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ACCURACY AND RELIABILITY OF DOGS IN SURVEYING FOR DESERT TORTOISE (*GOPHERUS AGASSIZII*)

Mary E. Cablk[1,3] and Jill S. Heaton[2]

[1]*Desert Research Institute, 2215 Raggio Parkway, Reno, Nevada 89512 USA*
[2]*University of Nevada, Reno, Department of Geography/154, Reno, Nevada 89557 USA*

Abstract. The desert tortoise (*Gopherus agassizii*) is federally listed as "threatened" and is afforded protection in several U.S. states including California, Nevada, Utah, and Arizona. Numerous factors ranging from habitat destruction to disease are thought to contribute to the species' decline throughout its range. Data collection on desert tortoises in the wild is challenging because tortoises are secretive, and many age and size classes are virtually undetectable in the wild. Detection dogs have been used for decades to assist humans, and the use of dogs for wildlife surveys is of increasing interest to scientists and wildlife managers. To address the basic question of whether dogs could be used to survey for the desert tortoise, we quantified the reliability and efficacy of dogs trained for this purpose. Efficacy is the number of tortoises that dogs find out of a known population. Reliability is a measure of how many times a dog performs its trained alert when it has found a tortoise. A series of experimental trials were designed to statistically quantify these metrics in the field setting where dogs trained to locate live desert tortoises were tested on their ability to find them on the surface, in burrows, and in mark–recapture surveys. Results indicated that dogs are effective at and can safely locate desert tortoises with reliability on the surface and are capable of detecting tortoises in burrows under a range of environmental conditions. Dogs found tortoises at the same statistical rate at temperatures between 12° and 27°C, relative humidity from 16% to 87%, and wind speeds up to 8 m/s. In both surface and burrow trials, dogs found >90% of the experimental animals. In comparative studies with humans, dogs found tortoises as small as 30 mm, whereas the smallest tortoise located by human survey teams was 110 mm. Although not all dogs or dog teams meet the requirements to conduct wildlife surveys, results from this study show the promise in using dogs to increase our knowledge of rare, threatened, and endangered species through improved data collection methods.

Key words: conservation biology; desert tortoise; detection dogs; endangered species; environmental monitoring; Gopherus agassizii; *Mojave Desert; southwestern United States; survey methodology; wildlife biology*.

Introduction

The Mojave population (i.e., populations west and north of the Colorado River) of the desert tortoise (*Gopherus agassizii*) was designated as "threatened" by the U.S. Fish and Wildlife Service in 1990 (USFWS 1990). Critical Habitat was designated in February 1994, and the Desert Tortoise (Mojave Population) Recovery Plan was completed in June 1994 (USFWS 1994). In addition, the desert tortoise has state protection throughout its range in the United States. Scientists have been concerned about the decline in desert tortoise populations since the 1970s. Although considerable research has been conducted, much of it has failed to adequately inform recovery efforts (GAO 2002, Tracy et al. 2004). The tortoise was listed because population numbers were declining precipitously in many areas due to a number of factors including deterioration and loss of habitat, collection for pets and other purposes, elevated levels of predation, loss from disease, and the inadequacy of existing regulatory mechanisms to protect tortoises and their habitat (USFWS 1990). These factors are exacerbated when one considers the rare, cryptic, and elusive nature of the desert tortoise, especially of smaller size classes (i.e., <180 mm). The desert tortoise spends as much as 95% of its time underground (Nagy and Medica 1986) and is slow to reproduce, with a single generation time of 25 years (USFWS 1994).

The Desert Tortoise (Mojave Population) Recovery Plan (USFWS 1994) calls for two priorities relevant to the use of trained dogs to locate desert tortoises in the wild. First, a scientifically credible monitoring plan must be established to assess trends in desert tortoise populations. Statistically significant upward or stationary trends must be observed for at least 25 years within each recovery unit before delisting can occur; Line Distance Sampling (LDS) was chosen as the method for determining range-wide desert tortoise population status. Surveys have been conducted annually since 2001 and are to be conducted consistently over

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[3] E-mail: mcablk@dri.edu

the next several decades until sufficient baseline data are established to determine population status (i.e., increase, decrease, or stabilization). Recent analyses suggest that it may be impossible to detect significant upward trends using existing techniques and methods (Tracy et al. 2004), due to certain desert tortoise life history characteristics (Kareiva and Klepetka 1994). This phenomenon was previously demonstrated for Bald Eagle populations and is not unique to the tortoise (Hatfield et al. 1996). Therefore it may not be possible to meet the delisting criteria using people to survey for desert tortoise.

The second recovery plan priority relevant to using dogs as survey tools results from a 2002 General Accounting Office Report, which indicated that, as of 2002, more than U.S. $10 million had been spent toward desert tortoise research and recovery efforts, but efforts were not coordinated among scientists and agencies. The report recommended that new means for surveying desert tortoises be explored because humans are neither consistent nor necessarily good at finding them, a problem also supported by Anderson et al. (2001). Furthermore, tortoises <180 mm are not included in LDS analyses because humans are unable to reliably locate this size class. Both of these recovery plan recommendations point to the need for a new, improved method for finding tortoises if recovery efforts are to have a chance at meeting delisting criteria.

We present the results of a research project directed to investigate one alternative method for finding desert tortoises: the use of dogs trained specifically to find tortoises without harming them, under natural working conditions. Although our work was focused on desert tortoises, there are clear implications for using trained dogs for surveying other rare, cryptic, or elusive species, including their nests, eggs, scat, or remains (carcasses), for research and management applications.

