

Detection and accuracy rates of dogs trained to find scats of San Joaquin kit foxes (*Vulpes macrotis mutica*)

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Abstract

Specially trained detection dogs have been used to locate faeces (scats) for faecal analyses but their effectiveness has not been quantified. We evaluated detection and accuracy rates of dogs trained to find scats of endangered San Joaquin kit foxes (*Vulpes macrotis mutica*). Four dogs found from 0.43 to 5.37 presumptive kit fox scats per km of transect searched in two field sites where kit foxes and coyotes (*Canis latrans*) but not non-native red foxes (*V. vulpes*) were present. The unusually low detection rate (0.43 scats per km) by one dog (probably due to excessive panting in hot weather) was still similar to the average scat detection rate of two experienced humans. DNA tests of 1298 scats showed that all dogs were 100% accurate at distinguishing kit fox scats under our field conditions. Because red foxes are sympatric with kit foxes in some areas, we also conducted controlled discrimination experiments to see if trained dogs could distinguish between scats from kit and red foxes. Four dogs were 100% accurate at choosing a kit fox scat when red fox scats were present ($n = 64$ trials), but were less accurate at ignoring red fox scats in trials where a kit fox scat was absent.

INTRODUCTION

Obtaining demographic information is critical for effective management and conservation. However, acquiring such data on endangered species can be challenging because low population size often makes traditional methods of locating and monitoring populations, such as live trapping and marking individuals, ineffective (Beckoff & Jamieson, 1996; Greenwood, 1996; Sutherland, 1996). Additionally, capture data can be biased by elusive behaviours, and techniques that require handling of endangered individuals involve injury risks (Greenwood, 1996). Consequently, use of non-invasive methods, which may provide similar information on rare species and eliminate the need to capture or visually observe individuals, is desirable.

Faecal analysis has been used to infer habitat use, range size and relative abundance (Putnam, 1984; Kohn

& Wayne, 1997), and to examine food habits and parasitology of wild populations (Kohn & Wayne, 1997). Moreover, advances in molecular genetics make faecal DNA sampling a promising approach for determining species, population size, sex ratio, home range, paternity and kinship (Kohn & Wayne, 1997; Kohn *et al.*, 1999; Ernest *et al.*, 2000; Mills *et al.*, 2000; Lucchini *et al.*, 2002). However, acquiring data from faeces (scats) often requires large sample sizes, and obtaining samples from populations with low densities or cryptic scats can prove difficult. Differing probabilities of finding scats in various habitats and the possibility of human error in identification of scats may also influence analyses of demographic data (Bulinski & McArthur, 2000). Although there is great potential for faecal analysis to provide essential information on ecological and demographic parameters, the logistical problems associated with using humans to find sufficient scats of some species necessitate a more effective method of scat recovery.

One such method is the use of trained dogs to recover scats of specific species. This technique has been used in combination with faecal DNA analyses on black

(*Ursus americanus*) and grizzly (*Ursus arctos*) bear populations (S. Wasser, M. Parker & B. Davenport, University of Washington, unpubl. data, 1998–99; S. Wasser & B. Davenport, University of Washington, unpubl. data, 2000–03). Additionally, for non-genetic analyses, trained dogs have been used to locate scats of species such as black-footed ferrets (*Mustela nigripes*) (Dean, 1979; Winter, 1981), wolves (*Canis lupus*), coyotes, black bears (P. Paquet, University of Calgary, unpubl. data, 1982–9) and lynx (*Lynx canadensis*) (U. Breitenmoser & C. Breitenmoser-Wursten, IUCN/SSC Cat Specialist Group, unpubl. data, 1984–94). However, no attempts have been made to evaluate the detection and accuracy rates of individual dogs trained to find scats of particular species.

