
ARE WILDLIFE DETECTOR DOGS OR PEOPLE BETTER AT FINDING DESERT TORTOISES (*GOPHERUS AGASSIZII*)?

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Abstract.—Our ability to study threatened and endangered species depends on locating them readily in the field. Recent studies highlight the effectiveness of trained detector dogs to locate wildlife during field surveys, including Desert Tortoises in a semi-natural setting. Desert Tortoises (*Gopherus agassizii*) are cryptic and difficult to detect during surveys, especially the smaller size classes. We conducted comparative surveys to determine whether human or detector dog teams were more effective at locating Desert Tortoises in the wild. We compared detectability of Desert Tortoises and the costs to deploy human and dog search teams. Detectability of tortoises was not statistically different for either team, and was estimated to be approximately 70% (SE = 5%). Dogs found a greater proportion of tortoises located in vegetation than did humans. The dog teams finished surveys 2.5 hours faster than the humans on average each day. The human team cost was approximately \$3,000 less per square kilometer sampled. Dog teams provided a quick and effective method for surveying for adult Desert Tortoises; however, we were unable to determine their effectiveness at locating smaller size classes. Detection of smaller size classes during surveys would improve management of the species and should be addressed by future research using Desert Tortoise detector dogs.

Key Words.—Fort Irwin, California, canine, Desert Tortoise, detector dogs, *Gopherus agassizii*, Mojave Desert, survey detectability

INTRODUCTION

Conservation efforts for threatened and endangered species often suffer from a lack of information on species requirements or distribution, especially when the species is rare or cryptic (Thompson 2004). Advancements in field survey techniques may provide increased knowledge about a population of rare plants or animals by increasing the number of individuals or populations located or by expanding the breadth of locations where they can be found, ultimately aiding in their conservation (McDonald 2004; Hernandez et al. 2006). For example, the Amargosa Toad (*Bufo nelsoni*), once thought to be near extinction (Altic and Dodd 1987) is now known to be locally common within its limited range, and its range is better defined (Simandle 2006). This change in knowledge, and therefore conservation status, was due to improving on where, when, and how to look for them (Jones 2004; Simandle 2006). Innovations have provided advances to sampling techniques for many rare or elusive species. Techniques such as photographic sampling of mammals in tropical

forests (Karanth et al. 2004), and noninvasive DNA sampling to detect species presence by hair or fecal samples (Farrell et al. 2000; Mills et al. 2001) among others have aided in sampling animals that are difficult to locate. Such techniques have added to our knowledge of their needs, behavior, habitat use, and distributions.

Working dogs are commonly used to conduct searches for target odors including wildlife and wildlife sign using primarily olfactory cues. For example, dogs have been successfully used to find turtles, mammals and mammalian scat for population assessment and monitoring in the wild (Schwartz et al. 1984; Morales-Verdeja and Vogt 1997; Smith et al. 2003, 2006; Akenson et al. 2004; Harrison 2006; Reindl-Thompson et al. 2006). Law enforcement contraband dogs are used to detect illegal animals and animal parts being smuggled in and out of countries around the world. Detector dogs are also used to aid in efforts to prevent additional dispersal of the Brown Tree Snake from Guam (Vice and Engeman 2000) and have been tested for their abilities to detect invasive weeds (Goodwin 2005), termites (Brooks et al. 2003), bat carcasses

(Arnett 2006), and even cancer in humans (Willis et al. 2004; McCulloch et al. 2006).

Surveys are frequently conducted to locate Desert Tortoises (*Gopherus agassizii*) to monitor population status (Anderson et al. 2001; McLuckie et al. 2002; Averill-Murray and Averill-Murray 2005), to clear tortoises from areas designated for development or construction (Clark County, Nevada. 2000. Clark County Multiple Species Habitat Conservation Plan and Environmental Impact Statement for Clark County, NV. Available from http://www.co.clark.nv.us/daqem/epd/desert/dcp_mshcp.html [Accessed 17 July 2007]), or to temporarily relocate tortoises during short-term construction or maintenance activities. Depending on the objective, surveys may involve capture-recapture studies on fixed study plots, random transects over broad areas, or removal clearances. Each of these methods uses humans to locate tortoises, or their sign, visually. This typically involves anywhere between two and 25 people and may take up to 60 days in the field (Berry 1986; Berry et al. 2006) depending on the size of the survey area and the objective. Surveys for Desert Tortoises are labor intensive and, therefore, can be costly. Detection rates on surveys are frequently not reported (Freilich and LaRue 1998). Recent range wide sampling efforts have provided some detection rates for models on training lines for Desert Tortoises ranging from 68% for adult-sized model tortoises (290 mm in length), 55% for subadult-sized model tortoises (180 mm), and only 46% for small juvenile-sized models (65 mm; Anderson et al. 2001). Reported detection values from five years of line-distance transect sampling on free ranging tortoises in the Mojave Desert between 2001-2005 ranged from 53 to 71% for animals > 180 mm in carapace length (CL), and tortoises < 180 mm were encountered so irregularly that detection rates were not reported (U.S. Fish Wildlife Service 2006. Range-wide monitoring of the Mojave population of the desert tortoise: 2001-2005 summary report. Available from http://www.dmg.gov/documents/rangewide_monitoring_report_20061024.pdf [Accessed 21 July 2007]).

Detector dogs have been shown to be adept at finding tortoises under semi-natural conditions (Cablak and Heaton 2006). Given this success, we hypothesized that detector dogs may exceed the ability of humans to detect tortoises in realistic field surveys, and potentially excel in the ability to locate smaller size classes of tortoises that typically elude human search teams due to their visual crypsis. We designed an experiment to assess directly the relative effectiveness of detector dog teams versus that of human survey teams to conduct an area-search on wild Desert Tortoises in their natural habitat and densities.

MATERIAL AND METHODS

Human Survey Team.—The human survey team consisted of nine people with a wide range of professional Desert Tortoise experience. Four of the people had between 15 and 40 years of experience, one person had four years of experience, and four of the people had 12 weeks of training on surveying for Desert Tortoises.