Dog olfaction capabilities make them a natural choice for surveying for wildlife

Scent discrimination in dogs is well documented (Johnston 1999, Syrotuck 2000) and canines are used every day to detect and positively identify specific objects or trace elements including live people (Fenton 1992), human remains (Komar 1999), accelerants (Tindall and Lothridge 1995), narcotics (Lorenzo et al. 2003), and termites (Brooks et al. 2003). Dogs have been shown to be trainable on up to 10 different target substances, and the more individual targets trained, the faster the dog learns (Williams and Johnston 2002). For wildlife detection in the field, a dog must be able to discern the difference between its target species and all other extraneous background odors, including other potentially similar species. Dog olfaction has been found to be more sensitive than human olfaction by as much as an estimated 100 million times (Syrotuck 2000), and dogs are capable of detecting scent molecules (vapor) at concentrations as low as 10 parts per quadrillion (10^{15}; Garner et al. 2001). At the same time, olfaction is probably the least well understood of the mammalian senses, despite the fact that evolution has apparently placed more emphasis on this sense than any other (Guyton 1982). Much of the canine olfaction research has focused on thresholds of detection, or how few molecules of a substance a dog can detect, and whether dogs can detect specific chemicals in which law enforcement agencies are interested. Such studies are typically conducted under strict laboratory conditions and controlled environments because they are aimed at measuring biological capabilities of dogs rather than field efficacies (Waggoner et al. 1997, Johnston 1999, Williams et al. 1999). We know that dogs have incredibly sensitive olfaction capabilities; our challenge lies in training them to find what we want them to find, to communicate that find to us, and to find it safely (whether it be tortoises or explosives), and in selecting appropriate dogs and handlers that are physically and mentally up to the task.

Because dogs are able to generalize (Williams et al. 1999; T. Boussom, M. Cicoria, L. O. Busbee, M. G. Williams, J. Edmonds, and M. Williams, *unpublished data*), they can be trained on a set of captive desert tortoises, residual scent training aids, or both, and then can effectively locate new and different tortoises that they had never previously encountered or been presented with residual scent during training. This holds true even though every individual possesses a unique odor that is the olfactory equivalent of a fingerprint that cannot be concealed (Donalty and Henke 2001, Shivik 2002). For the purposes of finding wildlife for research applications and data collection, dogs would be expected to generalize across a species, allowing them to identify an individual not only as unique, but also as a member of a species or target population. Dogs have been useful in finding mammalian scat, including that of San Joaquin kit fox, grizzly bear, and black bear (Conover 2001, Akenson et al. 2004, Smith et al. 2006), and genetic analyses from scat recovered by trained search dogs have been very successful in yielding wildlife population information (Smith et al. 2003). Although the dogs in these projects were trained on a few scats, they were able to generalize across a species and find scats belonging to the target for which they had been trained.

Issues in using dogs to find live, protected species

Zwickel (1980) presents an overview of the use of dogs for wildlife work, most of which was reported in the mid-1960s. More recently some research has been conducted on the use of dogs to find the brown tree snake, a pest species, in Guam (Engeman et al. 1998*a*, *b*). When dogs were used to search air cargo containers for brown tree snakes, they were not reliable in performing their trained alert (i.e., indicating that they had made a find) and thus were not communicating those finds to their handlers. This failure is a training issue, not a detection capability limitation. Other wildlife studies have used dogs as a survey tool without quantifying the effectiveness or evaluating potential biases of the dogs in surveys (Schwartz et al. 1984). There are also unpublished reports or reports in popular literature of dog(s) being deployed to find nonnative pythons in Everglades National Park, black-footed ferrets in North Dakota, and bat carcasses under wind generators in the East and Midwest. These studies or applications have used dogs for a specific wildlife survey purpose without documented testing of the dog teams and without quantitative studies to evaluate the effectiveness, reliability, or biases of the method for the specific target. Earlier works using dogs for wildlife biology document the increase in effectiveness of surveys using dogs (Zwickel 1980), and identifying bias in survey methods is critical (Gutzwiller 1990). Documentation of methods and metrics for evaluation is vitally important to the development and successful deployment of any new survey technique.

Wildlife detection dogs used for studies involving species that are afforded legal protection under state and/or federal law must be under permit by the permitting agency. The stakes are high when interfacing dogs with a listed species, because any negative interaction has legal ramifications. For this reason, there are three basic requirements for a wildlife detection dog: (1) the dog must find the target species; (2) the dog must indicate that it has found the target species every time it makes a find; and (3) the dog must do (2) and (3) without harming the target species, itself, or its handler.

Successful completion of the first criterion is a combination of the individual dog's work ethic and proper training. The dog must be motivated to find the target. The second criterion is critical for reliable data collection, whether for research or to support a management action such as translocation. All dogs will find things. Some dogs can be trained to find certain things, but not all dogs will consistently search for and then indicate to their handler that they have found something. If a dog does not indicate to its handler that it has found its target, that target goes undetected, uncounted or uncollected, thus biasing results. Additionally, if the dog is not working to task, it is ineffective, much as an uncalibrated sensor provides useless data. Most important from a legal perspective is the third criterion. Many dogs find wildlife; in the Mojave Desert, dogs have been reported by land managers to harass and chew on tortoises. There are reports of dogs chewing on other species of tortoise as well (Causey and Cude 1978, Platt et al. 2003). Young desert tortoises are soft and particularly vulnerable to being stepped on or otherwise squashed. Larger tortoises can also be harmed by dogs; they can retract within their shell, but cannot close it completely (as many turtles can), thus leaving soft, vulnerable body parts exposed. Target animal safety must be a priority when considering dogs for use in wildlife detection, particularly when that species has legal designation and protection.

The objective of the research presented here was to assess the potential utility of dogs in finding the listed desert tortoise. We addressed the following issues. (1) How accurate and effective are dogs at finding desert tortoises? (2) How reliable are dogs at indicating they have found desert tortoises? (3) Can dogs detect the presence of desert tortoises in burrows? (4) Can dogs find desert tortoises without harming them?

