest gecko. The dogs were split into two groups, one searching for Marlborough green gecko scat-scented target cloths and the other searching for forest gecko scat-scented target cloths. One decoy cloth was prepared for each group, scented with the scats of the non-target gecko species. The dogs were required to identify the target cloth from among one decoy cloth and six neutral cloths. The target cloth was placed further along the line than the decoy cloth.

Trial 7 – Weathered Marlborough green gecko scats

Marlborough green gecko scats were placed in young planted native forest for two weeks before being used to scent the target cloths (see Chapter 3, section 3.2.4). The dogs were split into two groups. The first group's target scent was scats that had been completely exposed in the forest; the second group's target scent was scats that had been covered by a plastic container and protected from rainfall (Figure 4.6).

Decoy cloths were also used in Trial 7. They were prepared using soil and leaf litter from the ground immediately surrounding the area where the scats had been placed in the forest. One target cloth was positioned amongst one decoy cloth and six neutral cloths. The cloths were arranged so that the decoy cloth was encountered along the line before the target cloth.

4.2.5 Statistical analysis

If the dogs were randomly selecting cloths, a success rate of one in eight or 12.5% would be expected (see Chapter 3, section 3.2.5). An average success of over 34.6% over nine repetitions of the same scent exercise (i.e. a standard trial) would be statistically significant from chance (95% confidence interval, $p = 0.05$). Over 10 exercises, an average success of over 33.4% would be significant; over 11 exercises, an average success of over 32.4% would be significant; and an average success of 31.6% would significant across 12 exercises (95% confidence interval, $p = 0.05$).

Differences between dogs

Chi-square analysis was used to test for overall differences between the successes of all of the dogs. Percentages of success were calculated per trial per dog.

No statistical comparison was made between the different breeds of dog because the sample sizes in each breed were too small.

Differences between trials

Differences between the results of all trials were tested for using binary logistic regression (see Chapter 3, section 3.2.5). The proportion of the individual dogs' success was used as the response variable in all analyses. The initial analysis used 'dog' (success or failure) as

Figure 4.6: Gecko seats sitting in the forest (in the two pouches on the left), with rain gauge and high/low thermometer. One pouch is covered by a plastic container to protect it from direct rainfall.

the response variable versus 'dog' and 'trial number' as the predictors, and both predictor variables were fitted as factors. On the basis of these results, a second analysis was run in which the influence of the dogs was removed.

Evidence of learning

Binary logistic regression was used to examine whether there was evidence of the dogs learning across the trials (see Chapter 3, section 3.2.5). The response variable in all analyses was the proportion of individual dogs' success.

The initial analyses compared the success of the dogs in Trials 1 and 2 to their success in Trials 3-7. The first analysis used 'dog' (success or failure) as the response variable versus 'dog' and 'Trials 1 and 2 results compared to Trials 3-7 results' as predictors, and both predictor variables were fitted as factors. In the second analysis the dogs were excluded from the model. Based on the results from these analyses, the results from Trials 1 and 2 were removed from further analysis for learning.

Three dogs (numbers 11, 15 and 20) did not perform some scent exercises in sequential date-order (see Appendix 3). However, each dog only completed three exercises out of order, so these were considered to be negligible and these data were not rearranged into date order for this analysis. The success of the dogs across Trials 3-7 was examined for a linear trend. The analysis used 'dog' as the response variable versus 'dog' and 'Trials 3-7 results' as the predictors; only 'dog' was fitted as a factor.

Failed scent exercises

The reasons the dogs failed scent exercises were not compared statistically because the sample sizes were too small.

The chi-square and binary logistic regression analyses were performed using Minitab® Release 14 statistical software. In all statistical tests, significance was accepted when $p < 0.05$.

4.3 Results

Trials at the Feilding Dog Training Club ran from 31 March until 29 October 2003 (see Appendix 3 for a timetable). The total average success for each of the trials varied, as did the performance of individual dogs (Table 4.2). Four dogs (numbers 10, 14, 16 and 18) were withdrawn from the research due to either consistently poor performances or at their handler's discretion.

Most of the dogs' average success rates in the trials are significantly higher than would be expected if they were randomly retrieving cloths (random selection = 34.6% for nine scent exercises, 33.4% for 10 exercises, 32.4% for 11 exercises and 31.6% for 12 exercises) (95% confidence interval, p = 0.05) (Table 4.2).

Table 4.2: The success of all dogs in the seven different scent trials at the Feilding Dog Training Club. The dogs were required to identify a different target scent in each trial. The results are calculated as the average percent correct.

Dog	Trial 1 Handler	Trial 2 Unfamiliar people	Trial 3 Paper towels, scats or skins	Trial 4 Scats or skins	Trial 5 All 3 gecko scents	Trial 6 Two gecko species' scats	Trial 7 Weathered scats	Average
4	100*	100*	88.9	100	88.9	81.8	66.7	89.5
8	100*	88.9*	44.4	100	88.9	63.6	77.8	80.5
10	100	44.4	33.3	-	-	-	-	59.2
11	66.7	77.8	77.8	88.9	77.8	60	44.4	70.5
12	100	100	66.7	66.7	55.6	91.7	55.6	76.6
13	100	77.8	66.7	55.6	77.8	30	-	68.0
14	100	66.7	-	-	-	-	-	83.4
15	66.7	88.9	44.4	66.7	88.9	54.5	77.8	69.7
16	100	44.4	33.3	-	-	-	-	59.2
17	100	77.8	77.8	100	77.8	72.7	88.9	85
18	100	66.7	-	-	-	-	-	83.4
19	100	100	77.8	77.8	77.8	100	77.8	87.3
20	100	88.9	66.7	88.9	100	90.9	55.6	84.4
Average	94.9	78.6	61.6	82.7	81.5	71.7	68.1	

- Dogs withdrawn from the study.

* These data are from Trial 1 and 2 performed at the Tararua Allbreeds Dog Training Club, prior to trials at the Feilding Dog Training Club commencing.

4.3.1 Differences between dogs, between trials and evidence of learning

Differences between dogs

The average success of most dogs varied across the trials, although three dogs (numbers 4, 17 and 19) achieved consistently high rates of success throughout the study (Table 4.2).

The difference between the overall successes of individual dogs was statistically significant ($\chi^2 = 38.984$, DF = 12, p = 0.000).

Differences between trials

When the results of all the trials were compared, taking into account the success of individual dogs, there were significant differences between trials (G = 75.413, DF = 18, p = 0.000). However, the difference between the dogs' success could have accounted for the significance of this model, so the analysis was performed a second time, excluding the influence of the dogs. There was a significant difference between the results of each trial (G = 32.744, DF = 6, p = 0.000).

Evidence of learning

The success of the dogs in Trials 1 and 2 was significantly different to their success in Trials 3-7 (G = 56.735, DF = 13, p = 0.000). When the dogs' success was removed from the model, there was still a significant difference between the results of Trials 1 and 2 as compared to the results of Trials 3-7 (G = 8.519, DF = 1, p = 0.004).

The model analysing Trials 3-7 for a linear trend was significant, although this significance was due to the significant difference between the successes of the dogs. The 'Trials 3-7 results' variable was not significant (p = 0.381), indicating that there was no evidence of the dogs learning across these trials.

4.3.2 Trial 1 – Handlers' scent

The dogs achieved a high average success of 94.9% at finding their handler's scent; success of individual dogs ranged from 66.7% to 100% (Table 4.3).

Table 4.3: Trial 1 results. The target cloths were scented with the dogs' own handler's scent. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Total correct	Percent correct
	1	2	3		
4				9*	100*
8				9*	100*
10	1	1	1	3	100
11	1	0	1	2	66.7
12	1	1	1	3	100
13	1	1	1	3	100
14	1	1	1	3	100
15	1	1	0	2	66.7
16	1	1	1	3	100
17	1	1	1	3	100
18	1	1	1	3	100
19	1	1	1	3	100
20	1	1	1	3	100
Total	11	10	10	49	94.9

* These data are from Trial 1 performed at the Tararua Allbreeds Dog Training Club, prior to trials at the Feilding Dog Training Club commencing.

Trial 1 was completed on one night, 31 March 2003. All of the dogs completed the trial on the same evening. Dogs 4 and 8 had already completed this trial at the TADTC, so did not repeat it at the Feilding club.

The grass at the club grounds had been mown short, and was damp. It rained lightly at times throughout the evening of Trial 1 and there was a slight breeze.

4.3.3 Trial 2 – Unfamiliar people's scent

The dogs correctly selected the cloths scented by unfamiliar people in 92 of 117 exercises (78.6%) in Trial 2; individual dog success ranged from 44.4% to 100% (Table 4.4).

Table 4.4: Trial 2 results. The target cloths were scented with unfamiliar people's scent. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
4	1	1	1	1	1	1	1	1	1	9*	100*
8	1	1	1	0	1	1	1	1	1	8*	88.9*
10	0	0	0	1	1	0	1	0	1	4	44.4
11	1	1	0	1	1	1	1	1	0	7	77.8
12	1	1	1	1	1	1	1	1	1	9	100
13	1	1	1	1	0	1	1	1	0	7	77.8
14	1	1	1	1	1	1	0	0	0	6	66.7
15	1	1	1	1	1	1	1	0	1	8	88.9
16	0	0	0	1	0	1	1	0	1	4	44.4
17	1	0	1	1	1	0	1	1	1	7	77.8
18	1	0	1	0	1	1	0	1	1	6	66.7
19	1	1	1	1	1	1	1	1	1	9	100
20	1	1	0	1	1	1	1	1	1	8	88.9
Total	9	7	7	10	9	9	9	7	8	92	78.6

* These data are from Trial 2 performed at the Tararua Allbreeds Dog Training Club, prior to trials at the Feilding Dog Training Club commencing.

Trial 2 ran from 7 April until 28 April 2003. All dogs completed the scent exercises on the same evenings over three consecutive weeks. Dogs 4 and 8 had also completed this trial at the TADTC, so did not repeat it again.

The evenings when the scent exercises were performed for Trial 2 were dry and without wind.

4.3.4 Trial 3 – Marlborough green gecko-scented paper towels, scats or skins

The dogs were split into three groups in Trial 3, each searching for a different type of Marlborough green gecko scent. They achieved a combined average success of 61.6%, ranging from 33.3% to 88.9% (Table 4.5).

Table 4.5: Trial 3 results. The target cloths were scented with Marlborough green gecko-scented paper towels, scats or skins. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
4	1	1	1	1	1	1	0	1	1	8	88.9
8	0	0	1	1	1	0	0	0	1	4	44.4
10	0	1	0	1	1	0	0	0	0	3	33.3
11	1	0	1	1	1	1	1	1	0	7	77.8
12	1	1	1	0	1	1	0	1	0	6	66.7
13	1	1	1	1	0	1	0	0	1	6	66.7
14	0	0	0	-	-	-	-	-	-	-	-
15	1	0	1	1	0	1	0	0	0	4	44.4
16	0	0	0	0	0	1	1	0	1	3	33.3
17	1	0	1	1	0	1	1	1	1	7	77.8
18	0	0	0	-	-	-	-	-	-	-	-
19	1	1	1	1	1	0	1	1	0	7	77.8
20	1	1	1	1	1	0	0	0	1	6	66.7
Total	8	6	9	9	7	7	4	5	6	61	61.6

- Dogs withdrawn from the study.

The dogs with gecko-scented paper towels as their target scent produced an average success of 66.7%, ranging from 33.3% to 77.8% (Table 4.6). The dogs searching for scat-scented target cloths had an average success of 63.9%, which ranged from 33.3% to 88.9% (Table 4.6). The average success of the dogs with skin as their target scent was 51.8%, ranging from 44.4% to 66.7% (Table 4.6).

Table 4.6: Trial 3 results, showing the three groups the dogs were split into. The target cloths were scented with Marlborough green gecko scats, skins, or paper towels. The results are calculated as the average percent correct.