Previously, we reported briefly on the accuracy of one dog in locating kit fox scats (Smith *et al.*, 2001). Mitochondrial DNA tests revealed that our German shepherd was 100% accurate ($n = 329$ scats) in identifying kit fox scats in the presence of coyote, striped skunk (*Mephitis mephitis*) and American badger (*Taxidea taxus*) scats along transects in the Carrizo Plain National Monument, California. Furthermore, our trained dog found four times as many kit fox scats as an experienced person searching for scats visually in the same area.

Here, we present data on the utility of using detection dogs as a reliable approach to scat collection of a target species. We conducted experiments (1) to compare the detection and accuracy rates of four dogs searching for kit fox scats during field trials at two locations and (2) to determine whether four dogs could discriminate between scats of two fox species in the same genus, the kit fox and the red fox, in controlled scat-discrimination trials using two experimental designs. Although red foxes are not present at the two sites where we conducted our field trials, this non-native species is sympatric with the kit fox in some parts of its range and has replaced it in other areas (Ralls & White, 1995). Thus, it would be useful to know if dogs can discriminate between these two fox species before using them to search for kit fox scats in areas where the two species are known to occur in sympatry.

METHODS

Study areas

We conducted field trials in two areas: in the northwestern portion of the Carrizo Plain National Monument (Carrizo), San Luis Obispo County, California, and within the LoKern Natural Area (LoKern), Kern County, California. The Carrizo lies adjacent to the southwestern edge of the San Joaquin Valley, is one of the largest continuous habitats (> 750 km²) for San Joaquin kit foxes, and is one of three 'core areas' considered essential for conservation of this species (United States Fish and Wildlife Service, 1998). Kit fox density within the study area is not known. The principal habitat types include non-native annual grassland, alkali sink and saltbush scrub, and upper Sonoran subshrub scrub. The climate is semiarid with hot,

dry summers and cool, wet winters. Approximate summer high and winter low temperatures are 40°C and –10°C, respectively. Average yearly precipitation is 26 cm, occurring primarily as winter rains.

The LoKern is located in the southwestern corner of the San Joaquin Valley in western Kern County, California. The LoKern lies within another of the three 'core areas' for San Joaquin kit foxes (United States Fish and Wildlife Service, 1998). Again, kit fox density within the study area is not known. The principal habitat types include non-native annual grassland, saltbush scrub, and upper Sonoran subshrub scrub. The climate is semiarid with hot, dry summers and cool, wet winters. Approximate summer high and winter low temperatures are 37°C and 1°C, respectively. Average yearly precipitation is 14.5 cm, occurring primarily as winter rains.

We conducted controlled scent discrimination tests at the PackLeader Dog Training facility in Steilacoom, Washington.

Dog selection, training and acclimatization

We trained dogs to detect kit fox scats with a combination of detection dog training techniques. We utilized methods for training dogs to detect species' specific scats (S. Wasser, M. Parker & B. Davenport, University of Washington, unpubl. data, 1998–9), and incorporated procedures described for training dogs to detect species' specific scats, urine and tracks (Dean, 1979; Sturdivan, 1993). Moreover, we employed significant elements of cadaver, narcotic, and search and rescue detection dog training techniques (Pearsall & Verbruggen, 1982; Button, 1990; Bulanda, 1994; Robicheaux & Jons, 1996; Rebmann, David & Sorg, 2000).

First, we selected dogs that had an obsession with a particular toy or food (Bulanda, 1994; Robicheaux & Jons, 1996; Rebmann *et al.*, 2000). We evaluated each dog's response to these items. Ideal candidates were unable to look away from the object regardless of distractions within the testing area, and demonstrated a frantic desire to possess the object.

Appropriate candidates were conditioned to associate the scent of kit fox scats with their reward object. We used a line of blocks or 'scent line', with five to ten individual blocks, each with a 5 cm hole opening towards the surface (Robicheaux & Jons, 1996; Rebmann *et al.*, 2000). A kit fox scat was placed within one block. First, we led the dog down the line of blocks, tapping each hole in order to lead the dog's nose to the hole. When the dog reached the hole of the block containing a kit fox scat, we immediately rewarded the dog. Once the dog learned to associate the scent of kit fox scats with its reward, we conditioned the dog to indicate that it had found a kit fox scat by sitting next to the block containing the scat. This method of indication would allow us to accurately view the location of kit fox scats found in the field.