Methods

Definitions

A *trained alert* is a behavior, such as sitting, that a dog is trained to do immediately and unprompted when it encounters its target. In this project, the target was a tortoise. When the dog encountered and recognized a tortoise, it performed its trained alert to indicate to the handler that it had found its target (see Plate 1).

Body language is a change in the dog's behavior upon encountering scent or the target, indicating that the dog has scent or has located the target. This is natural behavior, not trained, and is an alternative, albeit not preferred, means of communicating encounter with target scent to the handler.

Drive is a motivational characteristic inherent in a dog. Drive cannot be trained, but is a required element of a working dog. Without drive, a dog has no motivation to perform or work. Three types of drive are relevant to wildlife detection dogs: *hunt, prey,* and *play*. *Hunt drive* is the dog's persistent desire to find something, which is critical for wildlife detection work. A dog with very high hunt drive will search for its target despite fatigue, difficult terrain, or adverse environmental conditions. Hunt drive is what motivates dogs to search for hours without distraction from task. *Prey drive* is the dog's desire to chase. For live animal wildlife detection work, prey drive is acceptable only to a limited degree because prey drive can lead to unacceptable chasing or destruction of the target. *Play drive* is the desire to retrieve or tug with a human. Play drive is necessary to train the dog to alert upon locating the target. The dog will perform the task (the trained alert once the target is located) to gain the reward of a toy to retrieve or a game of tug. The combination of hunt and play drives is most desirable in a wildlife detection dog. Prey drive is acceptable in dogs that are trained to find inanimate objects that do not move, because inanimate objects do not elicit chase.

Accuracy is the actual measure of the dog's ability to find tortoises. Accuracy is the number of tortoises found by dogs divided by the number of tortoises that were available to be found, and is very different from dog *reliability*. For example, if a handler is able to determine that his or her dog has located a tortoise, regardless of whether or not the dog performs its trained alert, this indicates that the dog has the physical capability to locate tortoises, although there may be a training issue to resolve. Accuracy is a measure of the usefulness of

PLATE 1. DTK9 "Rip" waits for his handler to reward him with play after finding and sitting near a desert tortoise. Rip holds the sit, his trained alert, at an appropriate distance. The tortoise continues to walk, undisturbed by the dog and handler activity. Photo credit: J. S. Heaton.

dogs as a survey tool, which can be compared with measures of humans' abilities to find tortoises.

Reliability is defined as the number of times a dog encounters a tortoise and performs its trained alert. This is not a measure of a dog's ability to find tortoises, but a measure of the dog's behavior in the context of being used as a tool. Because wildlife dogs work off-leash and potentially many meters away from their handler, the alert is an important component of the dog as a survey tool. The alert is the means for the dog to communicate to the handler that it has located a desert tortoise. In this manner, the handler may approach the dog and likewise find the tortoise to be measured, transmittered, collected, or otherwise treated, appropriate to the particular survey.

Residual scent remains after the source has been removed. In this study, residual scent remained on gauze pads after being rubbed on tortoises, even after the tortoise was removed.

Training aids are artificial sources of target scent used to teach the dogs the preferred target that they are to find and alert upon. Training aids for this study were gauze pads with residual tortoise scent.

Dog training

Dogs were trained on residual scent, with training aids obtained by wiping captive tortoises with sterile gauze. Only the front forelegs and neck of the tortoises were wiped. The carapace, plastron, and rear portions of the tortoise were not wiped. The objective of focusing only on the front fleshy parts of the tortoise was to teach dogs to specifically identify live tortoises and not carcasses or feces. Standard detection dog training protocols based on operant conditioning were employed to teach the dogs the target scent: live tortoise. Trials were conducted at the Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada, USA between 1 and 28 April 2004. The DTCC is a research facility managed by the Bureau of Land Management (BLM) that includes ~445 ha of fenced Mojave Desert landscape in its natural state, unsubsidized (no planting, weeding, watering, or other manipulation). Numerous pens of varying size (from a few square meters to 8 ha) are delineated within the DTCC.

Dogs were first introduced to live tortoises at the DTCC under controlled conditions. During this time, the research team, which included a master dog trainer, evaluated dogs for drive, obedience, control, and general suitability for the task. Initially, five dogs were trained on residual scent training aids and all had exposure to captive live tortoises before arriving at the DTCC. Three of the five dogs proved to be inappropriate for finding live tortoises due to high prey drive, lack of handler control, and inappropriate behavior toward live animals. Two of the five dogs demonstrated suitable play and hunt drive as well as direction and control by the handler, and did not show inappropriate behavior toward live tortoises. Although Gutzwiller (1990) suggests that using two or more dogs in multiple trials is acceptable for minimizing study biases, we concede that two dogs are not a large enough sample size to make blanket statements about the capabilities of dogs, in general, for desert tortoise work. Therefore we present this study as a pilot to demonstrate initial proof-of-concept for using dogs to safely locate federally listed species.

Surface plots

In total, 26 trials were run on tortoises on the surface (not in burrows). Two different-sized plots were delineated with Global Positioning Systems (GPS): 0.5 ha (phase I) and 2 ha (phase II). Plot locations were varied for each trial within larger pens at the facility. Tortoises were captured and fitted with transmitters, and sex and size were recorded. The number of remaining resident, non-transmittered "wild" tortoises within individual pens was unknown. Non-transmittered tortoises were not included in the experimental design, but many of these "wild" tortoises were found by dogs. For each trial, 2–4 tortoises were placed and tethered at spatially random locations. To the extent possible, different tortoises were used in subsequent trials. Each trial setup was blind to the handler. Tortoises were tethered to a rebar stake using 1″ (2.54 cm) wide black nylon webbing ~24″ (~61 cm) in length through a ring epoxied onto the back end of the carapace. The tether setup was not readily visible to a passerby. Each tortoise was temporarily marked with a unique identification number (ID).