Dog	Target scent		
	Paper towels	Scats	Skins
4		88.9	
8			44.4
10		33.3	
11	77.8		
12		66.7	
13		66.7	
15			44.4
16	33.3		
17	77.8		
19	77.8		
20			66.7
Average	66.7	63.9	51.8

Trial 3 began on 5 May and ran until 12 July. All dogs performed the scent exercises on the same evenings, with the exception of Dog 20. Dog 20 started Trial 3 one week later than all the other dogs, and completed the final three exercises one and a half months after the other dogs had finished this trial. Dogs 14 and 18 were withdrawn from the study after the first week of Trial 3. The three scent exercises these two dogs performed in the first week of this trial were not included in analysis. Dogs 10 and 16 were withdrawn from further trials after they completed Trial 3.

Dog 8 was on prednisone, a steroid medication, for a fungal infection during all of Trial 3.

Week 3 of this trial was extremely wet, with heavy rain that persisted during all the scent exercises that evening. The weather conditions on all the other nights that Trial 3 was held were very cold, slightly damp and windless. On the final evening of the trial there was a very heavy smell of fertiliser in the air.

4.3.5 Trial 4 – Marlborough green gecko scats or skins

Trial 4 was added to further examine the relatively low success produced in Trial 3. The dogs produced a high average success of 82.7%; success rates for individual dogs ranged from 55.6% to 100% (Table 4.7).

Table 4.7: Trial 4 results. The target cloths were scented with either Marlborough green gecko scats or skins. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise.

Dog	Week 1			Week 2			Week 3			Total	Percent
	1	2	3	4	5	6	7	8	9	correct	correct
4	1	1	1	1	1	1	1	1	1	9	100
8	1	1	1	1	1	1	1	1	1	9	100
11	0	1	1	1	1	1	1	1	1	8	88.9
12	1	1	1	1	1	1	0	0	0	6	66.7
13	0	0	1	1	1	0	1	1	0	5	55.6
15	0	1	1	1	1	0	1	0	1	6	66.7
17	1	1	1	1	1	1	1	1	1	9	100
19	0	1	0	1	1	1	1	1	1	7	77.8
20	1	1	1	0	1	1	1	1	1	8	88.9
Total	5	8	8	8	9	7	8	7	7	67	82.7

The group of dogs searching for scat-scented target cloths achieved an average success of 86.7%, with individuals ranging from 66.7% to 100% (Table 4.8). The dogs with skins as their target scent were successful in 77.8% of the exercises, ranging from 55.6% to 100% (Table 4.8).

Table 4.8: Trial 4 results, showing the two groups the dogs were split into. The target cloths were scented with either Marlborough green gecko scats or skins. The results are calculated as the average percent correct.

Dog	Target scent	
	Scats	Skins
4		100
8	100	
11		88.9
12		66.7
13		55.6
15	66.7	
17	100	
19	77.8	
20	88.9	
Average	86.7	77.8

This trial ran from 16 June until 29 October 2003. The dogs all completed Trial 4 within three consecutive weeks, apart from Dogs 4, 8 and 11, whose handlers were absent from some club training nights. If handlers did not attend several club nights and their dogs had fallen behind the rest by a number of exercises, the dogs would sometimes perform extra exercises on the same night if the handlers thought their dogs were capable of doing so (see Chapter 3, section 3.3.2). Dogs 4 and 8 started the trial one week late, performing scent exercises 1-6 when most of the other dogs were doing exercises 4-9, and completed the final three exercises at the club grounds at a weekend two weeks after the other dogs had finished the trial. Dog 11's handler missed two weeks of club meetings, so performed exercises 1-3 on the same evening as most of the dogs were doing exercises 7-9. Dog 11 then carried out exercises 4-6 of Trial 4 on the same evening as exercises 7-9 of Trial 5, and the final three exercises four months after most dogs had finished the trial.

Dog 4 was on heat during the final two weeks of Trial 4. During this time she seemed less able to concentrate on the scent exercises, and was more easily distracted.

It had been raining heavily on the days of exercises 1-3 and 4-6 (for all dogs excluding 4, 8 and 11), and was very damp with intermittent showers as the exercises were being carried out on both of those nights. The grass at the club grounds was very long on the first evening, but had been mown short by the second week. All other occasions that exercises for Trial 4 were completed were without rain or wind, although the grounds were damp.

4.3.6 Trial 5 – All three Marlborough green gecko scents (paper towels, scats and skins)

Despite Trial 5 being a harder test of the dogs' discriminatory abilities they still achieved a very high average success of 81.5%, ranging from 55.6% to 100% (Table 4.9).

There were 15 failed scent exercises in Trial 5, nine (60%) of which were due to dogs incorrectly retrieving the decoy cloths (Table 4.9). The dogs with scat-scented target cloths retrieved the skin-scented decoy cloths on five occasions, and the paper towel-scented decoy cloth once. The dogs trying to locate skin-scented target cloths retrieved the scat-scented decoy cloths in two exercises, and the paper towel-scented decoy cloth in one.

Table 4.9: Trial 5 results. The target cloths were scented with either Marlborough green gecko scats or skins. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise, D indicates a failed scent exercise when a decoy cloth was retrieved instead of the target cloth.

Dog	Week 1			Week 2			Week 3			Total correct	Percent correct
	1	2	3	4	5	6	7	8	9		
4	1	1	1	D	1	1	1	1	1	8	88.9
8	1	1	1	1	1	1	1	1	D	8	88.9
11	1	1	1	1	1	1	1	D	D	7	77.8
12	1	0	D	0	1	D	1	1	1	5	55.6
13	1	1	D	1	1	1	1	D	1	7	77.8
15	1	1	1	1	D	1	1	1	1	8	88.9
17	1	1	1	1	0	0	1	1	1	7	77.8
19	1	1	1	0	1	0	1	1	1	7	77.8
20	1	1	1	1	1	1	1	1	1	9	100
Total	9	8	7	6	7	6	9	7	7	66	81.5

The dogs searching for target cloths scented with scats made correct retrievals in 82.2% of the exercises, ranging from 77.8% to 88.9% (Table 4.10). The dogs with skin-scented target cloths selected the correct cloths 80.6% of the time, ranging from 55.6% to 100% success (Table 4.10).

Table 4.10: Trial 5 results, showing the two groups the dogs were split into. The target cloths were scented with either Marlborough green gecko scats or skins. The results are calculated as the average percent correct.

Dog	Target scent	
	Scats	Skins
4		88.9
8	88.9	
11	77.8	
12		55.6
13	77.8	
15	88.9	
17	77.8	
19		77.8
20		100
Average	82.2	80.6

Trial 5 started on 14 July and finished on 29 October 2003. All of the dogs completed this trial within three consecutive weeks except Dog 15. Dog 15 performed exercises 1-3 and 4-6 one week later than the rest of the dogs, due to its handler being absent in the first week of Trial 5. Dog 15 completed the final three exercises three months after the other dogs had finished because of the inconvenience of setting up Trial 5 exercises during subsequent trials, which had already began.

Dog 4 remained on heat for the first week of Trial 5. Her behaviour during this week was different to normal; her attention was easily diverted from the scent exercises.

The weather was very cold, but without rain or wind for all three weeks of Trial 5. The grass at the club grounds was long and damp for the first two weeks, but had been mown short by the third. There was a fire close to the grounds in week 2, which filled the area with smoke. The grounds were damp but the weather was fine on the day that Dog 15 completed exercises 7-9.

4.3.7 Trial 6 – Two gecko species' scats

The dogs made an average of 71.7% correct choices in Trial 6; their individual success ranging from 30% to 100% (Table 4.11).

An observer accidentally gave Dogs 4, 8 and 15 the wrong target cloths in the first week, so the trial was extended by one week (Table 4.11). This mistake was made again in the fourth week, but with different dogs (numbers 11, 13, 17 and 20). All dogs had completed at least nine scent exercises by this stage, so the trial was not extended further. The results of the exercises in which the dogs were given the incorrect target cloths were not included in any analysis.

Of the 27 failed scent exercises in Trial 6, eight (29.6%) of them were due to dogs retrieving decoy cloths instead of target cloths. The dogs searching for Marlborough green gecko-scented target cloths retrieved the forest gecko-scented decoy cloths five times. The dogs with forest gecko-scented target cloths incorrectly retrieved the Marlborough green gecko-scented decoy cloths in three exercises. During another two failed scent exercises, two dogs searching for Marlborough green gecko-scented target cloths heavily mouthed (but did not retrieve) the decoy cloths.

Table 4.11: Trial 6 results. The target cloths were scented with either Marlborough green gecko scats or forest gecko scats. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise, D indicates a failed scent exercise when a decoy cloth was retrieved instead of the target cloth.

Dog	Week 1			Week 2			Week 3			Week 4			Total correct	Percent correct
	1	2	3	4	5	6	7	8	9	10	11	12		
4	1	1	1	1	1	1	D	1	1	D	1	1	9	81.8
8	1	1	1	0	1	1	0	1	1	0	1	0	7	63.6
11	1	1	1	0	1	0	0	0	0	1	1	1	6	60
12	1	1	1	1	1	1	1	1	D	1	1	1	11	91.7
13	1	1	0	D	D	0	0	D	0	1	0	0	3	30
15	1	1	1	1	0	0	0	1	0	1	1	0	6	54.5
17	0	D	1	1	1	1	D	1	1	1	D	1	8	72.7
19	1	1	1	1	1	1	1	1	1	1	1	1	12	100
20	1	1	1	1	1	1	D	1	1	1	D	1	10	90.9
Total	8	8	5	6	7	6	2	7	5	7	5	6	72	71.7

The dogs were accidentally given the wrong target scents in these scent exercises. These data were not included in any analysis.

The dogs with Marlborough green gecko scat-scented cloths as their target scent produced an average of 60.9% correct exercises, ranging from 30% to 90.9% (Table 4.12). The dogs searching for forest gecko scat-scented target cloths achieved an average success of 78.3%, which ranged from 54.5% to 100% (Table 4.12).

Table 4.12: Trial 6 results, showing the two groups the dogs were split into. The target cloths were scented with either Marlborough green gecko scats or forest gecko scats. The results are calculated as the average percent correct.

Dog	Target scent	
	Marlborough green gecko	Forest gecko
4		81.8
8		63.6
11	60	
12		91.7
13	30	
15		54.5
17	72.7	
19		100
20	90.9	
Average	63.4	78.3

Trial 6 was held over four weeks, from 4 August to 1 September 2003. All of the dogs, excluding Dogs 11 and 13, carried out the exercises over four consecutive weeks. Dog 11's handler did not attend club on week 3, so the dog performed exercises 7-12 on the final week of the trial. Dog 13's handler was absent in week 2, so exercises 4-6 were carried out on the evening of week 3, and exercises 7-12 were all completed on week 4. Dog 13 was withdrawn from further trials at the completion of Trial 6.

Dog 4 had dermatitis in one ear during the third week of Trial 6. Dog 15 behaved strangely during week 2, continuously and intently sniffing the ground, paying very little attention to the scent exercises.

All evenings during Trial 6 were very cold. Weeks 2, 3 and 4 were also very damp; it rained during the exercises, but there was little wind.

4.3.8 Trial 7 – Weathered Marlborough green gecko scats

The dogs had a total average success of 68.1% (ranging from 44.4% to 88.9%) for finding Marlborough green gecko scats that had been exposed in native forest (Table 4.13).

Nine (39.1%) of the 23 failed scent exercises in Trial 7 resulted from dogs retrieving the decoy cloths. The soil-scented decoy cloths were retrieved six times by the dogs searching for the target cloths scented with Marlborough green gecko scats that had been completely exposed in the forest, and three times by the dogs with target cloths scented with scats that had been covered. In two successful scent exercises two dogs searching for exposed scat-scented target cloths mouthed the decoy cloths, but proceeded to retrieve the target cloth.

Table 4.13: Trial 7 results. The target cloths were scented with weathered Marlborough green gecko scats. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise, D indicates a failed scent exercise when a decoy cloth was retrieved instead of the target cloth.