After the dogs were competent at showing us which block of the 'scent line' contained a kit fox scat, we subjected all field trials of dogs to numerous search drills in a variety of environments (Bryson, 1976;

American Rescue Dog Association, 1991; Rebmann *et al.*, 2000). Drills were performed with increasing levels of difficulty (e.g., open versus closed terrain, strong versus no wind conditions).

Finally, we trained the dogs to ignore scats that were from species other than kit foxes. In both 'scent line' and field training, we led the dog to a scat that was not from a kit fox and waited for its reaction. If the dog ignored this scat, we verbally praised the dog. However, if the dog sniffed at this scat for more than a few seconds, or attempted to indicate it was kit fox scat, we gave the dog a voice and leash correction. Immediately after the correction, the dog was led to a kit fox scat and rewarded.

We trained four dogs to locate kit fox scats in the field: one male German shepherd (Dog 1), one male Labrador retriever (Dog 2), one male flat-coated retriever (Dog 3) and one female Labrador retriever (Dog 4). Dog 1 was also used during controlled experiments that tested his ability to distinguish between kit and red fox scats. Three additional dogs were trained for this discrimination test: one female Labrador retriever (Dog 5), one male Labrador retriever mix (Dog 6) and one male Australian shepherd (Dog 7).

In the Carrizo, fresh scat collection was conducted from 17 July to 1 August 2000. Before experimental searches were initiated, dogs were allowed to acclimatize to the hot, summer climate for 3 weeks. In the LoKern, fresh scat collection was conducted from 16 January to 11 February 2002. Because this trial was performed during the cooler, winter months, dogs were only given 1 week to acclimatize to the field conditions.

Scat detection and accuracy rates of dogs during field trials

In the Carrizo, we tested two dogs (Dog 1, Dog 2) on their ability to find kit fox scats along transect lines. We established eight 2×1 km grids. Within each grid was a smaller grid of 1×0.5 km. One side of all grids encompassed the main unpaved road. All other grid sides were considered transects through vegetation. Additional road transects were established on unpaved roads that branched from the main unpaved road. Transect length varied from 0.5 to 2 km. The entire transect route included 23.2 km of roads and 48 km of vegetated area. Each transect was searched by a dog/handler team, and fresh scats were collected during each search. Scat searches on all transects were completed within an 8-day period. We alternated dog/handler teams on all established routes so that the search effort by each dog was equal. Finally, Dog 1 was used to search all transects for a subsequent 8-day period of fresh scat collection. Average temperature during the hours of scat collection was 23°C (range $14\text{--}32^{\circ}\text{C}$).

In the LoKern, we tested three dogs (Dog 1, Dog 3, Dog 4) on their ability to find kit fox scats along transect lines. We established 17 transects running from north to south and spaced at 400 m intervals. All transects were in vegetation, though the majority of these transects randomly intersected one or more unpaved roads. Transect length

varied from 0.3 to 6.2 km and the entire transect system covered 56 km. All transects were searched four times, with each search completed within a 5-day period. Again, fresh scats were collected during each search, and we alternated dog/handler teams on transects so that the search effort by each dog was equal. Average temperature during the hours of scat collection was 15°C (range $8\text{--}22^{\circ}\text{C}$).

Eight days prior to beginning the experiment in the Carrizo, dog/handler teams were used to find and remove presumed kit fox scats from all transect lines. This ensured that only fresh kit fox scats would be collected during experimental searches and used for DNA analyses since fresh scats yield higher-quality DNA (D. A. Smith, unpubl. data). Removing scats before beginning searches would have been impractical on our larger transect system in the LoKern, so we developed a method for determining which scats were fresh.