Detector Dogs.—We issued a call for handlers and qualified respondents were interviewed to gain more information about the handler and the candidate dog, with emphasis on previous experience, training, and drive. Twelve candidate handler/dog teams were invited to participate in the training and evaluation required in this study. Ten teams accepted the invitation. The teams initiated an eight week training session at their homes, designed to introduce the target odor (using residual tortoise scent; Cablak and Heaton 2006) and to begin conditioning the desired alert behavior (i.e., the “sit”). After this session, the teams came to the Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada from 18-30 September 2005 to complete training and undergo evaluation. Each dog progressed through training and was assessed for its ability to find tortoises, its behavior in the presence of tortoises, and safety. Handlers were trained to recognize tortoises and indirect evidence of their presence (e.g., scat, burrows, pallets, tracks), and were given orientations on Desert Tortoise biology and on Mojave Desert ecology and safety. By the end of the training at the DTCC, six of the ten canine teams were considered to have the skill and safety needed to conduct searches for Desert Tortoises in the wild. The dogs were of typical working breeds, and there appeared to be no general pattern in dog breeds that were selected (1 Border Collie, 2 German Shepherds, 1 Australian Kelpie, and 2 Labrador Retrievers) versus those that were not (1 Golden Retriever, 1 Labrador Retriever, and 2 German Shepherds), although there may be breeds of dogs that are unsuitable for this type of work.

Field Trials.—Field trials were conducted at the U.S. Army National Training Center (NTC) at Fort Irwin, California between 3 October and 4 November 2005. The NTC is in the north-central Mojave Desert, about 90 km ENE of Barstow in San Bernardino County, California (Fig. 1). Previous surveys of this area indicated patchy tortoise distribution ranging from low (<5/km²) to high (>15/km²) densities (Charis Corporation. 2003. Biological assessment for the proposed addition of maneuver training land at Fort Irwin, CA. Available from

<http://www.fortirwinlandexpansion.com/BA.htm> [Accessed 17 July 2007]). The study area was largely dominated by Mojave desertscrub vegetation (Turner 1982) consisting of a creosote bush (*Larrea tridentata*) / white bursage (*Ambrosia dumosa*) plant association.

We established 10 adjoining 1 km² plots in an area slated for future expansion of military training activities within the study area. We subdivided each plot in to 16 subplots, 250 m on a side, delineated with vertically placed PVC pipes (~ 3 m tall) to aid in navigation during

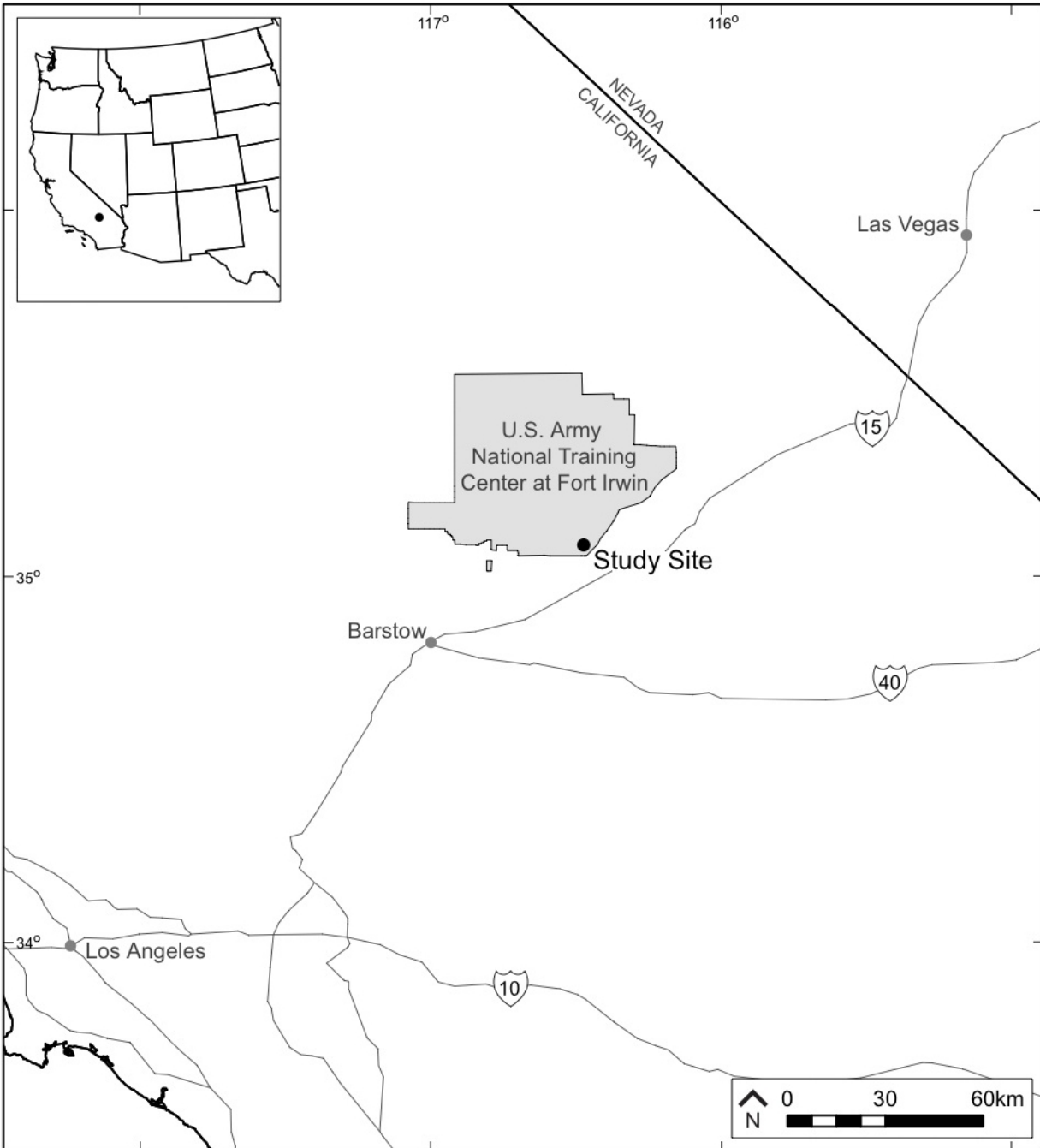


FIGURE 1. Map depicting the location of the field trials at Ft. Irwin National Training Center northeast of Barstow, California, USA.

the surveys. We used Global Positioning System receivers (GPS) to track the movements of both human and dog teams to ensure complete coverage of the plots. Each search team (human and canine) surveyed a single 1 km² plot per day. We conducted searches on two adjoining plots each week. After each team made a pass of their plot on two consecutive days, the teams switched plots and surveyed the second plot.

The human survey team consisted of nine people with two support biologists following behind to collect data on, and attach radio transmitters to, tortoises that were encountered during surveys. Members of the human team were spaced evenly in a line at ~14 m intervals, collectively covering a 125 m strip per transect. Starting at one side of the plot, each member walked in a zigzag pattern (Fig. 2A) within their lane across the 1 km wide plot. Human teams traversed a total of eight transects to completely survey a 1 km² plot each day. The first day on each plot was spent walking north-south transects, and on the second day transects were walked east-west.