Dog	Week 1			Week 2			Week 3			Total correct	Percent correct
	1	2	3	4	5	6	7	8	9		
4	1	1	D	1	1	1	1	0	0	6	66.7
8	0	0	1	1	1	1	1	1	1	7	77.8
11	1	0	1	0	0	1	1	D	D	4	44.4
12	1	D	D	1	0	1	1	0	1	5	55.6
15	1	D	1	1	1	1	1	0	1	7	77.8
17	1	1	1	1	0	1	1	1	1	8	88.9
19	1	D	1	1	1	0	1	1	1	7	77.8
20	D	1	1	1	1	0	D	1	0	5	55.6
Total	6	3	6	7	5	6	7	4	5	49	68.1

The dogs with target cloths scented with exposed scats produced an average success of 75%, ranging from 55.6% to 88.9% (Table 4.14). The average success of the dogs with covered scats as their target scent was 61.1%; individual dogs ranged from 44.4% to 77.8% (Table 4.14).

Table 4.14: Trial 7 results, showing the two groups the dogs were split into. The target cloths were scented with weathered Marlborough green gecko scats that had been either completely exposed or covered. The results are calculated as the average percent correct.

Dog	Target scent	
	Exposed scats	Covered scats
4		66.7
8	77.8	
11		44.4
12	55.6	
15		77.8
17	88.9	
19	77.8	
20		55.6
Average	75	61.1

Trial 7 went from 6 October until 20 October 2003. All of the remaining dogs completed this trial in three consecutive weeks.

The weather was dry with no wind on the first and final evenings of Trial 7. The second evening however, was very cold, raining and windy.

The temperatures in the forest where the scats were placed ranged from 0-22 °C, and averaged 11.6 °C (Figure 4.7). The completely exposed scats received a daily average of 3.6 mm of rain, ranging from 0-20.5 mm (Figure 4.7), while the covered scats did not receive any direct rainfall.

Dog 13 was diagnosed with epilepsy after Trial 7 had finished.

4.3.9 Failed scent exercises

There were 149 failed scent exercises across all of the seven trials (Figure 4.8). Eighty-two (55%) failures were due to dogs selecting incorrect cloths (26 (17.4%) of which were decoy cloths), no cloths were selected in 48 (32.2%) and the reasons for 19 (12.8%) failed exercises were unknown (Figure 4.8). When some dogs (especially numbers 4, 11, 12, 13 and 15) failed a scent exercise, they retrieved an incorrect cloth more often than not selecting any cloth at all. This is in contrast to other dogs (i.e. numbers 8 and 14) that were more likely to make no selection when they could not locate the target cloth.

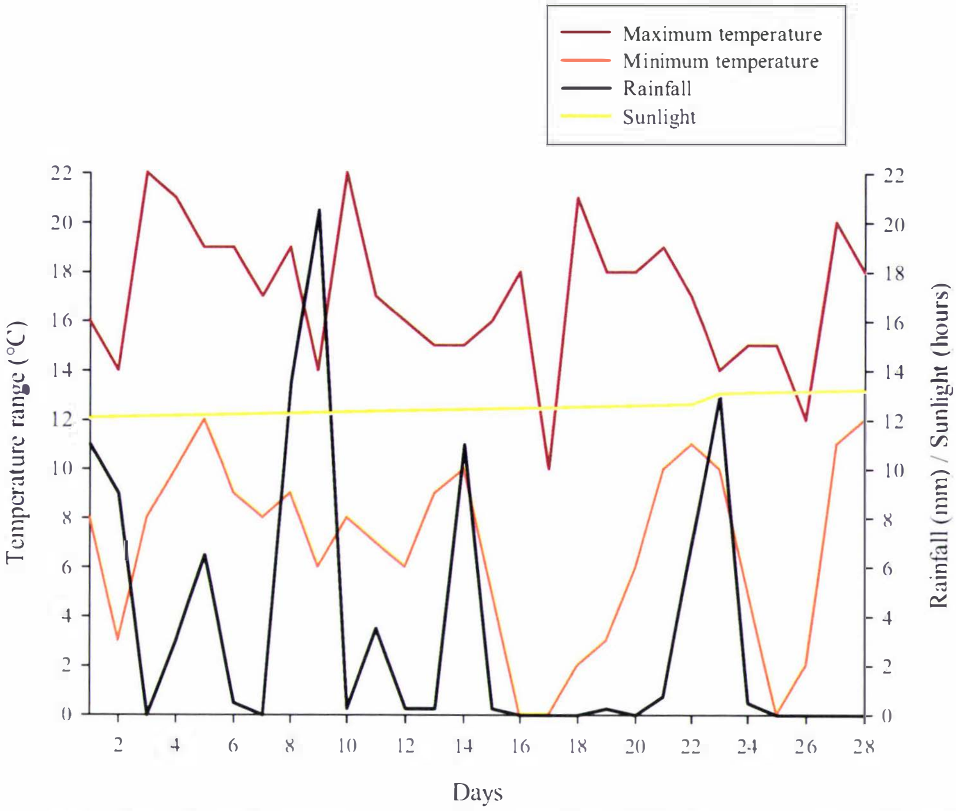

Figure 4.7: The temperature range, amount of rainfall and sunlight hours the Marlborough green gecko scats were exposed to in the forest between 21 September and 19 October 2003. (The covered scats did not receive any direct rainfall.)

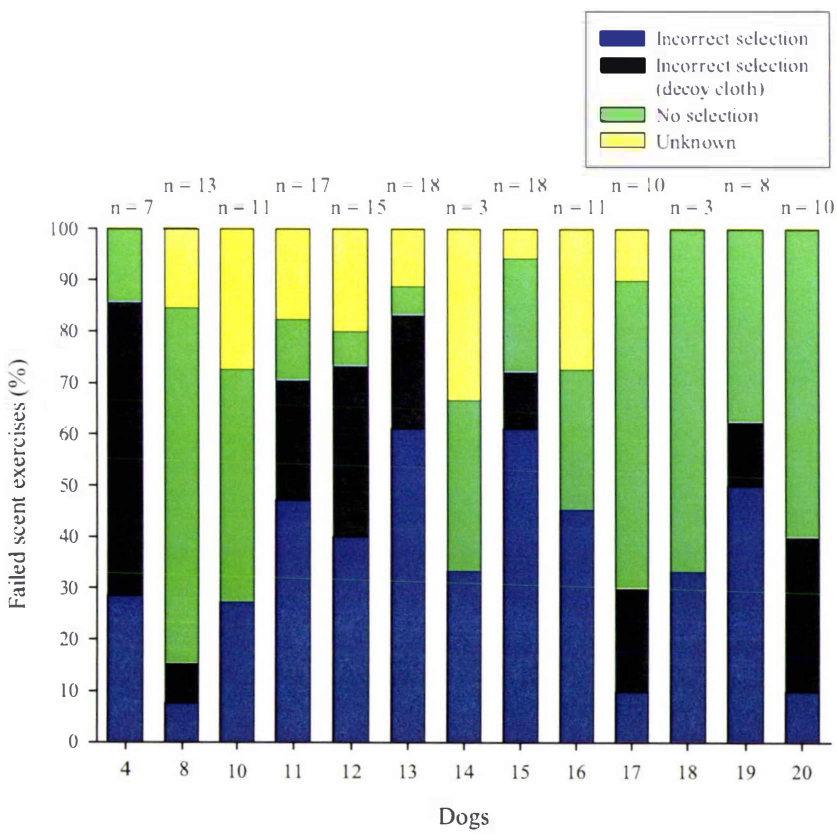

Figure 4.8: Causes of failed scent exercises for each dog, across all scent trials. n = total number of failed exercises.

4.3.10 Dog behaviour during scent exercises

The behaviours of the dogs at the Feilding club were the same as recorded by observers at the TADTC (see Chapter 3, section 3.3.10).

4.4 Discussion

The primary finding of this study is that dogs can detect Marlborough green gecko (*N. manukanus*) and forest gecko (*H. granulatus*) scents. The dogs used in this research were not selected on the basis of their aptitude for scent discrimination work, and they were not trained to detect gecko scent. Despite this, they achieved significant rates of success across the trials. They were able to distinguish gecko scent from neutral scent, identify several types of gecko scent, discriminate between two species of gecko and detect the scent of gecko scats that had been exposed to the weather in native forest.

Some of the methods within the study may have influenced the results and could be modified for future work. Differences in the aptitude and consistency of individual dogs, the handlers' potential influence on their dogs, and variable environmental conditions and distractions, may also have affected the results.

4.4.1 Limitations of the methodology

There are aspects of the methodology that potentially influenced the results (see Chapter 3, section 3.4.1). These include freezing and defrosting the gecko samples before use; using only half a gecko skin to scent each target cloth and re-using some pieces of gecko skin (due to short supply); the variable conditions the weathered scats were exposed to in the forest, and the disparity in odour strength among the scats this may have caused; drying the autoclaved cloths in sunlight; and having numerous observers throughout the study. A trial that required the dogs to identify one gecko species' scent from among a range of gecko and alternative reptile species' scents would have been a valuable addition to this trial. This trial did not take place due to limited supplies of reptile scent and time restrictions. An additional trial in which the target scent was absent was not held because it was outside the scope of the dogs' training and it was not planned at the start of the study (see Chapter 3, section 3.4.1).

Some handlers suggested that certain darker-coloured cloths were difficult for the dogs to see and therefore locate when placed on the grass at night. From the position where the handlers stood at the end of the lines, some of the cloths were difficult to see. However, when walking down the line as the dogs did, all of the cloths were clearly visible upon approach (personal observation). Dogs do not rely on vision when they are searching for scents; in both good and poor light conditions, olfaction is always their dominant sense (Gazit & Terkel, 2003b). For these reasons, it is highly unlikely that the dogs experienced any difficulty in locating the target cloths due to the colour of the cloths.

Trial 4 was added to the study to investigate the comparatively low average success rate (51.8%) the dogs produced when detecting Marlborough green gecko skin in Trial 3. This may have partly been due to the skins being cut in half and re-used, but because only three dogs (numbers 8, 15 and 20) had skin as their target scent in Trial 3, any individual variation in these dogs' detection abilities had the potential to overtly influence the average result. This made it difficult to assess whether the low result was due to poor performances by these three dogs, or if it was indicative of skin being difficult to detect. The dogs that searched for skin in Trial 3 were then in Trial 4 required to locate Marlborough green gecko scats, and vice versa (with the remainder of the dogs being split between the two groups). Almost all of the dogs produced higher success rates in Trial 4 than Trial 3, with Dogs 8, 15 and 20 in particular showing improvement. The higher results in Trial 4 suggest the scent of the skins did not significantly diminish with re-use, and the dogs may have performed uncharacteristically poorly in Trial 3.

4.4.2 The ability of the dogs to detect gecko scent

The dogs were able to reliably detect Marlborough green gecko scent, with average success rates that ranged from 51.8% for skin to 86.7% for scats. When presented with the scent of forest gecko scats the dogs were able to identify it in an average of 78.3% of the scent exercises. Despite the experimental nature of this study and that alternative types of gecko scent were used instead of live geckos, the dogs' success at detecting the scents indicates that dogs could be useful in finding geckos for conservation work. Although geckos are relatively small, they are known for their widespread use of chemoreception for communication purposes (Schwenk, 1993; Pianka & Vitt, 2003). If dogs are able to exploit geckos' chemical signals, this may help dogs to locate them. The current visual techniques of searching for New Zealand gecko species may be necessarily limited due to the cryptic nature of geckos; the use of dogs may complement and enhance these methods.

There are no other published accounts examining the ability of dogs to detect New Zealand geckos. There are currently two dogs in New Zealand trained to find lizards (gecko and skink species) in the field (see Appendix 1 for more information).

4.4.3 The dogs' previous training

The sample of dogs used in this study was selected solely on availability; the dogs were not randomly selected or chosen on the basis of exceptional aptitude for scent discrimination (see Chapter 3, section 3.4.3). Although there was variation between the dogs, the results illustrate that a group of non purpose-trained dogs with varying levels of scent discrimination experience can reliably detect gecko scent. This suggests that a dog specifically trained to detect gecko scent is likely to do so very accurately.