Dogs and handlers were fitted with GPS to record their actual movements. Start time and end time were recorded for correlation with local weather data recorded on site by four meteorological stations designed to collect data at dog nose height (~0.5 m). These stations were repositioned for each trial to ensure uniform coverage of each trial plot. Dog teams searched trial plots moving only in the forward direction, with no backtracking. They were allowed one pass through the area, with no time limit restriction on completing their search. Handlers determined their search strategy based on wind conditions and terrain. When a dog found a tortoise, it communicated that information to its handler via its trained alert or via body language. The handler then made a verbal statement to independent observers that the dog had found a tortoise. The handler then walked to the dog, waited for independent verification of the presence of a tortoise (if it was not obvious), and rewarded the dog upon verification. The following information was recorded in the GPS database at the location indicated by the dog: presence/absence of a tortoise, whether the tortoise was part of the trial or a "wild" tortoise, tortoise ID (if present and part of the trial), and whether or not the dog performed its trained alert or body language. If the tortoise was a wild tortoise, its midline carapace length (MCL) and sex (if determinable) were recorded. After the dog made a find, a tortoise was confirmed present, and the dog was rewarded, the handler and dog returned to the point on the search grid where they left and continued with the search. All GPS data were differentially corrected by post-processing to sub-meter accuracy. All GPS data collected on the dogs, the handlers, and by the meteorological stations were synchronized at 1-s intervals.

Accuracy assessment did not include "wild" tortoise finds (i.e., tortoises within the pens not exclusively identified and tethered for this study) because we did not necessarily know how many "wild" tortoises were present, or their location prior to being found, during the trial. Accuracy was calculated using a standard confusion matrix. Reliability was calculated using contingency table analysis (proportion parameters for three or more samples) and included errors of omission, commission, and chi-squared analysis.

The four meteorological stations placed within the boundaries of each plot collected data at 1-s intervals for temperature, relative humidity, wind speed, and wind direction. Mean and standard deviation of these variables were calculated for the time period when the dogs searched (start time to stop time). Reliability and efficacy were related with wind speed, temperature, and humidity, as recorded simultaneously and averaged over the trial time period. Environmental data were analyzed as factor levels. The levels of temperature, wind speed, and humidity were categorized accordingly.

Burrow trials

Burrow trials, broken into two phases, were conducted to determine if dogs could correctly identify whether or not a tortoise occupied a natural burrow. Natural burrows were flagged and the presence/absence of a tortoise in each burrow was known to the independent observers, but not the dog handlers. Handlers directed their dogs to sniff in the mouth of flagged burrows and articulated whether or not there was a tortoise in the burrow based on the dog's trained alert or behavior. Accuracy and reliability were calculated for each trial.

Mark–recapture

Two ~8-ha pens were withheld from use for surface and burrow trials so that mark–recapture survey comparisons between the dog teams and human survey teams could be conducted. We withheld these pens to ensure that there was no bias from the dogs having

TABLE 1. Reliability data for surface trials showing each dog, study phase, the number of tortoises found, the number of trained alerts, and the reliability quotient.

Dog	Phase	No. finds	No. trained alerts	Reliability (%)
1	1	27	8	30
1	2	29	7	24
2	1	30	16	53
2	2	26	25	96
All	All	112	56	50

learned individual tortoises during the previous trials. Thus, human surveyors and dog teams searched for a population consisting of individual tortoises that were completely unknown to them and also unhandled and unmarked by humans. Each dog team was assigned to one pen and searched that pen to completion three times in three successive days. Human teams of three searchers also searched these pens three times in three successive days. The first search was the mark and the remaining two searches were recaptures. Summary statistics were used to report basic findings by pen and by survey method. Small sample size coupled with unequal capture probabilities between large and small tortoises precluded mark–recapture data analyses such as Program MARK (White and Burnham 1999).

RESULTS

Surface plots

In total, 22 different individual tortoises were tethered during the 26 surface trials (df = 25 for all statistical tests), for a total of 86 tether stations with tortoises. In some instances, tortoises were located up to three separate times within one trial because dogs will find the same target repeatedly. Therefore the total number of detections on tortoises in the trials is greater than the actual number of tortoises tethered in the trials. In total, there were 112 finds over all 26 trials. Pooling the dog response data, 56 of 112 finds had no trained alert but were communicated by body language. The other 56 of 112 finds were indicated by the dog's trained alert. Therefore, although the dogs were able to find tortoises and communicate the finds to handlers, they were collectively only 50% reliable in their trained alert, as defined by this research. Dog 1 had an overall reliability of 27% and dog 2 was 73% reliable. Dog 1′s reliability decreased over the course of the surface trials whereas dog 2′s reliability almost doubled over the course of the surface trials. Table 1 summarizes reliability data for the surface trials.

In the trials, 78 of the total 86 tortoise tether stations were located at least once (overall effectiveness 91%). An additional 34 finds were logged as repeat finds, for a total of 112 finds over all 26 trials. Dog 1 was 93% accurate and dog 2 was 88% accurate. Accuracy increased between the two phases: overall accuracy was 87% for phase I and 95% for phase II. Data and results are summarized in Table 2. A Wilcoxon rank sum test was run to determine if there was a significant difference in the detection rates (accuracies) of the dogs and to assess if the detection rate increased between the two phases. This nonparametric alternative to the two-sample t test was run because the data were not normally distributed. There was no significant difference between the dogs ($Z = 0.3509$, $P = 0.7257$) or between phases ($Z = -1.9393$, $P = 0.0525$).