The canine survey team was comprised of all six detector dog teams, where each team consisted of a wildlife detector dog, its handler, and one support biologist. The support biologist followed behind each dog team to confirm Desert Tortoise presence in burrows, capture tortoises, collect data, and attach transmitters to tortoises that were encountered. Dog teams were deployed such that each team was assigned an area to search (between two and four of the 16 subplots) each day.

Within the subplots, dog teams employed one of two search strategies that were assigned based on terrain - either a zigzag pattern or a contour pattern (Fig. 2B and 2C, respectively). These two search strategies were developed to keep a consistent search effort while optimizing the ability of the dog to use wind and terrain to its advantage. Dogs were deployed off-leash, and guided by voice commands of the handler. The zigzag pattern (e.g., France et al. 1992) was employed where the terrain was fairly level or sloped in one direction. The contour strategy was employed in areas where the landscape was physically complex due to arroyos and steep topography.

Data Collected.—Upon each encounter of a tortoise, we recorded its sex, carapace length (CL), GPS location and microhabitat location (in the open, under vegetation, or in a burrow).

Water soluble paint (with a different color assigned for each day of the week) was placed on the rear of the tortoise carapace to aid in subsequent identification of tortoises that were in burrows and could not be removed. In this way animals that would not come out of burrows could be marked, and be counted as previously identified if encountered later. Radio transmitters were attached to all tortoises > 180 mm in carapace length.

When daily searches were completed, all tortoises previously found within 500 m of the plots that were surveyed that day were tracked using radio telemetry. This allowed us to determine whether animals that were known to range on or near the active survey plots were on or off of the plot immediately after the surveys had taken place. These data allowed us to approximate the number of tortoises that were available to be encountered on each plot on a daily basis. This was only an approximation because animals that were undetected by search teams could have moved onto the plot after search teams had completed an area.

We recorded start and end times for each team on each day to allow us to quantify the amount of time each team spent searching; this time included any brief breaks taken by either team. A weather station (H21-001, Onset Computer Corporation, Pocasset, Massachusetts, USA) was placed centrally to collect environmental data, including rainfall (mm), relative humidity (%RH), wind speed (m/s, measured 1 m above the ground) and direction (degrees), and air temperature (°C at 5 cm and 1 m above ground) during the experiment.

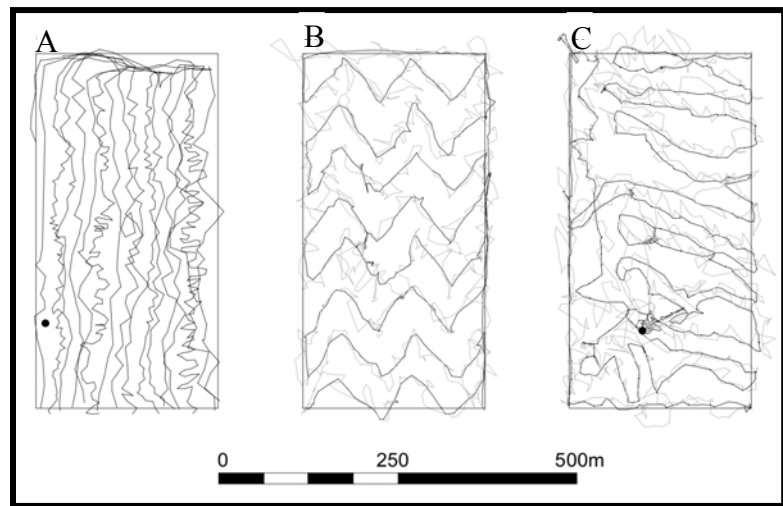


FIGURE 2. Global Positioning System receiver (GPS) tracking data illustrating two 125 m passes of the human team across two of the 250 m x 250 m subplots (A) and dog and handler zigzag (B) and contour (C) search strategies. Desert Tortoise locations are indicated by filled circles. The handler tracks are the darker lines in B and C, while the dog tracks are the lighter traces. Note no tortoises were located during the search depicted in panel B, and only 8 of the 9 surveyors carried a GPS in panel A. All but one of the GPS tracks was smoothed when downloaded due to equipment limitations of the GPS.

TABLE 1. Cost breakdowns and comparison for the human and dog teams expressed in U.S. dollars per day and dollars per km² coverage (two complete passes).

Team	Job Description	Number of Staff	Cost/Day	Cost (\$/1km ²)
Human Team	Bio Tech	5	\$109	\$1,090
	Biologists	4	\$176	\$1,408
	Research	3	\$360	\$2,160
	<i>Subtotal</i>			\$4,658
Dog Team	Biologists	6	\$176	\$2,112
	Handler/Dog	6	\$480	\$5,760
	<i>Subtotal</i>			\$7,872

To evaluate and illustrate plot coverage and quantify the distance covered by human and dog teams, the teams carried a combination of GPS receivers (e.g., Garmin GPS III, V, 12, and eTrex, Garmin International Inc, Olathe, Kansas, USA) during coverage of one of the plots to record the tracks of the human searchers and the handlers and their dogs. Due to the difference in quality of the GPS units, some of the tracks recorded contained fewer points than others, or exceeded the memory capability of the GPS unit (Fig. 2). Nevertheless sufficient information was gathered to approximate distances covered, and illustrate search strategies and plot coverage of the two teams.

Analyses.—We compared the relative effectiveness of human and dog teams at detecting tortoises using detection rates, sex distributions, microhabitat locations, and climate variables at the time of detection of tortoises found by each team. We also compared the cost of using human and dog teams and the amount of time daily that each team took to survey.

Detection Rates.—We estimated the detection rates of tortoises by humans as well as dog teams using data from all passes of all 10 plots. We express the rates of detection by human (event “H”) and dog (“K”) teams as both marginal probabilities of detecting the tortoise, $p(H)$ and $p(K)$, and conditional probabilities of detecting the tortoise given that the tortoise is present (“T”), denoted $p(H|T)$ and $p(K|T)$. Note that the probability of detection by human team, $p(H)$, is the product $p(T)p(H|T)$, where $p(T)$ is the probability that the tortoise is present. We can use the data to directly estimate $p(H)$ and $p(K)$, and their complements (i.e., $p(H^c)=1-p(H)$), but ultimately we are interested in the difference in human and dog-team detections conditional upon the presence of the target, $p(H|T)-p(K|T)$. The telemetry data can also be used to directly estimate the conditional probabilities of a tortoise’s presence given that it was not found by human, $p(T|H^c)$, or dog-team, $p(T|K^c)$. By Bayes’ formulas (i.e., $p(T)p(H|T) =$

$p(H)p(T|H)$ and $p(T)[1-p(H|T)] = p(H^c)p(T|H^c)$); Ross 1988) it is possible to solve for $p(T)$, $p(H|T)$, and $p(K|T)$, while observing that $p(T|H)$ and $p(T|K)$ are equal to 1 by definition. All estimates and their errors were solved by a Markov Chain Monte Carlo simulation with 20,000 iterations in a Bayesian framework using WINBUGS software (Version 1.4.1; Lunn et al. 2000).