None of the dogs used in this study was specifically trained to detect gecko scent, yet they were able to do so successfully. The only scent they had previously been required to locate was human scent, and the dogs' level of experience in scent discrimination work ranged from three weeks (e.g. Dog 10) to three years (e.g. Dog 12). The amount of scent work the dogs had done prior to this study appeared to have no clear influence on their success rates. The dog with the highest average rate of success across all trials (Dog 4) had only six months training; while the first two dogs withdrawn from the study (numbers 14 and 18), both had two years experience.

Dogs can be more successful at detecting scents if they have had previous experience with them (Schoon & De Bruin, 1994; Kurz *et al.*, 1996; Komar, 1999; Hurt *et al.*, 2000). Although the dogs were introduced to gecko scent for the first time in Trials 3-7, most of the dogs in this study were able to detect the gecko scents with average success rates that were significantly higher than random. However, the results of Trials 1 and 2, when human scent was the target scent, and the results of Trials 3-7 when gecko scents were used, were significantly different, so Trials 1 and 2 results were excluded from analysis for learning (see Chapter 3, section 3.4.3). There was no indication that the dogs learnt, thereby improving their success rates, over the course of all the trials that used gecko scent.

The results of this study are comparable to similar studies (see Chapter 3, section 3.4.3).

4.4.4. Detection of different gecko species

The dogs were able to discriminate between the scent of the scats of two gecko species: Marlborough green geckos and forest geckos, with average successes of 63.4% and 78.3%, respectively. Green and forest geckos belong to two different genera (*Naultinus* and *Hoplodactylus*). The two species have a different geographical distribution, activity patterns and physical characteristics (see Gill & Whitaker, 1996). It is not known how the chemical composition of their pheromones differs. The Marlborough green geckos that provided sources of scent for this study were fed on a diet of Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.). The forest geckos were fed mainly moths, with some flies. Two of the four components of the geckos' diets were the same and two were different. The dogs would almost certainly have been able to detect this dietary difference between the two types of scats, and this may have had some influence on the dogs' ability to discriminate between the two species. It is not known, however, to what extent this affected the results. Ideally both species of gecko would have been fed exactly the same diet (if appropriate). However, since this study relied on receiving reptile samples from external sources, there was no control over this. Scat-detection dogs trained to find scats from one population of animals may hesitate or initially fail to identify scats from another population of the same species fed on a different diet (Hurt *et al.*, 2000; Smith *et al.*, 2003). With sufficient training dogs can rapidly learn to generalise across diets of different populations of the same species (Smith *et al.*, 2003; Wasser *et al.*, 2004). Because dogs have the ability to overcome differences in diet when identifying scats of a specific species it is likely that the dogs in this study were accurately discriminating between the two species of gecko, despite there being some differences in their diets.

4.4.5 Detection of weathered Marlborough green gecko scats

The dogs achieved high average successes when detecting weathered Marlborough green gecko scats. The weathered scats presented to the dogs probably received more rainfall and lower temperatures than scats naturally deposited by geckos in the field during summer months. This may have caused excessive deterioration of the scats and less invertebrate and bacterial action within them, which may mean they produced less scent than scats found in the forest (see Chapter 3, section 3.4.4). Gut passage times are negatively correlated with temperature for lizards (geckos and skinks); the average time it takes for food material to travel through lizards' guts is approximately 11 days at 10 °C and 27 hours at 20 °C (Lawrence, 1997). Dogs working in the field to detect gecko scats (during summer when geckos are most active) would therefore probably encounter scats that were fresher, exposed to less rainfall and temperature variation and subsequently producing more volatile odours. These results suggest that dogs could reliably detect gecko scats in the field.

The dogs achieved a higher average success at detecting the exposed scats (75%) than the covered scats (61.1%), which was unexpected. However, as there were only four dogs in each of the two groups and two dogs performed relatively poorly in the group searching for covered scats, this may explain the difference.

Scat-detection dogs can reliably locate the scats of endangered species. These scats may then be analysed for DNA and hormones, allowing extensive information to be gained about the species in a non-invasive way (Hurt *et al.*, 2000; Wasser *et al.*, 2000; Smith & Ralls, 2001; Kerley, 2003; Smith *et al.*, 2003; Wasser *et al.*, 2004) (see Chapter 3, section 3.4.4). Although this study has demonstrated that dogs could potentially detect gecko scats in the field, gecko scats are very small and therefore their odour is probably spread over a relatively limited area. If scat-detection dogs were able to efficiently locate gecko scats in the field, then it could be a potential alternative method of surveying and collecting information for conservation purposes. Further research needs to done to explore the possibility of dogs being used in this capacity.

4.4.6 Accurate scent discrimination

In Trials 3 and 4 the dogs showed they were able to detect the three types of gecko scent. The aim of Trial 5 was to ensure that the dogs were locating the specific scent, and were not simply selecting the one scented cloth; this was done by adding two decoy cloths to the line of cloths. The dogs produced very high average successes in this trial, for both target scents of scats (82.2%) and skins (80.6%). One decoy cloth was used in Trials 6 and 7 and again, the dogs achieved high average success rates (of 71.7% and 68.1% respectively). These results confirm that the dogs were identifying the correct scents.

Out of the 15 failed scent exercises in Trial 5 (where the dogs were presented with all three types of gecko scent), nine (60%) were incorrect selections of decoy cloths. This suggests that the gecko scents are similar, but still distinguishable by the dogs. Only a small proportion of the failed scent exercises in Trials 6 and 7 were due to decoy cloth retrievals. Cross-contamination between cloths was highly unlikely (see Chapter 3, section 3.4.5).

4.4.7 Limitations of the dogs

Some dogs were significantly more successful than others across all seven trials. Dogs 4, 17 and 19 for example, had success rates that were consistently higher than 77.8%. In comparison, Dog 8's success ranged from 100% in Trials 1 and 4 to 44.4% in Trial 3. Sometimes one dog's performance disproportionately affected the average results for that specific trial (see Chapter, section 3.4.6).

There were times throughout the trials when dogs that were typically consistent failed several scent exercises in a row. Dogs 12 and 15, for example, failed all three scent exercises in the final weeks of Trials 4 and 3 respectively. Both of these dogs had reasonably consistent success rates. Failures that appear to be linked may be attributed to a number of factors, including boredom of the dogs and motivation of the handlers (see Chapter 3, section 3.4.6).

Physical complaints may have contributed to some failed scent exercises. In the course of the study Dog 4 was on heat in weeks 2 and 3 of Trial 4, and week 1 of Trial 5, and had dermatitis in an ear during week 3 of Trial 6; Dog 8 was on steroid medication for all of Trial 3; and Dog 15's behaviour was noticably distracted during the second week of Trial 6. Although the success of Dog 4 did not appear to change during this time, the performance of Dogs 8 and 15 may have been affected. Dog 8 failed most of its scent exercises during the period in which it was unwell, producing its lowest average success of the entire study; this was possibly due to impaired scenting ability caused by the dog's steroid medication (Ezeh *et al.*, 1992). Dog 15 failed two exercises during its week of odd behaviour in Trial 6. Dog 13 was diagnosed with epilepsy after the trials had finished. This dog's undiagnosed condition may have impaired its olfactory abilities (Myers, 1991 and references therein).

4.4.8 Handler influences

The motivation and disposition of the handlers may have influenced the way the dogs behaved and performed in the scent exercises (see Chapter 3, section 3.4.7).

The club training grounds were the most convenient place to carry out the trials, but were not entirely satisfactory. The layout of the area enabled non-participating handlers to observe other dog and handler teams completing scent exercises and therefore the trials were not strictly blind (see Chapter 3, section 3.4.7).

When some dogs failed a scent exercise, they were more likely to retrieve an incorrect cloth rather than retrieve no cloth at all. This inclination to retrieve any cloth, regardless of its scent, may possibly be attributable to the system of reinforcement the handlers used when the dogs completed the exercises (see Chapter 3, section 3.4.7). Some dogs seemed eager to retrieve any cloth in order to please their owner and evoke positive reinforcement (personal observation).

Three scent trials (Trials 3, 4 and 5) were extended for a number of weeks for one to three dogs (see Appendix 3). Interruptions during assessment of scent discrimination work can result in a decrease in accuracy (Settle *et al.*, 1994; Kauhanen *et al.*, 2002); however, these disruptions had no noticeable impact on the success of the dogs. Interruptions are likely for a gecko-detection dog working in the field. Because geckos are ectothermic and more active during summer, a dog trained to locate geckos would probably only work seasonally, with supplementary training during the winter.

4.4.9 Uncontrolled variables

Uncontrolled influences such as distractions from other people and dogs, may have affected the results (see Chapter 3, section 3.4.8). The weather conditions were variable throughout this study, but there appeared to be no obvious relationship between the weather and the success of the dogs.

Overall, the results indicate that dogs can readily detect gecko scent, and therefore there is potential for dogs to be used to find geckos for conservation purposes.

CHAPTER 5

FINAL DISCUSSION AND CONCLUSIONS

Lines of cloths set up at the Tararua Allbreeds Dog Training Club. Photo: Clare Browne.

Lines of cloths being set up at the Feilding Dog Training Club. Photo: Louise June.

Dogs have long been recognised as reliable and efficient scent-detectors. Numerous studies have established dogs' proficiency at locating an extremely wide range of scents including hazardous chemicals, cancerous tissues, microorganisms and various animal species (Arner *et al.*, 1986; Furgal *et al.*, 1996; Crook, 2000; Nakash *et al.*, 2000; Kauhanen *et al.*, 2002; Browne & Stafford, 2003; Pickel *et al.*, 2004; Shelby *et al.*, 2004; Wasser *et al.*, 2004; Willis *et al.*, 2004). The ability of dogs to detect scents is far superior to that of humans (Thorne, 1995 and references therein); and dogs are often more sensitive, reliable and practical than electronic scent-detection devices (Furton & Myers, 2001; Bach & McLean, 2003; Lorenzo *et al.*, 2003).

Dogs are being used increasingly in the field of conservation. Internationally, conservation dogs are used to recover DNA, reduce the need for costly laboratory testing of samples and cause less disturbance to animal populations than traditional methods of study (Hurt *et al.*, 2000; Kerley, 2003; Smith *et al.*, 2003; Wasser *et al.*, 2004). In New Zealand, dogs have been used for conservation purposes since in the 1890s (Hill & Hill, 1987). They have proved to be extremely valuable when searching for endangered species (Best, 1980; Colbourne, 1992; Browne & Stafford, 2003), and are now well-established as a resource for conservation work. Tuatara and gecko are endemic New Zealand species, whose existence has been in a state of decline since the arrival of humans and the ensuing mammalian predators and habitat modification (Towns *et al.*, 1985; Daugherty *et al.*, 1994; Towns & Daugherty, 1994; Cree *et al.*, 1995). This study assessed the potential of using dogs as tools to detect tuatara and gecko species.

The methods used here were quite different to the methods used in most similar research. Many other studies used groups of dogs and/or handlers with prior training and experience in scent discrimination, and tested their scenting capabilities in dedicated, controlled testing facilities (Hawk *et al.*, 1984; Kurz *et al.*, 1994; Schoon & De Bruin, 1994; Settle *et al.*, 1994; Schoon, 1996; 1997; Hurt *et al.*, 2000; Brooks *et al.*, 2003; Kerley, 2003; Smith *et al.*, 2003; Pickel *et al.*, 2004; Shelby *et al.*, 2004; Willis *et al.*, 2004). While such situations are desirable, they are often not a realistic option, and were not available to this study. Some of the conditions in this study (e.g. distractions during scent exercises and the possibility of cloths picking up extraneous odours) may in fact lend some realism to the model; reptile-detection dogs would be faced with a multitude of distractions in the field.