Immediately prior to the LoKern field trial, we collected 12 kit fox scats that were deposited at latrines the preceding night, and divided them equally between vegetation and unpaved roads. Physical characteristics of each scat (e.g. moisture, coloration) were recorded for three consecutive 8-day periods to determine a 'freshness' rating. In the field trial, we collected only those kit fox scats with the same physical characteristics of scats less than 8 days old.

We stored scats in plastic bags containing one teaspoon of silica gel for desiccation (Fisher Scientific, Pittsburgh, PA) and shipped samples within 7 days to the National Zoological Park's Molecular Genetics Laboratory for storage at -4°C .

Genetic analyses

DNA was extracted from every scat sample using a QIAGEN DNeasy™ DNA extraction kit following manufacturer's protocol (Qiagen, Valencia, CA). Extractions were carried out in a separate room under quasi-clean conditions to prevent contamination. Each sample was isolated a minimum of two times and tested. Negative controls (no scat material added to the extraction) accompanied each set of extractions and were used to check for contamination. Once DNA was extracted, PCR amplification and restriction enzyme analyses were performed using a modified version of the protocol and reagents described by Paxinos *et al.* (1997) as follows: a 350 bp fragment of the mitochondrial cytochrome *b* gene was amplified using a canid-specific light primer (Canid L1, Paxinos *et al.*, 1997) and a universal heavy primer (H15915, Irwin, Kocher & Wilson, 1991) in a 50 μl polymerase chain reaction including 0.5 μM AmpliTaq Gold (Perkin-Elmer), 2.5 mM MgCl_2 , 1X reaction buffer (Perkin-Elmer) 200 μM each dNTP, 1.0 mg/mL α -Fraction-V BSA, and 1 μM each primer. Reactions were run for 30 cycles of (1 minute denaturing at 95°C , 1 minute annealing at 55°C and 2 minutes extension at 70°C) in a PTC programmable thermocycler (MJ Research Corp.). We screened PCR products with three species-diagnostic restriction enzymes (ALU I, HINF I and Taq I) as specified by Paxinos *et al.*

(1997). Positive controls for kit fox, coyote, domestic dog, red fox and gray fox were used for comparison in the restriction analysis. Scat samples that failed to produce PCR amplification products after the second extraction attempt were deemed unusable for genetic analysis.

Discrimination between scats of similar fox species

To examine the ability of dogs to distinguish between scats from similar fox species, we tested whether four dogs (Dog 1, Dog 5, Dog 6, Dog 7) could correctly identify kit fox scats in the presence of red fox scats and ignore red fox scats in the absence of kit fox scats. The experimental design consisted of using a 'scent box', with five individual compartments, each with a 5 cm hole. We placed two scent boxes end to end, with every other hole of the scent box containing a glass jar spaced 7.2 cm apart. Empty holes between jars were covered with cardboard. Each trial consisted of either four jars containing a red fox scat and one jar containing a kit fox scat, or five jars all containing red fox scats. One person placed scats in jars according to a random assignment, and, to avoid contamination with scents from different people, only this person handled all jars and scats. During each trial, the dog was instructed to search for a kit fox scat. The dog was allowed to sniff all jars before making a decision. The dog selected a jar by sitting next to it. The handler of each dog did not know the position of the jar containing kit fox scat. An assistant would verify if the dog was correct and after a correct choice the handler would reward the dog. The results of choices were scored as 'Correct' or 'Incorrect'.

Data analysis

We calculated the total number of scats located by each dog on all transects it searched, and calculated a detection rate for each dog as the number of scats found per km searched. We established accuracy rates for each dog as the number of kit fox scats located per total number of scats found that were deemed usable for genetic analysis and that produced unambiguous results in the species identification restriction enzyme technique. To test for differences in detection and accuracy rates among dogs, we used one-way analysis of variance with $\log(x + 10)$ transformed data. For the kit and red fox scat discrimination experiments, we used G -test analyses, pooling results from all subjects ($G_p = G$ for pooled data)

if no statistical heterogeneity between subjects was detected (G_h at $P < 0.05$). Subsequently, percentage 'Correct' and 'Incorrect' were calculated per experimental design per dog.