Wind speed ranged between 0 m/s (still) and 8.72 m/s over the course of the surface trials between 4 and 9 April 2004. Temperatures ranged between 12.16° and 26.73°C and relative humidity was 15.75–87.87%. Kruskall-Wallace rank sum tests indicated significant differences between trials for wind speed ($P < 0.0001$), temperature ($P < 0.0001$), and humidity ($P < 0.0001$).

The dogs were exposed to eight different female tortoises, 10 different males, and three unknowns that were too small to accurately sex. There were 34 female, 55 male, and 10 unknown encounters. Kruskall-Wallace one-way ANOVA indicated the difference between the MCL and sex of the tortoise was not significant ($P = 0.1040$). MCL ranged between 89 mm and 300 mm.

Burrow trials

The first set of trials involved 106 burrows: 29 with tortoises and 77 blank burrows. Dogs correctly identified 25 of 29 inhabited burrows (86% effective) and missed 4 of 29 animals in burrows (15% error of omission). Dogs correctly identified (by not indicating)

TABLE 2. Efficacy of dogs at finding tortoises on the surface.

Trial	No. tortoises	No. found	Dog	Phase	Found (%)
1	3	2	1	1	67
2	3	3	2	1	100
3	4	4	1	1	100
4	4	2	2	1	50
5	3	3	1	1	100
6	3	3	2	1	100
7	2	1	2	1	50
8	2	1	1	1	50
9	2	2	1	1	100
10	2	2	2	1	100
11	4	4	2	1	100
12	4	4	1	1	100
13	3	3	1	1	100
14	3	2	2	1	67
15	4	4	2	1	100
16	4	4	1	2	100
17	4	4	1	2	100
18	4	4	2	2	100
19	3	2	2	2	67
20	3	3	1	2	100
21	4	4	1	2	100
22	4	4	2	2	100
23	3	3	2	2	100
24	3	3	1	2	100
25	4	3	1	2	75
26	4	4	2	2	100
Sum	86	78			91

Note: This table shows how many tortoises were tethered in each trial, how many were found by dogs, at which phase of the research the trial occurred, and the per-trial efficacy.

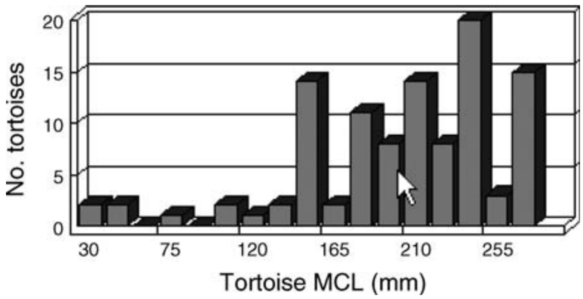

FIG. 1. Range of sizes of tortoises located by dogs during mark–recapture surveys. The x-axis is midline carapace length (MCL), which ranged from 30 mm to 280 mm.

66 of 77 blank burrows (86% accurate). In other words, they incorrectly indicated on blank burrows 11 times (10% error of commission). Accuracy for the dogs during the first trials on burrows was 86% (91 correct indications, tortoises present as present and blanks as blanks, out of 106 burrow encounters). Dogs performed trained alerts 17 of 25 times, for a 68% reliability. For the second set of trials, 58 burrows were used, of which 39 had known tortoises and 19 were blank burrows. Dogs correctly identified tortoises in 39 of 39 encounter opportunities (100%) and incorrectly indicated a tortoise present on a blank burrow once (5% error commission). Accuracy for the dogs during the second trials on burrows was 98%. Dogs performed trained alerts on 22 of 39 burrows with tortoises (56% overall reliability). For both trials, combined overall effectiveness for dogs on burrows was 90% (148 correct responses out of 164 opportunities). The dogs performed trained alerts on 47 of 68 correct indications on burrows with tortoises, for an overall reliability of 69% on burrows.

Mark–recapture

In the first mark–recapture pen, dog 1 found a total of 27 unique tortoises ranging in size from 30 to 270 mm MCL, whereas people found a total of 19 unique tortoises, ranging from 110 to 270 mm, in the same pen. In the second mark–recapture pen, dog 2 found a total of 23 unique tortoises, ranging in size from 50 to 280 mm MCL, and people found a total of 23 unique tortoises 150–280 mm in size. Figs. 1 and 2, respectively, show the overall size distribution of tortoises found by dogs and by people. Human and dog teams required a similar amount of time to complete a survey of a pen. Humans took 2–2.5 hours to complete a survey, whereas dogs took 2–3 hours. In total, humans found 40 tortoises and had 94 encounters in the two pens, whereas dogs found 50 tortoises and had 105 encounters. Dogs found smaller tortoises (30–280 mm) than did humans (110–280 mm).

DISCUSSION

The results of this study demonstrate that dog teams can locate tortoises under seminatural conditions, can communicate their finds, and can do so without harming the tortoise, themselves or their handler. Our results also indicate that not all dogs or handlers are well suited to this kind of work. Three dogs were rejected from the research study due to excessive prey drive and our assessment that they posed a significant threat to tortoises. The dogs that participated in the trials, however, proved to be very effective. During the trials, the dogs did not indicate on other natural desert elements such as lizards, snakes, rocks, or plant life. The dogs did not encounter tortoises without relaying this information to their handlers, as determined by the fact that handlers had to identify whether or not their dog was indicating that it had found a tortoise before knowing whether or not a tortoise was actually present. In addition, independent observers did not observe a dog leaving a tortoise without indicating a find to its handler. All of this verifies that the dogs were able to differentiate tortoises as tortoises and everything else as non-tortoise.