The handlers participated in this research with their dogs voluntarily, and the dogs' previous experience in scent work ranged widely. None of the dogs was trained solely for scent discrimination. The trials were held at times and locations that were convenient to the handlers, which made gathering sufficient data very difficult. Virtually all other similar studies conducted at least some preliminary training with the target scent prior to testing and some also trained their dogs throughout the testing period (e.g. Settle *et al.*, 1994; Brooks *et al.*, 2003; Pickel *et al.*, 2004); the dogs in this study had no prior experience with tuatara or gecko scent. The significant variation between the success rates of individual dogs highlights the importance of selecting suitable dogs for such work and emphasises that dogs and handlers must work well together.

Despite these differences, the dogs in this study could accurately detect a range of tuatara and gecko scents and the results compared well to those of other studies. This suggests that using ordinary dogs and handlers can be a useful model for scent detection and discrimination research. It also indicates that using dogs to detect these reptile species for conservation purposes is certainly a viable option.

Using dogs for the conservation of tuatara and geckos may not provide the extraordinary level of assistance they have given in the past to other species, such as kakapo and kiwi for instance, primarily due to the differing nature of the target species. Kakapo and kiwi are large, strong-smelling, endothermic animals, that can move relatively large distances in short times (e.g. kiwi can travel 1 km in a night) (Colbourne, 1992; McLennan *et al.*, 1996; Hagelin, 2004). A dog can detect scent only when and where it is present, and the size and activity levels of tuatara and geckos may be limiting in this respect in comparison to other target species. However, tuatara- and gecko-detection dogs would offer an alternative to the visual search methods currently used, which are not ideally suited for species that are small, nocturnal, burrowing or cryptic. Surveying reptile populations with dogs may be more efficient and reduce sample bias by detecting more than just the conspicuous individuals.

Using dogs to locate a target species' scats instead of capturing and sampling individuals by traditional methods is not a practice currently used in New Zealand, although it is a field of research rapidly growing internationally (e.g. Hurt *et al.*, 2000; Smith & Ralls, 2001; Smith *et al.*, 2002; Kerley, 2003; Smith *et al.*, 2003; Reindl *et al.*, 2004; Wasser *et* *al.*, 2004). The results of this study show dogs can reliably detect the scent of tuatara and gecko scats. Further research is needed to examine the limits of their scat-detection abilities to determine if this is a practical option.

Tuatara-detection dogs could potentially help DoC achieve the objectives outlined in the current tuatara recovery plan (Gaze, 2001). Dogs could assist with monitoring tuatara population trends and help identify unknown relict populations through their more effective detection abilities. Conservation dogs appeal to a wide range of people, so could be used to boost public awareness of tuatara conservation issues. These benefits also apply to gecko conservation.

Currently there are three dogs in New Zealand trained to detect native reptiles. Each dog can identify one of the three main groups: tuatara, geckos and skinks (see Appendix 1 for more information). The training of the tuatara-detection dog is detailed in Appendix 1, and is a practical extension of the theoretical work in this study.

5.1 Recommendations for Further Research

1. Dogs that have a demonstrated proficiency at scent discrimination work should be used for further research of this nature.

2. Ideally, live reptiles inside perforated, dog-proof containers, should be used for additional research. This would necessitate modifications in the methods, however, because the retrieval would no longer be an ideal indication. Pointing, sitting, or lying down at the target scent, for example, could be substituted for the retrieval.

3. The ability of dogs to discriminate between many different reptile species should be tested (extending the trial in the gecko study in which the dogs were required to differentiate between Marlborough green gecko and forest gecko scents). Ignoring the scent of non-target species is a vital skill for tuatara- or gecko-detection dogs working in habitats where several species of reptiles are present.

4. The ability of dogs to differentiate between reptile species within the same genus should be investigated.

5. The ability of dogs to discriminate between reptiles of different sex and age should be evaluated. Particularly because exotic gecko species are known to be able to do this through chemoreception, and therefore dogs may be able to make use of the chemical signals of geckos and possibly other species.

6. The capacity of dogs to detect reptile scats should be examined further. In order to understand if this is a practical option for conservation work, information such as the dogs' detection range needs to be assessed.

7. Dogs' response to the scent of non-target species in the absence of their target species' scent should be tested.

8. The potential of using dogs to detect other species for conservation work should be investigated. Dogs should be assessed on their ability to detect species such as land snails (*Powelliphanta* spp., *Paryphanta* spp., *Placostylus* spp., *Rhytida* spp. and *Wainuia* spp.), weta (*Deinacrida* spp. and *Hemideina* spp.), frogs (*Leiopelma* spp.) and bats (*Mystacina* spp. and *Chalinolobus* spp.).

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APPENDIX 1

TRAINING A TUATARA-DETECTION DOG: A CASE STUDY

Apple, a tuatara-detection dog, investigating a freeze-dried tuatara (*Sphenodon punctatus*). Photo: Clare Browne.

This appendix describes the training of my own dog, Apple, to detect tuatara (*Sphenodon* spp.) in the field for conservation work. She was selected with the express intention of training her to detect tuatara. Her training was similar to that for cadaver- and mine-detection dogs, based on operant conditioning methods and using mainly positive reinforcement. Throughout Apple's training I encountered difficulties in keeping her motivated, getting her to show clear indication behaviours and gaining sufficient experience in the field. The following sections outline her training in detail.

1.1 Selection of a Dog

Apple is a German shorthaired pointer (GSP) border collie cross, spayed bitch. I selected her at just over eight weeks of age, based on her breeding and her temperament. I considered both GSPs and border collies to be desirable breeds for protected species conservation work. Border collies are hard working and responsive dogs, renowned for their sheep herding abilities (Morris, 2001). German shorthaired pointers are sporting dogs, primarily pointers (although they will trail and retrieve prey), and are considered to be methodical and efficient (Morris, 2001). Both are working breeds, and neither has strong tendencies to use their mouth (an advantage when searching for protected species). Border collies in particular are reputed to be intelligent and eager to please their handler, and have a lot of stamina. I spent quite a bit of time handling and observing Apple before selecting her. As a puppy, she was alert, confident, curious, intelligent and responsive to commands.

1.2 Training Methods

Apple's training was based on operant conditioning theory. Operant conditioning is when an individual associates its actions with certain reinforcing or punishing consequences, and modifies its behaviour accordingly (Ridley, 1995). Reinforcement aims to increase a specific behaviour by either the introduction (positive reinforcement) or removal (negative reinforcement) of a stimulus; punishment aims to decrease a specific behaviour, again, by either introducing (positive punishment) or removing (negative punishment) a stimulus (Martin & Pear, 1999). I employed mainly positive reinforcement to train Apple to detect tuatara scent. She is extremely play-motivated, so allowing her to play with a toy or myself as a reward for a correct response, formed the basis of the positive reinforcement using throughout her training.

Shaping is an aspect of reinforcement that was used to teach Apple to indicate when she had pinpointed tuatara scent. Shaping is the process of reinforcing successive approximations of a desired behaviour, until a behaviour that was not previously performed by an individual has been taught (Eggen & Kauchak, 2001). It is important that the steps used in the shaping process are flexible, to account for different styles and rates of learning.

Because continuous reinforcement (i.e. after every correct response) produces the fastest rates of initial learning (Eggen & Kauchak, 2001), positive reinforcement was applied to every correct behaviour Apple displayed in the early stages of her training. This also functioned to keep her motivated and enjoying the training.

Other aspects of Apple's training that were important to her eventual success as a tuatara-detection dog include her socialisation and physical condition. Conservation dogs are often exposed to large numbers of different people through their work, and they need be accustomed to using many modes of transport including boats, planes and helicopters (Browne & Stafford, 2003). Whenever possible, I took the opportunity of exposing Apple to different people, loud noises (i.e. trains, aeroplanes, road works, etc.) and travel in vehicles, in order to accustom her to a variety of experiences and establish her trust in me when we encountered novel situations. Conservation dogs are often required to search long hours for their target species in rough terrain (Browne & Stafford, 2003). Physical conditioning can improve dogs' sense of smell (Altom *et al.*, 2003), so I maintained Apple's fitness at a high level.

1.3 Teaching the "Find" Command

My aim was to teach Apple the command "find", meaning that she had to search for a specific object hidden from view. I did this with her on a daily basis by playing games in which she had to search for hidden items. Because of her strong play-motivation, the hidden object was initially her favourite toy, a tennis ball, and her reward was being allowed to play with the ball when she found it. This method of positive reinforcement was extremely effective in motivating her to search for the ball.

I gradually increased the difficulty of the search games. To begin with, I threw a ball directly in front of her and said, "find". She would run to the ball and be rewarded with verbal praise and play with the ball and myself. I then advanced to throwing the ball out of her line of vision (i.e. behind a bush), saying, "find". She would go to the area where she saw the ball disappear, and search for the ball. She adjusted to this small change very easily, and searched every time until she found the ball.

The next progression in this training was to restrain Apple out of sight (i.e. inside a building), and place the ball in open view. I would then bring Apple outside, and tell her to "find". By this stage she knew the command "find" meant to locate her ball, and would start searching for it without hesitation. Because the ball was placed in full view, she was able to find it very quickly; this behaviour was instantly reinforced by a game with the ball and myself. This step was then extended further. I hid the ball out of sight (i.e. under a shrub or in a garden) while Apple was shut indoors. She was released outside, and commanded to "find". She was unable to see the ball, so this exercise required her to thoroughly search the area and use her sense of smell to locate the ball.

When Apple was approximately nine months old, I started using the command "find" on a range of different objects so that she did not associate the command exclusively with tennis balls. This was done in the same way, by hiding the objects in progressively more difficult exercises, and rewarding her with play once she found them. She was able to rapidly generalise the "find" command to any object we used.

1.4 Tuatara Scent Training

The training methods I used to teach Apple to detect tuatara scent were very similar to those for cadaver and mine-detection dogs (Rebmann *et al.*, 2000; Hayter, 2003). My goal was to get her to generalise the scent of all species of tuatara (*S. punctatus, S. punctatus punctatus* and *S. guntheri*). I aimed to achieve this by using tuatara scents from as many different individuals as possible. I hoped by doing this Apple would learn to generalise across the two species (and the sub-species) of tuatara, individuals, sex, age and diet. This follows the training methods of other detection-dogs (e.g. Wasser *et al.*, 2004).

Most of the training took place in paddocks at Massey University, Palmerston North, although much of the indication teaching was done at my house. The training sessions were kept short to maintain Apple's interest, particularly in the initial stages. Most sessions lasted 10-15 minutes, although some went for up to 40 minutes in the later stages of her training.

Due to the absolute protection status of tuatara, tuatara-scented paper towels, tuatara scats and sloughed skins were the resources most available to me for training. So that I did not contaminate the tuatara scent with my own scent, I placed the samples inside perforated plastic jars and used these jars during Apple's training. To ensure that she was not looking for the scent of the jars, I also used some decoy jars, which did not contain tuatara scent. I used samples from as many individual tuatara as possible. I wanted Apple to learn to generalise the scent of tuatara; and her searching not be constrained by an animal's diet, a specific individual's scent, sex, or the age of the sample.

Tuatara are ectothermic reptiles reaching 250 mm in SVL (Cree, 1994). Although they can move rapidly tuatara spend much of their time motionless. The scent from these animals may travel a shorter distance in comparison to other protected species (e.g. kiwi, which are endothermic and much more mobile). A relatively shorter detection radius, combined with no chance of an intrinsic reward for a dog finding a tuatara (i.e. it is not allowed to treat the tuatara like a true prey item and kill it), may mean that searching for tuatara is not particularly exciting for a dog. The act of finding tuatara was probably not going to be stimulating enough to motivate Apple to search for prolonged periods of time. Therefore, I had to find a way to make tuatara-detection exciting. I decided that because the actual tuatara would not be a reinforcer, I had to use extrinsic reinforcers. Because she is very motivated by play, I chose highly arousing toys and play. I used rubber toys (some that squeaked), which she could chew and we could wrestle with, as positive reinforcement when she located tuatara scent.