RESULTS

Identifying fresh scats in the LoKern

During the first 8-day observation period, the experimental scats varied from wet to semi-dry and all scats maintained their brown coloration. In the second period, all scats were dry and had gray-speckled marks. In the third period, all scats were very dry and had more prominent gray-speckled or small white marks. One scat placed on the unpaved road disappeared during the second period. Thus, we judged that scats that were wet to semi-dry and had a solid brown color were 'fresh', i.e., less than 8 days old, and suitable for collection.

Scat detection and accuracy rates of dogs during field trials

In the Carrizo, Dog 1 had an elevated rate of panting during the first week of the acclimatization period. However, by the second week, his panting level returned to normal. In contrast, Dog 2 had an elevated rate of panting throughout the acclimatization period and the entire field trial.

Dog 1 and Dog 2 found an average of 2.75 ± 3.80 and 0.43 ± 0.82 scats per km searched, respectively, in the Carrizo (Table 1). Thus, there was a significant difference in the detection rates of the two dogs ($F = 10.738$, d.f. = 1,70, $P = 0.002$).

Dog 1, Dog 3 and Dog 4 found an average of 5.37 ± 3.23 , 3.90 ± 3.56 and 2.42 ± 2.19 scats per km searched, respectively, in the LoKern (Table 1). There was no difference in the detection rates of Dog 1 and Dog 3 ($F = 1.007$, d.f. = 1,79, $P = 0.319$). Yet, there was a significant difference in the detection rates of Dog 4 and Dog 1 ($F = 18.349$, d.f. = 1,62, $P = 0.000$) and Dog 3 ($F = 11.272$, d.f. = 1,61, $P = 0.001$).

We were able to isolate DNA from 76% ($n = 355$) and 98% ($n = 943$) of the total scat samples found by the dogs in the Carrizo and the LoKern, respectively. All scats analyzed yielded kit fox mitochondrial DNA. Thus, in both field trials, all dogs were 100% accurate at identifying kit fox scats in areas where red fox scats were not present.

Table 1. Results for each of the dogs in the Carrizo Plain National Monument, San Luis Obispo County, CA, and the LoKern Natural Area, Kern County, CA

| Study area | Dog (years of detection experience pre-trial) | Total # of scats found | Total distance searched (km) | Rate of detection (scats/km) | No. of scats successfully ID to species | Rate of accuracy (%) |
|------------|---|------------------------|------------------------------|------------------------------|---|----------------------|
| Carrizo | Dog 1 (1) | 435 | 158.32 | 2.75 | 329 | 100 |
| Carrizo | Dog 2 (2) | 34 | 79.16 | 0.43 | 26 | 100 |
| LoKern | Dog 1 (2) | 508 | 94.53 | 5.37 | 496 | 100 |
| LoKern | Dog 3 (2) | 364 | 93.31 | 3.90 | 360 | 100 |
| LoKern | Dog 4 (0) | 91 | 37.67 | 2.42 | 87 | 100 |

Discrimination between scats of similar fox species

Results of these experiments were very similar across dogs. All four dogs correctly chose the kit fox scat in all trials where a kit fox scat was present ('kit fox scat present design') but were less accurate at ignoring red fox scats in trials where a kit fox scat was absent ('red fox scats only design') (Table 2). However, dogs correctly ignored red fox scats in 32 of 48 (67%) trials using the 'red fox scats only design', which is significantly better than random ($G_p = 5.420$, d.f. = 1, $P = 0.020$). Although results varied slightly across dogs, with percentage correct varying between 82 and 89 and percentage incorrect varying between 11 and 18 (Table 2), these differences were not significant ($G_h = 0.820$, d.f. = 3, $P = 0.845$). All dogs performed significantly better in the 'kit fox scat present' experimental design than in the "red fox scats only" experimental design ($G_p = 4.301$, d.f. = 1, $P = 0.038$; $G_h = 0.220$, d.f. = 3, $P = 0.974$).