No tortoises were harmed during the course of this study and tortoises did not exhibit visible signs of stress from being found by dogs. For every interaction of dog and tortoise, we recorded whether or not the tortoise urinated or defecated, a sign of stress. In no instances did a tortoise of any size, age, or sex urinate or defecate upon interacting with, or being found by, a dog. The only time tortoises urinated or defecated was during transport in buckets, a method approved through our permit and required to move tortoises. In most instances, but not all, the reaction of the tortoise to the approach of a dog was to retract and, in some instances, hiss. We noted in many instances that once the dog made the initial find and focused on its handler, the tortoise relaxed its head and limbs out of its shell and often resumed its activity.

How good are dogs? Accuracy and reliability and why they are important to know

Dogs have been reported to be "100% accurate" at finding scat and other wildlife species (Smith et al. 2003). Such reports are potentially misleading in that they imply that the dogs find every target all the time and that everything a dog finds and identifies as a target is correct. Reported accuracy statistics will vary with the

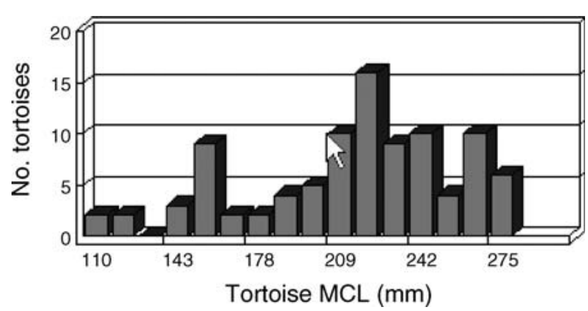

FIG. 2. Range of size classes located by people during mark–recapture surveys. The x-axis is midline carapace length (MCL), which ranged from 110 mm to 280 mm.

method of testing, the direction of the accuracy statistic, whether or not the reported score is, in fact, an accuracy statistic, and to what the statistic specifically refers. Overall accuracy can only be quantified experimentally, when the entire population of targets is known and the number of targets found can be compared to the number missed, as well as counts of things incorrectly identified as a target. Although accuracy at differentiating targets from nontargets is important to know, field efficacy is equally, if not more, important for assessing sample bias and its effects on resulting analyses. Questions remain to be answered to address dog survey bias, such as sex or age preferences and age of the target. Wasser et al. (2004) discuss some of the potential sources of sampling biases encountered during scat surveys for grizzly and black bear scats; these result from handler skill differences, sampling strategy, and environmental effects. These biases reduce the effectiveness of dogs in the field, but do not affect a dog's basic scent capability. Field efficacy is the accuracy of the dogs under natural working conditions, accounting for all of the variables that affect sampling, including handler limitations and environmental conditions. It is important not to overstate the capabilities of dog teams, because no tool is 100% accurate and, certainly, field efficacies are never perfect.

To be considered a viable tool for surveying wildlife, dogs need to be "better" at finding tortoises in some respect, either significantly faster, able to find significantly more tortoises, or able to find demographic size or age classes not typically found by humans. In addition to the experimental animals in our study, "wild" tortoises were available to be found during surface trials and during mark–recapture surveys, and dogs readily indicated on these tortoises as well. "Wild" tortoise and mark–recapture finds indicate that the dogs were not cueing off of human scent on experimental tortoises that were handled, nor were they cueing on other elements related to our handling of the tortoises, such as the tether stations. We conclude that dogs can recognize the scent of a tortoise regardless of whether or not a human has recently handled it.

Dogs missed fewer tethered tortoises as the trials progressed and, relatively speaking, they missed very few tortoises overall. We attribute this increased accuracy over time to the dog learning curve, decreased levels of stress on the part of the handlers over time, and increasing handler skill at grid searching. Stress of handlers decreased over time as they became more comfortable with the suitability of their dog for the task. Handlers also became more proficient at grid search strategy, which is much more complex than transect surveys and requires attention to environmental conditions.

The importance of dog reliability and the trained alert cannot be overemphasized; failure to perform a trained alert has been cited as reducing the effectiveness of wildlife and scat dog teams (Engeman et al. 1998*b*, Wasser et al. 2004). A dog must perform its trained alert, not indicate by body language alone, to meet the second criterion for a wildlife dog. A dog with low reliability, by our definition, would not be certifiable. In reality however, a good handler with a good working relationship with his or her dog is able to read body language and can ascertain finds without a trained alert. Our results demonstrated that even though dog 1 had low reliability, it remained as accurate as dog 2.

Despite these findings, we remain convinced that a reliable trained alert is vital to a good working dog team for the following reasons. First, although no studies have been conducted on trained alert behavior extinction in the field, it is common knowledge among working dog handlers that trained alert behavior in the field deteriorates under stressful conditions, which may include any number of circumstances (e.g., handler stress, environmental stress, encounter of a new and unfamiliar situation). When such conditions occur, dogs often revert to body language to communicate finds. If a dog does not have a trained alert and the handler relies on body language alone, the body language may deteriorate beyond recognition and, thus, finds will not be communicated. Second, handlers may not always be able to watch their dogs under actual search deployments, and a second person walking along with the team is unlikely to be able to read an unfamiliar dog's body language. If the dog does not have a trained alert and attempts to communicate through body language while the handler is not watching, that communication may be missed.

Dogs find tortoises in burrows despite the potential for residual scent

Finding tortoises in burrows is an important ability for a search team because tortoises spend as much as 95% of their time underground. Our study addressed the basic question: can dogs scent live tortoises in burrows (not residual tortoise scent)? To do this, we removed the search strategy element from burrow trials because the level of complexity of air-scenting tortoises in burrows (primarily burrow aerodynamics) is thought to be much greater than for surface tortoises. Our dogs were initially trained on residual scent, which is scent of tortoise but not an actual live tortoise. Given the amount of time that tortoises spend in burrows, residual scent would be expected to persist in and around burrows, although we have no knowledge of the residence time or duration of tortoise residual scent at burrows. It would be completely acceptable for a dog trained on residual scent to alert on a burrow without a tortoise but with residual scent in or around that burrow, if residual scent identification had not be extinguished through training.