1.4.1 Initial scent training

Apple was first introduced to tuatara scent when she was three and a half months old (August 2002). No formal training was done with it at this time; some paper towels that captive tuatara had been sitting on in their enclosures were put inside a perforated container and placed near her basket. I drew her attention to it several times, and repeated the word "tuatara".

At 10 months of age (March 2003), I started training Apple to detect tuatara scent. She was very interested in it. I started associating the word "tuatara" with the scent by repeating it and giving her verbal praise each time she smelt the samples. I set up a basic search exercise as I had previously done with toys and other objects, and told her to "find" the "tuatara". When she located the tuatara scent, I immediately rewarded her with a game of tug of war on her leash. We did short training sessions (10 minutes long) such as this at least once a week. After several weeks she started to find the tuatara scent and then instantly look to me and for the leash to play with. I continued to reinforce this response, because my ultimate aim was for her to indicate her find to me without touching the tuatara. We did all of this initial training at home, preferably outside, but inside if the weather was poor.

When Apple was 11 months old (April 2003), I noticed a slight change in her search behaviour. When she was tracking a scent, she held her tail very high and rigid, and it quivered. She had also started to 'quarter' the wind (working up the wind and moving sideways across the air currents) when searching. By this stage Apple was absolutely focused on her task when she was scenting; it was very difficult to get her attention or break her concentration. She would ignore food, people and other dogs while trying to locate a scent, and was 100% successful at finding all scents that I hid for her. We did scent training at home, in some paddocks at Massey University and at a dog exercise area along a section of the Manawatu river.

By the time Apple was 14 months old (July 2003), I was confident that she recognised tuatara scent and was associating the word "tuatara" with it. At this stage I was getting volunteers to hide tuatara scent for Apple to find, so that she did not always associate my scent with tuatara scent. While I held Apple's attention, the volunteers would drop a scent jar as they walked through a paddock (traversing it randomly several times, so they did not leave a single scent trail leading straight to the tuatara scent), or they would throw the scent jar across a paddock. Apple found all of the hidden scents without difficulty. I also started putting a harness on Apple during scent training sessions. The aim was for the harness to be a signal to her that she was working, and I noticed that she settled down quickly once I put the harness on her.

When Apple was 15 months old (August 2003) and we had carried out a substantial amount of scent training in several different locations, I realised that she needed at least 10 minutes before she would settle down and be ready to work. I always allowed her to investigate the area we were going to be working before expecting her to work efficiently. I also noticed that Apple had started to search in a radius around myself. As I moved across a paddock, she searched the area that I moved into.

I started getting Apple accustomed to wearing a muzzle on when she was 16 months old. I concentrated on doing just basic obedience work (heeling, sitting, lying down, etc.) while she was wearing her muzzle. She worked well while wearing it, although it was clear she preferred to be without it.

When Apple was about 17 months of age (October 2003), I felt that she had successfully mastered the type of scent exercises I had set her to date, and started preparing more difficult ones. I constructed some small (5 × 5 cm) mesh pouches (similar to those used to contain the scats I placed in the bush during Trial 7, see Chapter 3, section 3.2.4), which were secured to the ground with metal pins. I set up a series of scent exercises in which tuatara scats and skin fragments were put in separate pouches, placed in paddocks, and left for 3-24 hours before getting Apple to find them. Although she found these exercises more difficult, she still managed to locate the tuatara scent approximately 80% of the time without any assistance (i.e. verbal or physical cues).

1.4.2 Problems with motivation and indication

In early October 2003, I started having difficulty identifying when Apple had located a tuatara scent. The changes in her body language were minute. She often ceased searching when she found the scent, no longer looking to me for a game, although she still reacted extremely enthusiastically when I approached her with positive reinforcement. Apple also seemed to lose her motivation to search for tuatara scent. During scent training exercises she was clearly uninterested, and I could not get her to focus, despite my best efforts at rewarding her for finding the scent with her favourite games, toys, or food.

I arranged for Apple and I to be assessed for the interim certificate at the end of October, deciding to take a break from scent work until after the test and concentrate solely on her obedience work.

New Zealand conservation dog certification

The Department of Conservation has a set of standards that all conservation dogs in New Zealand (protected species dogs and predator dogs) must meet (Browne & Stafford, 2003). This consists of a certification system split into two stages. The initial 'interim training certificate' tests the general obedience of the dogs, the dogs' fitness, how well the handlers work with their dogs and the handlers' experience with both dogs and the target species. The full certificate is issued on a successful field assessment of both the dogs and handlers working on the targets species. This final stage often uses live animals and non-target species.

For the rest of October 2003 I did daily obedience training with Apple. I focused on things we would be examined on in the interim certificate test which included Apple walking at heel (on and off leash); her sitting and lying down on command and staying down while I was out of sight; stopping instantly on command while at a distance from me; coming to me when I called her; and working well while wearing a muzzle. We trained on our morning walks (usually along the Manawatu river), at Massey University and at a local dog obedience club (TADTC). On the morning of 27 October 2003 we did some obedience training in the paddocks at Massey University where the test for the interim certificate was to be held. In the afternoon we sat and passed the interim certificate.

At the end of November 2003, when Apple was 18 months old, I decided to take a slightly different approach to the scent training in an effort to increase Apple's motivation to search. Although Apple could competently detect and locate tuatara scent, I took a step backwards in her training to try and get her enthusiastic about searching again. Using tuatara scent inside a perforated jar as usual, I held her at my side, and threw the jar a few metres in front of her. I then told her to "find the tuatara", and released her; she ran to the jar and found it easily. I reinforced this behaviour immediately with verbal praise and play. I continued with these very simple exercises for several training sessions, always stopping before Apple showed any signs of boredom. In each successive session, I increased the difficultly of the exercise slightly, i.e. by throwing scent-containing jars and decoy jars, and increasing the number of decoy jars. Her body language was much more positive: her tail was held high and moving fast, and she was searching well once more. Up until this stage in her training, Apple had shown no inclination to mouth or retrieve the tuatara scent. But when I started throwing the jars directly in front of her, she sometimes picked them up. I told her to drop them, but did not punish her in any way because I didn't want to dampen her enthusiasm.

It was at this point that I started to shape Apple's behaviour into a clear indication. I eventually wanted her to lie down when she found a tuatara in the field. I set up a line of six jars, two of which contained tuatara scent. I walked Apple along the line of jars, and encouraged her to sniff each jar, saying, "find the tuatara". When she came to a scented jar, I commanded her to lie down and immediately reinforced this with verbal praise, play and sometimes food. The third time we walked along the line, she lay down when she detected the tuatara scent without me prompting her. I also arranged jars in a circle and did the same thing, saying "no" if she attempted to mouth the jars. After three days of such training, Apple was lying down independently when she located the tuatara scent approximately 70% of the time.

When Apple reached 19 months of age (December 2003), I started to muzzle her during scent training exercises. Initially I put the muzzle on for only part of a training session, because it seemed to irritate her, particularly when she was searching in long grass. I gradually increased the length of time I left it on during each scent training session.

1.4.3 Apple's first encounter with live tuatara

In mid-December 2003 (at 19 months old), I took Apple to Nga Manu Scenic Reserve in Waikanae, to participate in their annual 'tuatara dig'. They held approximately 400 captive tuatara, and dug them up once a year to monitor their progress by weighing and measuring them. We went there on the final two days of the dig. Only a small number of tuatara remained to be found by this stage, and I took Apple to see if she could help locate the final animals.

The tuatara were kept in pens (approximately 1 × 2.5 m) inside large enclosures. I took Apple into an enclosure and showed her one of the tuatara that had already been found; this was her first introduction to live tuatara. She was extremely interested in the animal, but made no attempt to touch or mouth it at all. I repeated "tuatara" to her several times, and gave her quiet verbal praise when she remained interested but calm. I allowed her approximately 15 minutes to become accustomed to the surroundings. I then lifted Apple up onto the edge of a tuatara pen and let her smell the area. I told her to "find the tuatara", and she searched intently (Figure 1.1 (a-b)). She moved very quickly through each pen, and I directed her to sniff into burrows and vegetation. The conditions were difficult to work in, because the ground in many of the pens was unstable due to the many burrows the tuatara had dug, and I was concerned that it might collapse under Apple's weight or that she may accidentally step on a hidden tuatara. Because of this, I tried to slow her searching down by keeping her leash short and holding on to her. She lay down in three pens, although when I searched these pens I could not find any tuatara. Because I could not confirm the presence of an animal, I was unsure whether to reinforce her behaviour or not. I decided to do so, because the entire area would have been heavily scented with tuatara, so it was likely she was indicating correctly (even if it was only concentrated scent and not an actual animal she had found). When someone else later searched those three pens, a tuatara was found in each; so she probably had located animals that I failed to find myself.

a)

b)

Figure 1.1: Apple searching for captive tuatara at Nga Manu Scenic Reserve, Waikanae. a) Apple sniffing an excavated tuatara burrow; b) Apple being directed by myself to search down another burrow. Photos: Rhys Mills.

After two and a half hours of searching on the first day, Apple was no longer concentrating, so I stopped working with her. On the second day, Apple worked for about one and a half hours before losing motivation to keep searching. She did not seem to enjoy working as much on the second day. I thought that she could be frustrated being made to work slowly and carefully through the pens; so I did not push her to keep working.

1.4.4 Re-training the indication behaviour

For the next two months (January and February 2004) I continued to do scent training two or three times per week. Apple was reliably finding the tuatara scent in all exercises. Although she had previously been doing well with her indication behaviour (lying down), it now seemed she had once more reverted to displaying very unclear behaviour when she located tuatara scent. This was disappointing and frustrating, so I decided to again, backtrack in her training, and re-teach the indication behaviour step by step. I focused on getting her obsessed with particular toys, which I intended to use as positive reinforcers for the indication training. On an almost daily basis I played with her with a small number of specific toys that she found highly arousing. Apple was allowed access to these toys only when we were playing together, or during scent training.

I used scent boxes to re-train Apple's indication behaviour when she was 21 months old (February 2004). The boxes were identical in appearance (32 × 22.5 × 25 cm) with a 5 cm diameter hole cut out of one of their sides close to the ground (Figure 1.2). Inside the boxes were jars (without lids), facing towards the hole in the box, where scent was placed. Initially only one box contained tuatara scent and four boxes contained empty jars. Holding a toy in one hand, I led Apple along the line of boxes, encouraging her to sniff each box where the hole was, saying "find the tuatara". When she reached the box containing tuatara scent, I immediately praised her verbally and played vigorously with her using one of her training toys. I varied this exercise by increasing the number of boxes and setting up the boxes in different places (i.e. inside my house, my backyard, my front yard, etc.). After four days of this training, with short training sessions (5-15 minutes) up to twice daily, Apple was responding extremely well. She moved along the line of boxes very quickly, and as soon as she detected the tuatara scent she looked to