DISCUSSION

Detection dogs can locate the large numbers of kit fox scats necessary for faecal analysis studies. In our field trials, dogs found 0.43 to 5.37 scats per km searched. Environmental factors such as temperature, moisture and air movements, as well as training regimes and experience levels, are known to affect the abilities of detection dogs (Syrotuck, 1972; Gutzwiller, 1990). In the Carrizo, Dog 2 had an elevated panting level throughout the trial, probably owing to the high summer temperatures (average temperature during search hours was 23°C). High rates of panting can cause a reduction in scenting efficiency (Pearsall & Verbruggen, 1982). Both Dog 2 and Dog 1 had experience in detection work, 2 and 1 years respectively, prior to the start of the trial. Hence, we suspected that Dog 2's low rate of kit fox scat detection was due to his elevated panting level. To test this hypothesis, we compared scat detection rates of Dog 2 and Dog 1 in the LoKern during cooler weather from 15 March to 24 March 2002 and from 11 January to 20 January 2003 (average temperature during search hours was 17°C and 13°C, respectively). There was no difference in their scat detection rates during these months ($F = 0.526$, d.f. = 1, 31, $P = 0.474$; $F = 1.078$, d.f. = 1, 31, $P = 0.307$), and Dog 2 did not display an elevated panting rate during either period.

In the Carrizo, we attempted to reduce the effects of temperature on the detection abilities of the dogs by restricting search times to morning and evening hours,

keeping daily search times (3–4 hours) and the overall study period (16 days) short, and ensuring both dogs were physically fit before and during searches. Despite these efforts, Dog 2's detection rates were low. For future studies, we recommend that the ability of individual dogs to work under particular environmental conditions be considered before using them as detection dogs in certain months or in particular areas.

Interestingly, Dog 2's low detection rate in hot weather was not different from the detection rates of two human observers who were trained in kit fox scat identification (e.g., Halfpenny & Biesiot, 1986) and who walked similar transects in the Carrizo ($F = 0.784$, d.f. = 2, 69, $P = 0.461$). Thus, even the worst performance by a dog was as good as the performance of humans. Hence, we believe trained detection dogs would greatly increase recovery of scats in the field in the majority of searches.

In the LoKern, Dog 4 had a significantly lower rate of kit fox scat detection than Dog 1 and Dog 3. Dog 4 was a novice detection dog at the start of the trial, unlike Dog 1 and Dog 3, each of whom had 2 years of previous experience in detection work on a variety of species. Thus, lack of experience may have caused Dog 4's performance levels to be lower than that of the other dogs.

Although there were some differences in detection rates among dogs, there was no difference in accuracy rates of the dogs. In both the Carrizo and the LoKern, all of our trained dogs were 100% accurate in species identification despite an abundance of coyote, striped skunk and American badger scats present along transects.

Reliable conclusions from analyses of scats depend on correct identification (Neff, 1968). Both experienced and inexperienced human observers have been known to misidentify scats of sympatric species such as Bennett's wallabies (*Macropus rufogriseus*) and Tasmanian pademelons (*Thylogale billardierii*), and expert naturalists consistently failed to distinguish pine marten (*Martes martes*) from red fox scats (Bulinski & McArthur, 2000; Davison *et al.*, 2002). Our results show that detection dogs may be used to collect accurately the scats of individual species. This method may be useful for ascertaining the presence or absence of endangered or rare species in areas where it is not certain that they occur. Furthermore, locating scats of individuals of endangered species outside their known range may be particularly important to conservation management plans.