Microhabitat and Climate.— We used a chi-square contingency table analysis ($\alpha = 0.05$) to test whether tortoises were differentially encountered in the three different microhabitat locations by the search teams, and whether there were differences in microhabitat locations in which male and female tortoises were detected. We compared the averages and distributions (using ANOVA and Kolmogorov-Smirnov tests respectively; $\alpha = 0.05$) of relative humidity (RH, %), temperatures (°C), and wind speeds (m/s) present at the time each tortoise was encountered by the human or dog teams

Time to complete surveys.—We calculated the amount of time that the human team was on the plot (simply the start time subtracted from the finishing time), and the average time that it took the six dog teams to complete their surveys, as the dog teams worked independently. We analyzed the relative time of the human and dog teams to complete each pass, the change in time to complete a pass over the course of the experiment, and any interaction that may have indicated one team becoming fatigued more than the other using a mixed-model ANOVA ($\alpha = 0.05$) where time was the response variable, and the team (human or dog), the cumulative day of the experiment, and their interaction were model factors. Because two passes were made on each plot, the plot was entered into the model as a random factor to control for any variability in time due to physical plot-specific factors such as terrain.

Cost-benefit analysis.—One important management implication of this work includes a cost-benefit analysis assessing the efficiency of each team relative to the costs. Costs of typical surveys (by human teams) can vary widely depending on the purpose and goals of the project, and the composition of personnel conducting the work, which may range from diverse groups such as volunteers, interns, and students to scientists and commercial contractors, and is often a combination of these. To simplify the analysis and focus the results on the most relevant costs, we limited the financial cost analysis to the cost of fielding the teams as implemented

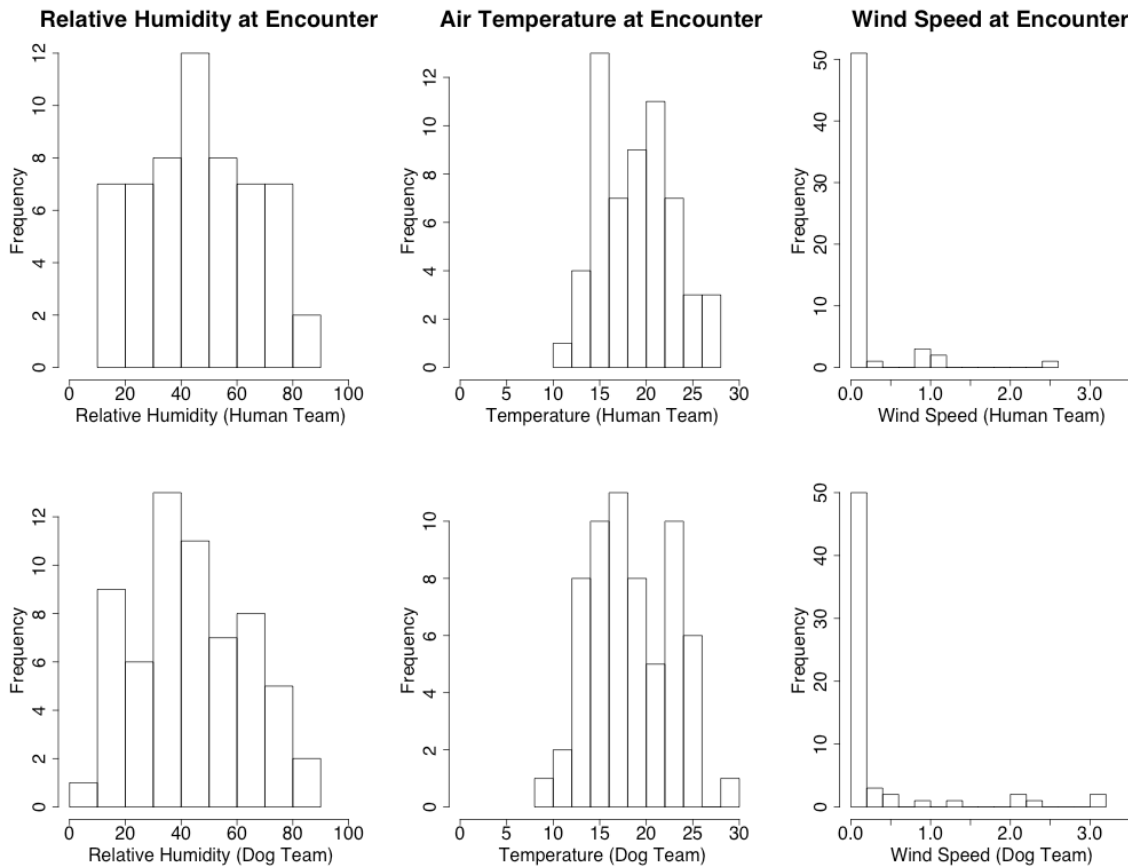


FIGURE 3. Frequency histograms of relative humidity, air temperature, and wind speeds present (from left to right respectively) at the time each Desert Tortoise was encountered by the human (upper panels) or dog teams (lower panels).

(i.e., USGS personnel and interns, and dog handlers plus support biologists), and we express this on a 1-km² basis, which included two passes of a plot. Thus, the cost was calculated as the dollar value of fielding teams for surveys without regard for peripheral costs such as training, equipment purchases, plot establishment, time to analyze or summarize the field data, per diem for travel and vehicles, or overhead and indirect costs.

RESULTS

Tortoises encountered.—Over the study period 60 tortoises (41 males, 16 females, and 3 of undetermined sex) were located by both teams. Throughout the trials, the human team located tortoises on 70 occasions and missed 19 tortoises likely to have been on the plots. The dog team located tortoises on 71 occasions and missed 17 tortoises likely to have been on the plots. The total number of detections exceeded the number of unique tortoises found (60) because many tortoises moved among plots during the experiment, thus becoming

available as a new detection on successive searches. On one occasion, a tortoise was found in adjacent plots during surveys on the same day.