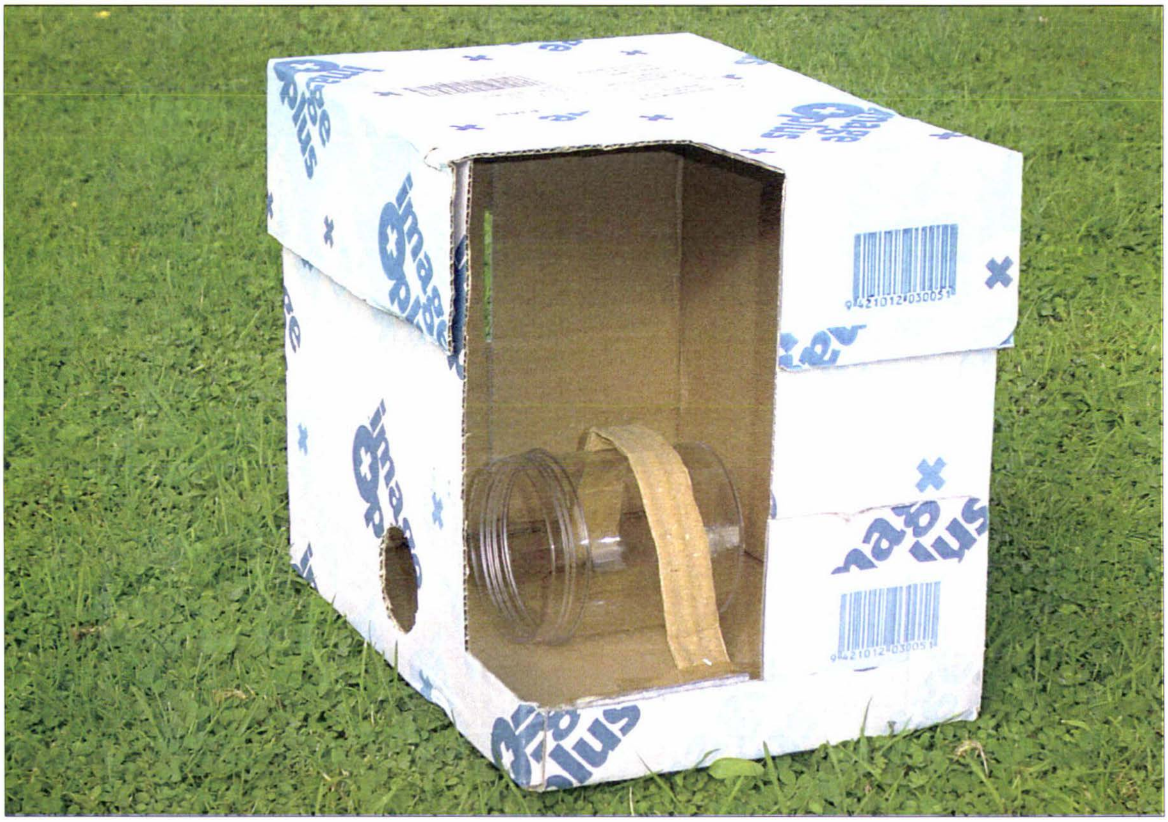

Figure 1.2: Example of a scent box. The corner is cut out so the jar inside the box is visible. The jar either contained a tuatara sample or was empty as a decoy. Photo: Clare Browne.

me to play with the toy. She appeared to be very motivated to obtain the toy, and understood she only got the toy once she had found the tuatara scent. At this point Apple seemed to start becoming bored with the exercises. They were very simple tasks, and she was able to find the tuatara scent very rapidly. I decided to teach her the next step in the shaping process, which was to lie down when she located the tuatara scent. Whenever Apple found the tuatara scent, I verbally praised her and told her to lie down. The instant she lay down, I reinforced this behaviour with verbal praise and vigorous play. In the first such training session, we performed three repetitions of the same exercise, with me prompting her to lie down each time. In the second training session a few days later, we did three exercises, and Apple lay down without prompting when she found the tuatara scent in the third exercise. After two more training sessions on different days, Apple was indicating the location of tuatara scent by lying down in front of it every time. I then returned to hiding tuatara scents inside perforated jars in the paddocks at Massey University, around my backyard or inside my house if the weather was too bad. We continued to train up to twice per week.

1.4.5 Trip to Tiritiri Matangi Island

In April 2004 (when Apple was 23 months old) Apple and I travelled to Tiritiri Matangi Island for five days. The island is a Scientific Reserve in the Hauraki Gulf, north east of Auckland. Sixty tuatara had been released on the island five months prior to our trip. Our goal was to assist an Auckland University Master of Science student, Jonathan Ruffell, who was studying this tuatara population, by locating the animals. Although Jonathan had recaptured several individuals, the majority of the animals had not been sighted since their release.

We searched in areas of the island where the tuatara had originally been released. We walked along random transects radiating from the release points. Apple strongly indicated by instantly lying down at least 11 times during the trip. She made some of these indications in front of what were very likely to have been tuatara retreats (i.e. burrows under fern fronds and leaf litter), and where there were scratch marks in the soil, characteristic of tuatara. Unfortunately, however, I could not confirm the presence of tuatara on any of these occasions because we were required to not disturb any potential tuatara retreats. When this occurred, I reinforced Apple's behaviour with verbal praise and play, trusting that she had detected tuatara scent. When we had been searching for some time with no sign of Apple detecting tuatara scent, I planted some tuatara scent for her to find. She always found these successfully. This served to keep her motivated and focused on searching (Wasser *et al.*, 2004).

Human searchers found two tuatara on separate occasions. The first was during the day in an area close to where we were searching; the animal did not appear to be well, and we only spent about ten minutes with it. The second tuatara was spotted at night; we took it back to the bunkhouse where I trained Apple for at least 30 minutes with it. She was very interested in both animals. When I told her to "find the tuatara", she lay down next to them. I attempted to reinforce this behaviour with verbal praise and play, but on both occasions she was more interested in the tuatara. She was extremely focused, but remained calm and did not attempt to touch or approach either of them too closely.

I had anticipated Apple being distracted by the birds on the island, as she had received very little aversion training. North Island robins (*Petroica australis longipes*) and fantails (*Rhipidura fuliginosa*) often followed us through the bush. When Apple became overly attentive towards these birds, I punished her with verbal reprimands and leading her away from the birds. Apple was extremely distracted by birds for the first two days, but paid them less attention after that.

Apple worked well, frequently searching in both weather conditions (windless, and either dry or extremely wet) and areas (dense scrub) that made it difficult for scent to move or pool. Unfortunately our DoC permit did not allow us to search at night. Given that tuatara are nocturnal reptiles and maximum numbers of tuatara are above ground between 2130-2230 h (Walls, 1983), night searches would probably have been a more effective way to search. However, groups of people went searching for tuatara at night on several occasions, and only one tuatara was seen (the aforementioned one we captured and Apple worked with). This suggested that the tuatara were not particularly active, which would have resulted in very little scent being spread around.

After this experience, I concluded that Apple could recognise the scent of tuatara and knew how I wanted her to respond when she detected a tuatara. From this point on, her training would benefit the most if trained with only live tuatara. Other conservation dog trainers I consulted about this agreed. Despite this decision, I did do several training sessions with tuatara scent before going to Hamilton with Apple.

1.4.6 Training Trip to Hamilton

There are currently two other dogs in New Zealand trained to detect reptiles, one is used to locate geckos and the other works with skinks. In June 2004 (Apple was two years and one month old), we travelled to Hamilton for two days to meet with the national co-ordinator of the DoC conservation dog program, John Cheyne, and the two other reptile dog handlers, Keri Neilson and Mandy Tocher (DoC employees). The trip was for us to meet, discuss training methods and do some training with our dogs. Hamilton Zoo let us have the use of a 20 year old male tuatara (*S. punctatus*) for both days. The tuatara was placed inside a sturdy plastic tube, perforated to allow airflow, with a removable cap at one end (Figure 1.3). This meant the tuatara could be safely hidden in vegetation without any chance of it escaping or Apple accidentally damaging it.

We worked in a patch of native bush within the Pirongia Forest Park, outside Hamilton city. The tuatara was repeatedly hidden in vegetation along the edges of a clearing and in the bush, without Apple or myself seeing where it was placed. I worked Apple on a long leash (Figure 1.4) for the first two searches, and worked her off-leash after that. She found the tuatara each time. On several occasions she returned to me when she had located the tuatara, without lying down. When I prompted her to show me where it was, she returned to the spot where the tuatara was located, and lay down. I reinforced this behaviour with verbal praise and play.

Apple lost interest in searching after we had repeated the exercises a number of times on both days. When this happened, we removed the tuatara from the tube and showed it to her. She instantly became much more animated and was very interested in the animal. I reinforced this interest with verbal praise, and repeated the word "tuatara". When the tuatara was hidden in subsequent exercises, Apple was much more motivated and searched really well.

Figure 1.3: Tuatara inside a dog-proof, perforated plastic tube. Photo: Clare Browne.

Figure 1.4: Apple searching for a hidden tuatara, working on a long leash, with John Cheyne watching. Photo: Kara Goddard.

The final exercises we did with all three dogs was to present them with a range of non-target pest species (birds and mammals), and all three reptile species (tuatara, geckos and skinks). Apple did very well at ignoring all of the pest species, except for one particularly rotten possum that she was interested in. She also successfully ignored both the geckos and the skinks, and located the tuatara. Both the gecko- and skink-detection dogs also found their target reptiles, ignoring the non-target species.

Both the gecko- and skink-detection dogs achieved full certification in late 2004.

1.5 Maintaining Apple's Training

Although Apple was still lying down reliably when locating tuatara scent, her body language now changed almost imperceptibly before she did so. After spending some time searching for live tuatara, she now tensed whenever she detected the scent, and I was able to recognise this change in her before she lay down. Being aware of this change in Apple's behaviour, prior to her indication, made it much easier for me to effectively reinforce it when she located a tuatara.

When Apple was two years and five months old (early October 2004), John Cheyne came to see how Apple's training was progressing. I had not done any scent training with Apple for several months. This was because I wanted her to focus on actual animals now, rather than their scent. Unfortunately there was no possibility of getting a live animal to train with without travelling out of town, and John wanted to set up some scent exercises for Apple and myself at Massey University. The only option was to use tuatara scent with which I had initially trained her. The day before our meeting, I set up four scent exercises in a paddock at Massey University and spent approximately 40 minutes working with Apple. She had retained all of her training and performed very well. On the day of our meeting John hid three tuatara scents (paper towels) in a paddock of long grass and regenerating native bush. Neither Apple nor I knew where they were located. Apple found all three tuatara scents. She located the first two relatively easily, while the third took her longer to find. We completed the entire exercise within about 15 minutes.

A few days after this meeting, I took Apple back to Nga Manu Nature Reserve, in Waikanae, for another tuatara dig. I took her into the tuatara enclosures, and she was extremely interested and animated. It was going to be too difficult to work in the pens as on the previous occasion, however, so we put a tuatara inside the tube we had used in Hamilton, and hid it in some bush in the reserve. Unfortunately Apple was too distracted by people and birds, and would not work. I gave up after about 10 minutes.

When Apple was 2 years and 7 months old (December 2004), I received a dead tuatara from DoC, and freeze-dried it so it would last longer. I was very pleased by her response to the body: she reacted in almost the same way as to live tuatara, and was extremely interested in it. For the next six weeks I set up semi-regular training sessions with Apple and the dead tuatara.

1.6 Trip to Wellington Zoo

In mid-January 2005 Wellington Zoo asked if I could bring Apple down to search for a missing tuatara. We travelled down on the same day, after doing approximately 30 minutes of training with the dead tuatara in my backyard. We searched inside the tuatara enclosure, which was flat with long grass and shrubs; and the area surrounding the enclosure, which was a mixture of flat ground and embankment covered in grass and shrubs. Inside the enclosure Apple immediately located the two tuatara that had already been accounted for. But she gave no sign of detecting any further tuatara scent, either within the enclosure, or outside the enclosure. Because she repeatedly indicated the two tuatara we knew to be remaining in the enclosure, I was confident that had the missing tuatara been present in the areas we searched, Apple would have indicated appropriately. We searched for about an hour in total, with Apple working enthusiastically the whole time.

1.7 Aversion Training

Most of Apple's training has been focused on teaching her to detect tuatara scent and indicating her find clearly. She has received some limited aversion training. She has been introduced to a variety of dead mammals and birds (possums, rabbits, hares and chickens), and live possums, rabbits and a range of common exotic and native birds (including chickens, ducks, swans, gulls, takahe and passerines). Whenever we encountered these non-target species, I always allowed Apple to initially investigate them, without any reinforcement or punishment. When she lost interest, I called her to me, and gave her quiet verbal praise. I then walked through the area, past the animal, ignoring it completely. If Apple paid excessive attention to the animal and was not responsive to my commands, I punished her by verbal reprimands and removing her from the area. When Apple paid no attention to the animal, I reinforced this behaviour with verbal praise and play. Further aversion training will also be necessary before we attempt to pass the full certification.