Although we agreed that it was possible that dogs would alert on empty burrows known to have recently harbored a tortoise, we agreed that it was equally likely that the dogs would not alert on burrows with residual scent, due to associative learning. These were conflicting expectations that are also mutually exclusive. Our results suggest that, despite the complicating factor of residual scent, few nonproductive finds occurred, and only one could be positively attributed to residual scent.

The reduction in error of commission over the course of the burrow trials is probably a function of learning, because the dogs improved their ability to differentiate between burrows without tortoises and burrows with tortoises. Over the course of the two phases of burrow trials, the dogs refined their scent picture of what constitutes "tortoise," essentially unlearning tortoise residual scent. The dogs were not rewarded on false alerts (they were not corrected for false alerts, they were given neither positive nor negative reinforcement) and without reinforcement, the behavior of alerting on residual scent was extinguished.

Future direction for wildlife dog teams

The next step needed is to assess dog teams' effectiveness under natural tortoise densities, which would be expected to be lower than at the DTCC. The greatest potential for using dogs is to find the very smallest desert tortoise size classes, which humans typically cannot locate or survey for. It was very clear from this project that although dogs can locate tortoises safely, not all dogs are suitable in this regard. Safety to the tortoises is the priority and must remain so regardless of the type of survey (e.g., research, monitoring, clearance, translocation) for protected species. The combination of dog drive, training, and handler control over the dog dictate whether or not a dog is suitable for live-animal detection work. A dog that chases or attempts to incite a tortoise to interact with it cannot be deemed safe, particularly given the fragile nature of very small tortoises. Similarly, a dog that is not under control when out of the handler's sight can pose a threat to tortoises in that harm can be done (such as eating a very small tortoise) without a handler knowing it. For this reason, evaluation of both the dog and the handler is critical before a team can be fielded. We are actively working to develop a set of standards and a certification program that permitting agencies can rely on to make permitting decisions regarding the fielding of dog teams.

Conclusions

Dogs were found to be very effective at locating desert tortoises in the field, with an overall accuracy, or field efficacy, of 91%. Dogs found more tortoises than did humans in comparative mark–recapture surveys, and were able to find tortoises in the neonate and juvenile cohort classes. Humans almost never locate neonate or juvenile tortoises in surveys; for this reason, dogs may fill a specific survey niche in the future. Data collection on these smaller tortoises will contribute a significant amount of knowledge about the natural history, population dynamics, habitat requirements, and other aspects of the desert tortoise and may shed light on the plight of the tortoises' status as a listed species.

Reliability was found to be a function of the level and maintenance of training on the part of the handler, rather than being affected by environmental conditions or time worked. Accuracy was found to be a function of experience as well, increasing with the number of encounters over time. Accuracy was not found to be a function of environmental conditions such as wind speed, temperature, or humidity, or even length of time worked. Dogs were able to work under a range of environmental conditions, but those conditions represented a relatively narrow range of what would be expected during a field survey campaign over the course of a year. However, dogs were shown to be effective during what could be considered typical survey conditions for spring surveys.

More research is needed before dog teams can be fielded with confidence, in terms of quantitative accuracy, reliability, and safety to tortoises. Until standards and a certification process are developed and are recognized by federal and state permitting agencies, based on empirical studies and field trial demonstrations, the use of dogs to find desert tortoises remains promising but experimental.

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Literature Cited

Akenson, J. J., M. G. Henjum, T. L. Wertz, and T. J. Craddock. 2004. Use of dogs and mark–recapture techniques to estimate American black bear density in northeastern Oregon. Ursus **12**:203–210.

Anderson, D. R., K. P. Burnham, B. C. Lubow, L. Thomas, P. S. Corn, P. A. Medica, and R. W. Marlow. 2001. Field trials of line transect methods applied to estimation of desert tortoise abundance. Journal of Wildlife Management **65**:583–597.

Brooks, S. E., F. M. Oi, and P. G. Koehler. 2003. Ability of canine termite detectors to locate live termites and discriminate them from non-termite material. Journal of Economic Entomology **96**:1259–1266.

Causey, M. K., and C. A. Cude. 1978. Feral dog predation of the gopher tortoise, *Gopherus polyphemus,* (Reptilia, Testudines, Testudinidae) in southeast Alabama. Herpetological Review **9**:94–95.

Conover, A. 2001. The little foxes. Smithsonian **August**:42–51.

Donalty, S. M., and S. E. Henke. 2001. Can researchers conceal their scent from predators in artificial nest studies? Wildlife Society Bulletin **29**:814–820.

Engeman, R. M., D. V. Rodriquez, M. A. Linnell, and M. E. Pitzler. 1998*a*. A review of the case histories of the brown tree snakes (*Boiga irregularis*) located by detector dogs on Guam. International Biodeterioration and Biodegradation **42**:161–165.

Engeman, R. M., D. S. Vice, D. V. Rodriquez, K. S. Gruver, W. S. Santos, and M. E. Pitzler. 1998*b*. Effectiveness of the detector dogs used for deterring the dispersal of brown tree snakes. Pacific Conservation Biology **4**:256–260.

Fenton, V. 1992. The use of dogs in search, rescue and recovery. Journal of Wilderness Medicine **3**:292–300.

GAO (General Accounting Office). 2002. Research strategy and long-term monitoring needed for the Mojave Desert Tortoise Recovery Program. GAO-03-23, Washington, D.C., USA.