The probability of detecting a tortoise, given its presence on the plot, was virtually identically estimated at 0.7 (70%) for both humans $p(H)$ and dogs $p(K)$ respectively with standard deviations of 0.05. The 95% credibility intervals were (0.60, 0.80) for humans and (0.60, 0.79) for the dog teams. There was statistically and functionally no difference between human and dog team detection of tortoises. The posterior distribution for $p(H/T)-p(K/T)$ had a mean of 0.006347 and a standard deviation of 0.07, and the 95% credibility interval was -0.13 to 0.14. This confidence interval indicates a potential for up to a 10% difference in detection rates given the sampling error allowed by this sample size, but this difference could occur in either direction.

Overall more male tortoises were found than females, but humans and dogs found/missed approximately the same proportions of both males ($\chi_1^2 = 1.072, P = 0.30$)

and females ($\chi_1^2 = 0.16, P = 0.69$). The human team found 52 males and missed 11, while the dog team found 58 and missed 11. The human team found 17 females and missed 7, and the dog team found 13 females and missed 4. Only one juvenile tortoise was found during the surveys (by the human team) although two hatchlings (47 and 41 mm CL) were located on the plots by outside observers during two one-day inspections by regulatory personnel.

There was a potential difference among the microhabitat locations that tortoises were encountered in by the human and dog teams ($\chi_2^2 = 5.64, P = 0.06$), and visual inspection of the data indicated that this may have been due to a differential number of tortoises detected under vegetation. Humans found 44 tortoises in burrows, 22 in the open and four under vegetation, while dogs found 37 in burrows, 21 in the open and 13 under vegetation. A subsequent analysis comparing tortoises found in vegetation to the other two microhabitat locations (pooled) yielded a significant difference in the number of animals encountered under vegetation relative to the team ($\chi_1^2 = 5.53, P = 0.02$). This indicated that the dog team found a greater proportion of animals in vegetation than humans did. Male and female tortoise detections did not differ statistically in their distribution among microhabitats ($\chi_1^2 = 2.33, P = 0.31$).

None of the climatic variables examined differed with respect to the range of conditions in which tortoises were encountered by the human, compared to the dog team. Tortoises were encountered by both teams where relative humidity ranged from 9.8% to 85.8%, and neither the average ($F_{1,118} = 0.49, P = 0.48$) nor the distribution ($D = 0.12, P = 0.78$) differed between teams. The distribution of tortoise encounters relative to RH did not show a skew in either direction that would indicate increased detections by the dog team in higher or lower RH conditions (Fig. 3). Tortoises were encountered at air temperatures ranging from 9.4°C to 29.9°C and neither the average ($F_{1,118} = 0.58, P = 0.44$) nor the distributions ($D = 0.13, P = 0.71$) differed between teams. Again there was no skew that would indicate differential ability to detect tortoises at different temperatures within the temperature ranges we experienced. Wind speed at encounters ranged from (0 to 3.15 m/s), was calm for the most part and also did not differ between teams with respect to either the average ($F_{1,118} = 1.7, P = 0.19$) or the distribution ($D = 0.10, P = 0.92$).

Time investment.—The human team searched an average 8.52 hrs per day, with each person walking an average linear distance of 15 km per day. Individual dog teams worked on average 5.92 hrs per day, which was significantly less time than the human team ($F_{1,27} =$

65.33 $P < 0.0001$). The dog handlers walked a linear distance of between 10-14 km per day; whereas, the dogs walked 40-80 km a day (as recorded by GPS). The time to complete each pass did not change significantly over the 5-week time period ($F_{1,27} = 0.33, P = 0.57$), and there was no significant team by day of experiment interaction ($F_{1,27} = 0.87, P = 0.36$) indicating that neither team had a significant trend in average survey time over the course of this study.

Cost.—Our estimated cost to survey two passes on 1 km² of Desert Tortoise habitat by the human team was US\$4,658 and the cost for the dog teams for the same survey was US\$7,872. Therefore, the cost of the human team was 60% that of the dog teams. Each search team ultimately required the same number of personnel (12); however, the cost discrepancy was largely due to the costs of dog handlers, which were more expensive (by US\$120 per day) than even the senior personnel on the human team, and twice as many were required (Table 1).

DISCUSSION

This was the first scientific comparison of human-based survey efforts with the use of dogs for surveying for Desert Tortoises under natural conditions. We found that dog teams and humans were able to achieve the same detection rates for tortoises, although all but one of the tortoises found during the surveys were adults. The detection rate for dogs was 20% lower than that reported by Cablk and Heaton (2006) under semi-natural conditions, which may reflect the difficulties of searching for tortoises under natural conditions and densities. The dog teams finished the daily surveys in 66% of the time required by humans, but the human team, as fielded, cost only 60% as much as the canine teams. There were no instances of dogs harming tortoises or chasing other wildlife during the study.

Individual handlers and human surveyors walked roughly the same distance on any given day (i.e., as much as 15 km). The human survey typically took the entire day (8.5 hours) to complete (day length averaged 11 hours during the study). However, detector dog-handlers were able to move at a faster pace than human search teams because the dog searched for the tortoises while the handler navigated. While the dog teams were able to complete their surveys in a shorter time (6 hours), they were not necessarily capable of searching a larger area than was covered each day due to dog fatigue. Thus, the time savings we report will be of little benefit unless other adjustments are made, for example, having a handler work two dogs in one day (sequentially) to cover a larger area; however, this may increase costs as well. There is the potential, once a certification

procedure is in place that allows detector dogs to be trained and used by tortoise biologists and permitted by state and federal agencies, that further cost savings may be realized. While dogs have been effective in earlier research finding turtles (Schwartz et al. 1984; Morales-Verdeja and Vogt 1997), the threatened status of the Desert Tortoise and our permit requirements precluded any interactions of the dogs with the tortoises. Earlier studies enumerating Box Turtle populations used retrieval by the dogs rather than non-interactive alerts, as were used for this research. Due to the possibility of encounters with dogs causing tortoises to urinate, potentially causing them harm (Averill-Murray 2002), our dogs were required to demonstrate performed alerts, without touching or harming tortoises; thus, we could not use dogs to retrieve tortoises (Schwartz et al. 1984) or without prior training for this species as has been done in other research (Morales-Verdeja and Vogt 1984). Besides, only the smallest tortoises could be retrieved by dogs.