Our controlled discrimination experiments demonstrate that dogs are capable of distinguishing scats of similar fox

Table 2. Results of the controlled discrimination test for each of the four dogs in both experimental designs

| Dogs | <i>Kit fox scat present</i> | | <i>Red fox scats only</i> | | <i>Total</i> | |
|-------|-----------------------------|-----------|---------------------------|-----------|--------------|---------------|
| | Correct | Incorrect | Correct | Incorrect | Correct (%) | Incorrect (%) |
| Dog 1 | 16 | 0 | 9 | 3 | 89 | 11 |
| Dog 5 | 16 | 0 | 8 | 4 | 86 | 14 |
| Dog 6 | 16 | 0 | 8 | 4 | 86 | 14 |
| Dog 7 | 16 | 0 | 7 | 5 | 82 | 18 |
| Total | 64 | 0 | 32 | 16 | – | – |
| (%) | (100) | (0) | (67) | (33) | – | – |

species. All dogs were completely accurate when asked to pick out kit fox scat in a line-up of red fox scats. Each dog was less able to ignore red fox scats when these scats were the only option in a trial. Three factors that possibly contributed to this result are (1) dogs received relatively little fox scat discrimination training (3 days) before being tested, (2) dogs were exposed to a very low diversity of scat samples ($n =$ five kit fox scats; four red fox scats) in training exercises, and (3) the dogs used for this experiment were dogs immediately available for use rather than dogs that were specifically selected for discrimination work. Another factor contributing to this result may have been the intrinsic difficulty of the experimental design with no correct choice present. Previous studies have found that dogs and rats produce lower scores when presented with only incorrect items in scent line-up trials (Lu, Slotnick & Silberberg, 1993; Schoon, 1996). In addition, our dogs' limited exposure to this design (3 days) probably caused greater error in their performance (Rebmann *et al.*, 2000). It has been shown that proper selection and training can produce dogs that can reliably discriminate and match scents (Settle *et al.*, 1994).

We conducted a very simple discrimination test, with limited fox scat samples and dog training exercises, in a short time-frame because our goal was limited – to conduct only enough repetitions to assess if training a dog for discrimination work would be worth pursuing. Typically, narcotic discrimination dogs complete ~ 600 repetitions using ~ 100 different training aids (scents) in which amount and packaging is varied (Davenport, 1984). We suggest that training at least four times a week in a 2–4 week course (time-frame is dependent on each dog's aptitude) would be necessary for greater accuracy in discriminating between scats of similar species, and we recommend practice sessions on at least a weekly basis once training is completed (Robicheaux & Jons, 1996; Rebmann *et al.*, 2000). We also believe it is imperative that dogs be introduced early to the design concept of no correct choice present, and screened for their responses to such trials.

Additionally, we recommend that dogs used to detect scats in the field and/or controlled discrimination tests be accurately selected, trained and evaluated (Table 3). We noticed that some detection dogs were highly accurate in the field yet performed poorly in scent box trials. These dogs became frustrated or bored with the simple scent box line-up, indicating they found a kit fox scat the instant they were brought into a room with a scent box or indicating they found a kit fox scat in each compartment in the box. For fieldwork, detection dogs are usually trained for 3–5 days on an item in a scent box and then moved on to more complicated search patterns. Therefore, dogs should be tested for their ability to stay motivated with simple repetitive tasks such as pre-screening of scats from a scent box line-up before being used for that job.

Finally, we stress that the experience of the trainer and handler will play a crucial role in the success of each dog (Gutzwiller, 1990). Inadequate training and handling, as well as personality conflicts between dogs matched to particular handlers, can cause a severe reduction in detection efficiency.