Garner, K. J., L. Busbee, P. Cornwell, J. Edmonds, K. Mullins, K. Rader, J. M. Johnston, and J. M. Williams. 2001. Duty cycle of the detector dog: A case study. Final report to the FAA (Federal Aviation Administration). Institute for Biological Detection Systems, Auburn University, Auburn, Alabama, USA.

Gutzwiller, K. J. 1990. Minimizing dog-induced biases in game bird research. Wildlife Society Bulletin **18**:351–356.

Guyton, A. C. 1982. Human physiology and mechanisms of disease. W. B. Saunders, Philadelphia, Pennsylvania, USA.

Hatfield, J. S., W. R. Gould, B. A. Hoover, M. R. Fuller, and E. L. Lindquist. 1996. Detecting trends in raptor counts: Power and Type I error rates of various statistical tests. Wildlife Society Bulletin **24**:505–515.

Johnston, J. M. 1999. Canine detection capabilities: operational implications of recent R & D findings. Institute for Biological Detection Systems, Auburn University, Auburn, Alabama, USA.

Kareiva, P. S., and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the western Mojave Desert. Ecological Applications **4**:446–460.

Komar, D. 1999. The use of cadaver dogs in locating scattered, scavenged human remains: preliminary field test results. Journal of Forensic Sciences **44**:405–408.

Lorenzo, N., T. L. Wan, R. J. Harper, Y. L. Hsu, M. Chow, S. Rose, and K. G. Furton. 2003. Laboratory and field experiments used to identify *Canis lupus* var. *familiaris* active odor signature chemicals from drugs, explosives, and humans. Analytical and Bioanalytical Chemistry **376**:1212–1224.

Nagy, K. A., and P. A. Medica. 1986. Physiological ecology of desert tortoises in southern Nevada. Herpetologica **42**:73–92.

Platt, S. G., W. K. Ko, L. L. Khaing, K. M. Myo, T. Swe, T. Lwin, and T. R. Rainwater. 2003. Population status and conservation of the critically endangered Burmese star tortoise *Geochelone platynotai* in central Myanmar. Oryx **37**:464–471.

Schwartz, E. R., C. W. Schwartz, and A. R. Kiester. 1984. The three-toed box turtle in central Missouri, Part II: a nineteen year study of home range, movements and population. Missouri Department of Conservation Publication, Terrestrial Series 12, Jefferson City, Missouri, USA.

Shivik, J. A. 2002. Odor-adsorptive clothing, environmental factors, and search-dog ability. Wildlife Society Bulletin **30**: 721–727.

Smith, D. A., K. Ralls, A. Hurt, B. Adams, M. Parker, B. Davenport, M. C. Smith, and J. E. Maldonado. 2003. Detection and accuracy rates of dogs trained to find scats of San Joaquin kit foxes (*Vulpes macrotic mutica*). Animal Conservation **6**:339–346.

Smith, D. A., K. Ralls, A. Hurt, B. Adams, M. Parker, and J. E. Maldonado. 2006. Assessing reliability of microsatellite genotypes from kit fox fecal samples using genetic and GIS analyses. Molecular Ecology **15**:387–406.

Syrotuck, W. G. 2000. Scent and the scenting dog. Second edition. Arner Publishing, Rome, New York, USA.

Tindall, R., and K. Lothridge. 1995. An evaluation of 42 accelerant detection canine teams. Journal of Forensic Sciences **40**:561–564.

Tracy, C. R., R. Averill-Murray, W. I. Boarman, D. Delehanty, J. S. Heaton, E. McCoy, D. Morafka, K. Nussear, B. Hagerty, and P. Medica. 2004. Desert tortoise Recovery Plan assessment. Report submitted to the U.S. Fish and Wildlife Service. ⟨http://www.fws.gov/nevada/desert_tortoise/dtro_recover_plan_assess.html⟩

USFWS (U.S. Fish and Wildlife Service). 1990. Endangered and threatened wildlife and plants; determination of the threatened status of the Mojave population of the desert tortoise: Final Rule, 2 April 1990. RIN 1018-AB35. Federal Register **55**:12178–12191.

USFWS (U.S. Fish and Wildlife Service). 1994. The desert tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

Waggoner, P., J. M. Johnston, M. Williams, J. Jackson, M. Jones, T. Boussom, and J. A. Petrousky. 1997. Canine olfactory sensitivity to cocaine hydrochloride and methyl benzoate. Proceedings of the First Annual Symposium on Enabling Technologies for Law Enforcement. Pages 216–226 *in* P. Pilon and S. Burmeister, editors. Chemistry- and biology-based technologies for contraband detection. International Society for Optical Engineering, Bellingham, Washington, USA.

Wasser, S. K., B. Davenport, E. R. Ramage, K. E. Hunt, M. Parker, C. Clarke, and G. Stenhouse. 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. Canadian Journal of Zoology **82**:475–492.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations for marked animals. Bird Study **46**(Supplement):120–138.

Williams, M., and J. M. Johnston. 2002. Training and maintaining the performance of dogs (*Canis familiaris*) on an increasing number of odor discriminations in a controlled setting. Applied Animal Behavior Science **78**:55–65.

Williams, M., J. M. Johnston, L. P. Waggoner, M. Cicoria, S. F. Hallowell, and J. A. Petrousky. 1999. Canine substance detection: operational capabilities. Proceedings of the 1999 Office of National Drug Control Policy Technology Symposium, Washington, D.C., USA.

Zwickel, F. C. 1980. The use of dogs in wildlife biology. Pages 531–536 *in* S. D. Schemnitz, editor. Wildlife management techniques manual. Wildlife Society, Washington, D.C., USA.