1.8 Future Training

I intend to maintain Apple's training by regularly setting up scent exercises using the dead tuatara, and using live tuatara whenever possible. We have a trip to Matiu/Somes Island, in Wellington Harbour, planned for April 2005. The aim of this trip is to help survey the tuatara population on the island by finding as many individuals as possible.

After this trip, I will assess Apple's progress and consider sitting the full certificate. To date, I do not think we have had enough experience working with live tuatara to sit the test, but the work on Matiu/Somes Island may provide this.

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APPENDIX 2

TUATARA TRIAL DATES

Dog 5 enthusiastically retrieving a target cloth at the Tararua Allbreeds Dog Training Club. Photo: Clare Browne.

Dog	Trial 1 – Handler's scent			Trial 2 – Unfamiliar person's scent			Trial 3 – Tuatara-scented paper towels			
1	10 Dec 02	17 Dec 02	28 Jan 03	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	25 Mar 03	1 April 03	10 June 03
2	10 Dec 02	4 Feb 03	4 Mar 03	4 Mar 03	11 Mar 03	18 Mar 03	18 Mar 03	25 Mar 03	1 April 03	8 April 03
3	10 Dec 02	17 Dec 02	21 Jan 03	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	8 April 03	15 April 03	15 April 03
4	11 Feb 03	18 Feb 03	19 Feb 03	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	25 Mar 03	1 April 03	8 April 03
5	10 Dec 02	17 Dec 02	21 Jan 03	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	25 Mar 03	1 April 03	10 June 03
6	3 Dec 02	10 Dec 02	17 Dec 02	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	25 Mar 03	1 April 03	8 April 03
7	3 Dec 02	28 Jan 03	4 Feb 03	25 Feb 03	4 Mar 03	1 April 03	-	-	-	-
8	10 Dec 02	17 Dec 02	11 Feb 03	25 Feb 03	4 Mar 03	11 Mar 03	18 Mar 03	25 Mar 03	1 April 03	8 April 03
9	10 Dec 02	17 Dec 02	28 Jan 03	-	-	-	-	-	-	-

Dog	Trial 4 – Tuatara scats			Trial 5 – Tuatara skins			Trial 6 – All 3 tuatara scents			Trial 7 – Weathered scats		
1	24 June 03	2 July 03	4 July 03	8 July 03	15 July 03	29 July 03	-	-	-	-	-	-
2	11 July 03	11 July 03	29 July 03	29 July 03	29 July 03	14 Oct 03	5 Aug 03	9 Sept 03	9 Sept 03	7 Oct 03	14 Oct 03	11 Nov 03
3	13 May 03	20 May 03	27 May 03	8 July 03	15 July 03	22 July 03	5 Aug 03	2 Dec 03	2 Dec 03	4 Nov 03	4 Nov 03	11 Nov 03
4	13 May 03	27 May 03	24 June 03	8 July 03	15 July 03	22 July 03	5 Aug 03	12 Aug 03	2 Sept 03	7 Oct 03	4 Nov 03	25 Nov 03
5	24 June 03	2 July 03	4 July 03	8 July 03	15 July 03	22 July 03	5 Aug 03	2 Sept 03	2 Sept 03	4 Nov 03	4 Nov 03	11 Nov 03
6	13 May 03	20 May 03	10 June 03	8 July 03	15 July 03	29 July 03	5 Aug 03	12 Aug 03	2 Sept 03	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	13 May 03	27 May 03	24 June 03	8 July 03	15 July 03	22 July 03	5 Aug 03	12 Aug 03	2 Sept 03	7 Oct 03	4 Nov 03	25 Nov 03
9	-	-	-	-	-	-	-	-	-	-	-	-

- Dogs withdrawn from the study.

APPENDIX 3

GECKO TRIAL DATES

Dog 20 taking off during a scent exercise at the Feilding Dog Training Club. Photo: Louise June.

Dog	Trial 1 – Handler's scent	Trial 2 – Unfamiliar person's scent			Trial 3 – Green gecko-scented paper towels, scats, skins			Trial 4 – Green gecko scats, skins		
4					5 May 03	12 May 03	26 May 03	23 June 03	30 June 03	12 July 03
8					5 May 03	12 May 03	26 May 03	23 June 03	30 June 03	12 July 03
10	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	-	-	-
11	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	30 June 03	28 July 03	29 Oct 03
12	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	16 June 03	23 June 03	30 June 03
13	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	16 June 03	23 June 03	30 June 03
14	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	-	-	-	-	-
15	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	16 June 03	23 June 03	30 June 03
16	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	-	-	-
17	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	16 June 03	23 June 03	30 June 03
18	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	-	-	-	-
19	31 Mar 03	7 April 03	14 April 03	28 April 03	5 May 03	12 May 03	26 May 03	16 June 03	23 June 03	30 June 03
20	31 Mar 03	7 April 03	14 April 03	28 April 03	12 May 03	19 May 03	12 July 03	16 June 03	23 June 03	30 June 03

Dog	Trial 5 – All three green gecko scents			Trial 6 – Two gecko species				Trial 7 – Weathered green gecko scats		
4	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
8	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
10	-	-	-	-	-	-	-	-	-	-
11	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	1 Sept 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
12	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
13	14 July 03	21 July 03	28 July 03	4 Aug 03	18 Aug 03	1 Sept 03	1 Sept 03	-	-	-
14	-	-	-	-	-	-	-	-	-	-
15	21 July 03	28 July 03	29 Oct 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
16	-	-	-	-	-	-	-	-	-	-
17	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
18	-	-	-	-	-	-	-	-	-	-
19	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03
20	14 July 03	21 July 03	28 July 03	4 Aug 03	11 Aug 03	18 Aug 03	1 Sept 03	6 Oct 03	13 Oct 03	20 Oct 03

- Dogs withdrawn from the study

APPENDIX 4

TUATARA SAMPLE DETAILS

Pieces of tuatara (*Sphenodon punctatus*) skin, used to scent target and decoy cloths. Photo: Clare Browne.

Details of tuatara (*S. punctatus*) samples collected from Nga Manu Nature Reserve and used to scent target and decoy cloths.

Species of animal	Stephens Island tuatara (*S. punctatus*).
Sample type	1 scat.
Location	Nga Manu Nature Reserve, Waikanae.
Date and time collected	23 July 2002.
Estimated age of sample	24 hours.
Description of habitat	Tuatara was placed in a holding box for 24 hours.
Diet of animal(s)	Invertebrates.
Age of animal(s)	2 years.
Sex of animal(s)	Unknown.
Date sample frozen	14 August 2002.
Collector's name	Bruce Benseman.

Species of animal	Stephens Island tuatara (*S. punctatus*).
Sample type	2 scats.
Location	Nga Manu Nature Reserve, Waikanae.
Date and time collected	23 August 2002; 1348.
Estimated age of sample	48 hours.
Description of habitat	Tuatara was placed in a holding box for 48 hours.
Diet of animal(s)	Invertebrates.
Age of animal(s)	2.5 years.
Sex of animal(s)	Unknown.
Date sample frozen	26 August 2002.
Collector's name	Bruce Benseman.

Species of animal	Stephens Island tuatara (*S. punctatus*).
Sample type	An almost entire skin.
Location	Nga Manu Nature Reserve, Waikanae.
Date and time collected	August 2002.
Estimated age of sample	One week.
Description of habitat	Outdoor enclosure.
Diet of animal(s)	Invertebrates.
Age of animal(s)	Unknown.
Sex of animal(s)	Unknown.
Date sample frozen	29 August 2002.
Collector's name	Bruce Benseman.

Species of animal	Stephens Island tuatara (*S. punctatus*).
Sample type	Numerous paper towels and scats.
Location	Nga Manu Nature Reserve, Waikanae.
Date and time collected	November 2002, 2003, 2004; at various times during the day.
Estimated age of sample	0-3 days.
Description of habitat	Tuatara were placed in plastic buckets containing moist paper towels for up to 3 days.
Diet of animal(s)	Invertebrates.
Age of animal(s)	Juvenile.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Clare Browne.

APPENDIX 5

GECKO SAMPLE DETAILS

Pieces of Marlborough green gecko (*Naultinus manukanus*) skin, used to scent target and decoy cloths. Photo: Clare Browne.

Samples of Marlborough green gecko (*N. manukanus*) and forest gecko (*H. granulatus*) samples collected from Victoria University of Wellington and private breeders Roger and Barbara Watkins respectively. The samples were used to scent target and decoy cloths.

5.1 Marlborough green gecko sample information

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Paper towels (25 collections of individual and/or multiple towels). Scats (27 collections of sometimes single scats, but mainly numerous scats). Skins (7 collections of mostly skin fragments).
Location	Victoria University of Wellington, Wellington.
Date and time collected	April 2003, collected almost daily, at various time during the day.
Estimated age of sample	Paper towels < 5 days (average). Scats < 5 days (average). Skins < 3.5 days (average).
Description of habitat	Plastic containers/grass.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Juveniles and adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Paper towels (17 collections of individual and/or multiple towels). Scats (20 collections of sometimes single scats, but mainly numerous scats). Skin (1 collection).
Location	Victoria University of Wellington, Wellington.
Date and time collected	May 2003, collected approximately every third day, at various times during the day.
Estimated age of sample	Paper towels < 8 days (average). Scats < 7 days (average). Skin < 1 day.
Description of habitat	Plastic containers/plastic tubes.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Juveniles and adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Paper towel (1 collection). Scats (3 collections). Skin (1 collection).
Location	Victoria University of Wellington, Wellington.
Date and time collected	19 June 2003; 1000.
Estimated age of sample	Paper towel < 14 days. Scats < 14 days. Skin < 14 days.
Description of habitat	Plastic containers/metal enclosure.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Juveniles and adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Paper towel (1 collection). Skin (1 collection).
Location	Victoria University of Wellington, Wellington.
Date and time collected	31 July 2003; 0945.
Estimated age of sample	Paper towel < 2 days. Skin < 2 days.
Description of habitat	Plastic container.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Scats (13 collections of sometimes single scats, but mainly numerous scats). Skins (4 collections of mostly skin fragments).
Location	Victoria University of Wellington, Wellington.
Date and time collected	August 2003, collected approximately every second day, at various times during the day.
Estimated age of sample	Scats < 2 days (average). Skins < 3 days (average).
Description of habitat	Plastic container.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Juveniles and adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Scats (10 collections of sometimes single scats, but mainly numerous scats).
Location	Victoria University of Wellington, Wellington.
Date and time collected	September 2003, collected approximately every third day, at various times in the morning.
Estimated age of sample	Scats < 2 days (average).
Description of habitat	Plastic container.
Diet of animal(s)	Wattie's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

Species of animal	Marlborough green gecko (*N. manukanus*).
Sample type	Scats (6 collections of sometimes single scats, but mainly numerous scats). Skins (12 collections of mostly skin fragments).
Location	Victoria University of Wellington, Wellington.
Date and time collected	October 2003, collected approximately every 3/4 days, at various times in the morning.
Estimated age of sample	Scats < 2 days (average). Skins < 2 days (average).
Description of habitat	Plastic container.
Diet of animal(s)	Wattic's® canned baby food (pear flavour), mealworms (*Tenebrio molitor*), moths (Lepidoptera) and blowflies (*Calliphora* spp.).
Age of animal(s)	Adults.
Sex of animal(s)	Mixed.
Date sample frozen	Immediately upon collection.
Collector's name	Kelly Hare.

5.2 Forest gecko sample information

Species of animal	Forest gecko (*H. granulatus*).
Sample type	Numerous scats.
Location	New Plymouth.
Date and time collected	21 April 2003.
Estimated age of sample	1-2 weeks.
Description of habitat	Cage, sandy floor overlaid with totara needles, dead branches and potted native plants.
Diet of animal(s)	Moths and flies.
Age of animal(s)	5 years.
Sex of animal(s)	Mixed..
Date sample frozen	29 April 2003.
Collector's name	Barbara Watkins.