Table 3. Recommendations for accurate selection, training and evaluation of dogs used to detect kit fox scats in the field and in controlled discrimination tests

| Training basics |
|---|
| Evaluate dog's response to a particular toy or food |
| Select dog with a frantic desire to possess the object |
| Condition dog to associate the scent of kit fox scat with this reward object |
| Condition dog to indicate the kit fox scat location by sitting next to it |
| Train dog to ignore scats from other species |
| <i>For the field:</i> |
| Evaluate performance of dog in numerous search drills in a variety of environments |
| Select dog with high motivation and excellent detection performance |
| <i>For controlled discrimination tests:</i> |
| Evaluate dog's ability to stay motivated with simple repetitive tasks |
| Select dog with a high motivation to repeatedly pre-screen kit fox scats from a scent box line-up |
| Expose dog to line-ups that contain 'correct' and 'no correct' choice present designs |
| Select dog with excellent detection performance in both line-up designs |
| <i>Both field and controlled discrimination tests:</i> |
| Expose dog to a high diversity of scats from kit foxes and other species |
| Establish strict training schedules (~ four times a week for 4 weeks) |
| Maintain weekly practice sessions after training is completed |
| Require experience in trainers and handlers |

Further research on the olfactory components that allow a dog to differentiate species-specific scats is needed. In our training regime, we exposed the dogs used in the field to a high diversity of kit fox scats from both the Carrizo and LoKern field sites, as well as from an urban population in Bakersfield, CA. Our goal was to have the dogs recognize that they were being rewarded for locating kit fox scats on a species level, and were not being asked to distinguish between particular individuals, sexes, ages or diets.

During training, we noticed that when dogs trained on scats from wild populations were first exposed to scats from the urban population, which has a very different diet from the wild population, they initially hesitated before indicating the scat was a kit fox. Once rewarded, they became proficient at indicating kit fox scats from this population. Previous studies have shown that dogs trained with scats from wild grizzly bear populations initially hesitated before correctly identifying scats from grizzly bears fed a commercial diet in captivity (S. Wasser, M. Parker & B. Davenport, University of Washington, unpubl. data, 1998–9; Hurt, Davenport & Greene, 2000). Again, after sufficient training, these dogs reliably indicated grizzly bear scats from the captive population. Further research showed dogs were capable of distinguishing between black bear and grizzly bear scats even when the two species were fed the same diet in captivity (Hurt *et al.*, 2000). Thus, we suggest dogs trained to detect species-specific scat samples be exposed to a high diversity of scats from species that they are being asked to indicate or ignore.

Although dogs did not perform perfectly in our controlled discrimination tests, we believe that, given sufficient training and exposure to a large diversity of scat

samples, detection dogs would accurately discriminate between similar species in a majority of cases. Nevertheless, we recommend that faecal DNA analysis for species identification be performed on all samples to ensure accuracy until the accuracy of dogs in detecting scats of a particular species has been verified.

Even if dogs are not 100% accurate in distinguishing between the scats of similar species, they could be used to pre-screen scats before they are sent to a laboratory for species identification. For example, in our fox scat discrimination tests, each dog was exposed to a total of 124 red fox scats and 16 kit fox scats. Individual dogs correctly ignored red fox scats 119 to 121 times. If this was an example of pre-screening in the field, only three to five non-target red fox scats, along with the 16 kit fox scats that were positively identified by all dogs, would have been sent to the lab. The cost of extracting DNA from scats and conducting species identification analysis is ~ \$50.00 per scat sample. Hence, in our case, pre-screening of the scats by detection dogs would have generated a savings of approximately \$6000 (\$50 × 120 red fox scats ignored by the dogs which would otherwise have been sent to the lab for species identification).

On the whole, our results indicate that dogs trained in scat detection work can provide an important tool for faecal analysis studies, especially when dealing with rare or endangered species. We emphasize that physical and biological factors, adequate training, and experience will influence detection of scent by dogs (Syrotuck, 1972; Gutzwiller, 1990). Although, it is unlikely that dogs will detect every scat of a species in a particular area, they will increase sample sizes of scat recovered. This more efficient method of locating scats can enable enough samples to be collected for demographic and population studies to be performed, whereas human detection of scats would not. Use of scat detection dogs combined with faecal analysis methods is a promising technique for studies of rare and endangered species that may be sensitive to the disturbances created by direct observation and trapping.

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