Dogs are no different than humans with respect to potential wildlife detection biases. Even dogs with desirable traits are subject to unfavorable environmental conditions, which may result in bias and inconsistency (Gutzwiller 1990). This may be attributed to working in different habitats, weather, and the changing physical and psychological conditions for the dog as well as the target species (Gutzwiller 1990). Although these circumstances cannot always be avoided, careful study design and analyses can minimize such problems. We encountered some limitations to using the dogs due to increased body temperatures imposed by the environment. Temperature limitations for dogs are driven by many mechanisms of heat exchange, including solar insolation, and to a lesser extent, air temperature (Porter and Gates 1969). Dogs with a body temperature (measured rectally) $> 40^{\circ}\text{C}$ or showing outward signs of heat stress were stopped until they were passively or actively cooled to 38.8°C . Outward signs of a dog overheating include shade-seeking behavior, change in tongue color with thick and rope-like saliva, and excessive panting. During the surveys, the dog teams worked continuously in the field with breaks for water, rest, reward, and temperature regulation as needed until their survey assignment was completed. All surveys were completed. These guidelines were provided to us by the U.S. Army Research Office veterinarian assigned to review our Army Animal Use and Care Permit, and were instituted by us voluntarily. Human surveyor body temperatures or comfort are not regulated and humans can, are expected to, continue to work within reason regardless of the outside air temperature. We had no indication of heat stress in the human team during the surveys. Difficult terrain did tend to cause the survey

time to increase due to increased fatigue. The human team also took short breaks (5 min) at the end of each 1 km pass for water and was allowed a longer break (30 min) halfway through the plot survey.

It should be noted that our surveys took place in the fall (October and early November) when air temperatures were cool with an average temperature of 20°C and a maximum temperature of 30°C during the hours worked. Surveys in the spring months when tortoises are most active (Woodbury and Hardy 1948; Zimmerman et al. 1994) may present climatic conditions that limit time periods when dogs can be employed for searches based on acceptable animal husbandry practices. It may be optimal for dogs to be used during cooler times, such as during the night, or early morning; although, fewer tortoises are active and above ground during these periods (Nussear and Tracy 2007). While dogs are quite capable of finding tortoises in burrows, surveys during low levels of tortoise activity may not meet the needs of the specific study or survey if capturing and handling are required, as tortoises can be difficult to extract from burrows. This is one of the reasons humans typically conduct surveys coinciding with high tortoise surface activity when possible. However, dogs are able to detect tortoises in burrows, even when the tortoises are not visible, and thus potentially more animals could be identified using detector dogs; although, the human and dog teams did not differ statistically in this ability during this study. It might be very effective to combine human and detector dog searches benefiting from the advantages of both teams.

None of the local climate variables that we examined showed differences in either the average, or the underlying distribution of the respective parameters between the survey teams. The relative influences of these parameters are often discussed as being influential to both scent production and detection (Gutzwiller 1990), but have rarely been shown to influence detection by detector dogs, and often not in predicted directions (Shivik 2002) if at all (Long et al. 2007).

Each of the survey teams found a high ratio of male to female tortoises (2.56:1), relative to what is thought to be a typical sex ratio for this species (1:1; e.g., Turner et al. 1984; Freilich et al. 2000). One explanation for this observation is that the population may truly be biased. There is some support for this as the two survey methods, which rely on different cues to find tortoises, found nearly the same ratio of male to female tortoises. The observed sex bias could potentially result from sex ratios of tortoise populations altered via developmental mechanisms that control the determination of sex in response to temperature (Rostal et al. 2002) reflecting the soil micro-climate of the largely north-facing bajada

upon which the surveys were conducted. Other causes of sexual biases may result from bias in mortality due to disease or drought, although this is seldom reported (Peterson 1994; Longshore et al. 2003) or male biased recolonization following a recent die-off (Germano and Joyner 1988). An alternative explanation to the observed bias is that, while the surveys were conducted largely during the month of October, when tortoises are known to be mating (Woodbury and Hardy 1948), it is possible that females had already entered hibernation, and males were still relatively active (Rautenstrauch et al. 1998, but see Nussear et al. 2007). Therefore some behavioral or physiological aspect of hibernation may have allowed females to elude being detected both visually and by odor. However, this elusive behavior of females may extend beyond hibernation. During five years of transect sampling in the area that encompassed our survey plots (Superior Cronese Desert Wildlife Management Area), sex ratios of tortoises found ranged from 1.05:1 to 2.23:1 among years (U.S. Fish and Wildlife Service 2006. *op. cit.*), even during spring surveys. Thus, there appear to be years in which females elude sampling efforts (but see Freilich et al. 2000), as tortoise population demographics for adult tortoises are not typically thought to change this rapidly (e.g., Doak et al. 1994).

Both teams found tortoises in burrows, shrubs, and in the open. While both teams found tortoises in burrows in equal proportions, the dogs found more tortoises in shrubs than humans did, which is explained by the differences in the primary method of detection. Humans rely on visual cues to locate tortoises, while dogs rely primarily on olfaction. Burrows are easily detectable visually providing an obvious cue to human surveyors, and any burrow encountered is examined thoroughly for tortoises. Handlers also encouraged the dogs to check all burrows encountered. Shrubs in the Mojave can be very dense and provide good cover for tortoises such that they are difficult to see. While dense, shrubs are not impervious to wind and scent travels with the wind. Thus, the tortoise that is obscured from view by a shrub may be readily encountered by an olfactory search strategy. This has been demonstrated for other species (Homan et al. 2001).

We expected that the dog teams would have a higher encounter rate for the smaller, visually cryptic, tortoises because dogs use olfaction to confirm tortoise presence over visual cues and smaller tortoises are simply more difficult to see. We found no evidence to support this expectation as neither team detected appreciable numbers of small tortoises, yet at least two neonatal sized tortoises were present and discovered by outside observers during our surveys. This result is not atypical for human searches due to the relatively cryptic and

elusive behavior of small tortoises (Anderson et al. 2001; Bjurlin and Bissonette 2004; U.S. Fish Wildlife Service 2006. *op.cit.*). It is possible that smaller tortoises produce less scent than larger tortoises, causing them to be equally difficult for dogs to find. Search strategy likely plays a role for either team and if we need to find a smaller target then a more detailed search strategy is required. This will require more surveyor time spent on smaller search areas, both of which will increase costs irrespective of the surveyor (human or dog). Both teams were fielded using a search strategy designed to find tortoises over relatively large areas. For the dog teams, this resulted in a reduction in the level of detailing that could be implemented within the gross search strategy over the course of the day. It may be that a more detailed search strategy could increase the likelihood of detection of small tortoises by the dogs. Similarly, the humans might also increase detection rates for smaller tortoises by decreasing the area covered by each person, although tortoises in vegetation, or burrows (especially rodent burrows) would likely still elude detection.

This work confirms that wildlife detector dogs, if properly trained, can serve as an alternative and equally effective means for conducting field surveys for Desert Tortoises. This may be of benefit given the increasing demand for field surveys as a result of monitoring and clearances for urban and other development. The dog teams were a safe, quick, and effective way to detect tortoises, and their costs are within the range of cost for hiring researchers or consultants. These teams also only required several weeks of training to learn the target scent. Additional focus on training and adjustments in search strategy might increase detections of smaller size classes of tortoises, greatly improving this technique. Thus, we suggest that the use of wildlife detector dogs to survey for Desert Tortoises has direct application to conservation of this (and likely other) species.

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LITERATURE CITED

- Akenson, J.J., M.G. Henjum, T.T. 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.
- Altic, R., and K.C. Dodd. 1987. The status of the Amargosa Toad (*Bufo nelsoni*) in the Amargosa River drainage of Nevada. *The Southwestern Naturalist* 32:276-278.
- 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.
- Arnett, E.B. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. *Wildlife Society Bulletin* 34:1440-1445.
- Averill-Murray, Roy C. 2002. Effects on survival of Desert Tortoises (*Gopherus agassizii*) urinating during handling. *Chelonian Conservation and Biology* 4:430-435.
- Averill-Murray, R., and A. Averill-Murray. 2005. Regional-scale estimation of density and habitat use of the Desert Tortoise (*Gopherus agassizii*) in Arizona. *Journal of Herpetology* 39:65-72.
- Berna, H. 1990. Seven bat species from the Kaibab Plateau, Arizona, with a new record of *Euderma maculatum*. *The Southwestern Naturalist* 35:354-356.
- Berry, K.H. 1986. Desert Tortoise (*Gopherus agassizii*) research in California, 1976-1985. *Herpetologica* 42:62-67.
- Berry, K.H., T.Y. Bailey, and K.M. Anderson. 2006. Attributes of desert tortoise populations at the National Training Center, Central Mojave Desert, California, USA. *Journal of Arid Environments* 67:165-161.
- Bjurlin, C.D., and J.A. Bissonette. 2004. Survival during early life stages of the Desert Tortoise (*Gopherus agassizii*) in the south-central Mojave Desert. *Journal of Herpetology* 38:527-535.
- 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.
- Cablck, M.E., and J.S. Heaton. 2006. Accuracy and reliability of dogs in surveying for Desert Tortoise (*Gopherus agassizii*). *Ecological Applications* 16:1926-935.
- Doak, D., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the Desert Tortoise in the western Mojave Desert. *Ecological Applications* 4:446-460.
- Farrell L.E., J. Roman, M.E. Sunquist. 2000. Dietary separation of sympatric carnivores identified by molecular analysis of scats. *Molecular Ecology* 9:1583-1590.
- Fenton, M., D. Tennant, and J. Wyszecski. 1987. Using echolocation calls to measure the distribution of bats: the case of *Euderma maculatum*. *Journal of Mammalogy* 68:142-144.
- France, D.L., T.J. Griffin, J.G. Swanburg, J.W. Lindemann, G.C. Davenport, V. Tranunell, C.T. Armbrust, B. Kondrateiff, A. Nelson, K. Castellano, and D. Hopkins. 1992. A multidisciplinary approach to the detection of clandestine graves. *Journal of Forensic Sciences* 37: 1445-1458.
- Freilich, J.E., and E.L. LaRue. 1998. Importance of observer experience in finding Desert Tortoises. *Journal of Wildlife Management* 62:590-596.
- Freilich, J.E., K.P. Burnham, C.M. Collins, and C.A. Garry. 2000. Factors affecting population assessments of Desert Tortoises. *Conservation Biology* 14:1479-1489.
- Germano, D.J., and M.A. Joyner. 1988. Changes in a Desert Tortoise (*Gopherus agassizii*) population after a period of high mortality. Pp. 190-198 *In* Management of Amphibians, Reptiles, and Small Mammals in North America. United States Department of Agriculture, Forest Service, Fort Collins, Colorado, USA.
- Goodwin, K. 2005. Montana weed prevention areas: Partnerships for rangeland protection. Pp. 35-38 *In* Proceedings of the California Invasive Plant Council Symposium, Volume 9:2005. G. Skurka, (Ed.). California Invasive Plant Council, Berkeley, California, USA

- Gutzwiller, K.J. 1990. Minimizing dog-induced biases in game bird research. *Wildlife Society Bulletin* 18:351-356.
- Harrison, R.L. 2006. A comparison of survey methods for detecting Bobcats. *Wildlife Society Bulletin* 34:548-552.
- Hernandez, F., W.P. Kuvlesky, R.W. DeYoung, L.A. Brennan, and S.A. Gall. 2006. Recovery of rare species: Case study of Masked Bobwhite. *Journal of Wildlife Management* 70:617-631.
- Homan, J.H., G. Linz, and B.D. Peer. 2001. Dogs increase recovery of passerine carcasses in dense vegetation. *Wildlife Society Bulletin* 29:292-296.
- Jones, D. 2004. Aquatic and terrestrial use of habitat by the Amargosa Toad (*Bufo nelsoni*). M.Sc. Thesis, University of Nevada, Reno, Nevada, USA. 92 p.
- Karant, K.U., J.D. Nichols, and N.S. Kumar. 2004. Photographic sampling of elusive mammals in tropical forests. Pp. 229-247 *In* Sampling rare or elusive species. W.L. Thompson (Ed.). Island Press, Washington, D.C., USA.
- Long, R.A., T.M. Donovan, P. Mackay, W.J. Zielinski, and J.S. Buzas. 2007. Effectiveness of scat detection dogs for detecting forest carnivores. *Journal of Wildlife Management* 71:2007-2017.
- Longshore, K.M., J.R. Jaeger, and J.M. Sappington. 2003. Desert Tortoise (*Gopherus agassizii*) survival at two eastern Mojave Desert sites: death by short-term drought? *Journal of Herpetology* 37:169-177.
- Lunn, D.J., A. Thomas, N. Best, and D. Spiegelhalter. 2000. WinBUGS - a Bayesian modeling framework: concepts, structure, and extensibility. *Statistics and Computing* 10:325-337.
- McCulloch, M., T. Jezierski, M. Broffman, A. Hubbard, K. Turner, and T. Janecki. 2006. Diagnostic accuracy of canine scent detection in early- and late-stage lung and breast cancer. *Integrative Cancer Therapies* 5:30-39.
- McDonald, L.L. 2004. Sampling rare populations. Pp. 11-42 *In* Sampling Rare or Elusive Species. W.L. Thompson (Ed.). Island Press, Washington, D.C., USA.
- McLuckie, A.M., D.L. Harstad, J.W. Marr, and R.A. Fridell. 2002. Regional Desert Tortoise monitoring in the Upper Virgin River Recovery Unit, Washington County, Utah. *Chelonian Conservation and Biology* 4:380-386.
- Mills L.S., K. Pilgrim, M.K. Schwartz, K. McKelvey. 2001. Identifying Lynx and other North American felids based on MtDNA analysis. *Conservation Genetics* 1:285-288.
- Morales-Verdeja, S.A., and R.C. Vogt. 1997. Terrestrial movements in relation to aestivation and the annual reproductive cycle of *Kinosternon leucostomum*. *Copeia* 1997:123-130.
- Nussear, K.E., and C.R. Tracy. 2007. Can modeling improve estimation of Desert Tortoise population densities? *Ecological Applications* 17:579-586.
- Nussear, K.E., T.C. Esque, D.F. Haines, and C.R. Tracy. 2007. Desert Tortoise hibernation: temperatures, timing, and environment. *Copeia* 2007:378-386.
- Peterson, C.C. 1994. Different rates and causes of high mortality in two populations of the threatened Desert Tortoise, *Gopherus agassizii*. *Biological Conservation* 70:101-108.
- Porter, W.P., and D.M. Gates. 1969. Thermodynamic equilibria of animals with environment. *Ecological Monographs* 39:227-244.
- Priday, J., and B. Luce. 1999. New distributional records for Spotted Bat (*Euderma maculatum*) in Wyoming. *Great Basin Naturalist* 59:97-101.
- Rautenstrauch, K.R., A.L.H. Rager, and D.L. Rakestraw. 1998. Winter behavior of Desert Tortoises in south central Nevada. *Journal of Wildlife Management* 62:98-104.
- Reindl-Thomson, S.A., J.A. Shivik, A. Whitelaw, A. Hurt, and K.F. Higgins. 2006. Efficacy of scent dogs in detecting black-footed ferrets at a reintroduction site in South Dakota. *Wildlife Society Bulletin* 35:1435-1439.
- Ross, S. 1988. *A First Course in Probability*. 3rd Edition. Macmillan, New York, New York, USA.
- Rostal, D.C., T. Wibbels, J.S. Grumbles, V.A. Lance, and J.R. Spotila. 2002. Chronology of sex determination in the Desert Tortoise (*Gopherus agassizii*). *Chelonian Conservation and Biology* 4:313-318.
- 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 and population. Missouri Department of Conservation, Jefferson City, Missouri. 12 pp.
- Shivik, J.A. 2002. Odor-absorptive clothing, environmental factors, and search-dog ability. *Wildlife Society Bulletin* 30:721-727.
- Simandle, E.T. 2006. Population structure and conservation of two rare toad species (*Bufo exsul* and *Bufo nelsoni*) in the Great Basin, USA. Ph.D. Dissertation, University of Nevada, Reno, Nevada, USA. 110 p.
- 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 macrotis mutica*). *Animal Conservation* 6:339-346.
- Smith, D.A., K. Ralls, B.L. Cypher, H.O. Clark, Jr., P.A. Kelly, D.F. Williams, and J.E. Maldonado. 2006.

Relative abundance of endangered San Joaquin Kit Foxes (*Vulpes macrotis mutica*) based on scat-detection dog surveys. *Southwestern Naturalist* 51:210-219.

Thompson, W.L. 2004. Introduction. Pp. 1-7 *In* Sampling Rare or Elusive Species. Thompson, W.L. (Ed.). Island Press, Washington, D.C., USA

Turner, F.B., P.A. Medica, and C.L. Lyons. 1984. Reproduction and survival of the Desert Tortoise (*Scaptochelys agassizii*) in Ivanpah Valley, California. *Copeia* 1984:820-825.

Turner, R.M. 1982. Mohave Desertscrub. Pp. 157-168 *In* Biotic Communities of the American Southwest-United States and Mexico. Desert Plants 4. Brown, D.E. (Ed.). Arizona University for Boyce Thompson Southwestern Arboretum, Superior, Arizona, USA.

Vice, D.S., and R.M. Engeman. 2000. Brown Tree Snake discoveries during detector dog inspections following super typhoon Paka. *Micronesica* 33:105-110.

Willis, C.M., S.M. Church, C.M. Guest, W.A. Cook, N. McCarthy, A.J. Bransbury, M.R.T. Church, and J.C.T Church. 2004. Olfactory detection of human bladder cancer by dogs: proof of principle study. *British Medical Journal* 329:712-174A.

Woodbury, A.M., and R. Hardy. 1948. Studies of the Desert Tortoise, *Gopherus agassizii*. *Ecological Monographs* 18:146-200.

Zimmerman, L.C., M.P. O'Connor, S.J. Bulova, J.R. Spotila, S.J. Kemp, and C.J. Salice. 1994. Thermal ecology of Desert Tortoises in the eastern Mojave Desert: Seasonal patterns of operative and body temperatures, and microhabitat utilization. *Herpetological Monographs* 8:45-59.



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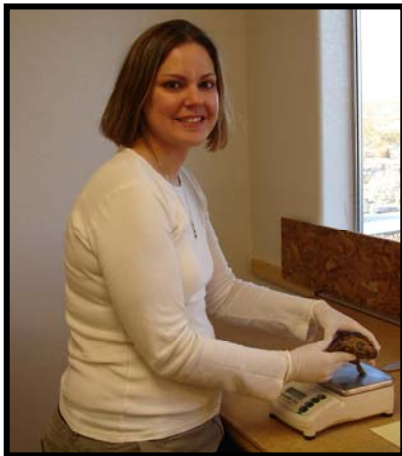
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PHILIP A. MEDICA is a Biologist/Ecologist with the U.S. Geological Survey, Western Ecological Research Center; He is shown here on a recent trip to the Galapagos Islands to view wildlife. His field studies in the southwestern deserts of the U.S. over the past 45 years include the long-term desert tortoise growth and population monitoring in the Mojave Desert. Additionally, he has conducted studies documenting environmental and anthropogenic impacts upon the desert ecosystem, i.e. drought as well and the impact of disturbance from roads, fire, blading, cratering from underground nuclear tests and gamma irradiation, upon the demography and reproduction of lizard and/or small mammal populations at the Nevada Test Site.

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