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SPATIAL RELATIONSHIPS OF THE DESERT BOX TURTLE (*TERRAPENE ORNATA LUTEOLA*) CAPTURED AT A STOCK TANK IN SOUTHEASTERN ARIZONA

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Abstract.—I radiotracked Desert Box Turtles (*Terrapene ornata luteola*) captured at a stock tank in desert grassland habitat in southeastern Arizona from 2001-2003. Individual turtles lived in well-defined 95% MCP home ranges, which included the stock tank and overlapped with home ranges of other turtles. Turtles moved 135 m daily in home ranges averaging 9.8 ha and 469 m across greatest axis. Turtles typically returned to the burrow from which they began their daily movements. There were no sexual differences in daily movement or home range size, nor were there annual differences in daily movement among individuals. Seven of 11 turtles made temporary long distance movements averaging 1,066 m away from their home ranges. Six of 11 turtles exhibited significant directionality in their movements relative to the stock tank. *Terrapene o. luteola* is a species of conservation concern in Arizona. The spatial information presented in this paper can assist science-based management decisions because it contributes to a better understanding of the core habitat requirements of *T. o. luteola*.

Key Words.—Box Turtle; conservation; core area; directionality; home range; migration; movement; *Terrapene ornata luteola*

INTRODUCTION

Terrapene ornata is a widely distributed terrestrial turtle ranging from Indiana to western Arkansas and Louisiana west to South Dakota, Colorado, southeastern Arizona, and northern Mexico (Legler 1960; Dodd 2001). The species is commonly recognized to be comprised of two subspecies (questioned by Martin et al. 2013). In the U.S., the Ornate Box Turtle (*T. o. ornata*) is the more widely-distributed form found in the central plains from South Dakota to southern Texas whereas the Desert Box Turtle (*Terrapene o. luteola*) is confined to the arid desert-grasslands of western and central New Mexico and southeastern Arizona (Legler 1960; Dodd 2001). Whereas extensive field studies of *T. o. ornata* populations in Kansas (Legler 1960; Metcalf and Metcalf 1970), Texas (Blair 1976), Wisconsin (Doroff and Keith 1990), Nebraska (Converse et al. 2002), and Iowa (Bernstein et al. 2007) have been reported over the last fifty years, field studies of *T. o. luteola* are limited to one population in New Mexico (Nieuwolt 1996; Germano and Nieuwolt-Dacanay 1999) and one population in Arizona (David Hall and Robert Steidl. 2003, unpubl. report; Plummer 2003, 2004). Because *T. o. luteola* is a species of conservation concern in Arizona (Hall and Steidl, unpubl. report), knowledge of its core area requirements, including the extent and use of space, is needed to assist possible management decisions (Semlitsch and Bodie 2003; Congdon et al. 2011). *Terrapene* spp. typically live in well-defined, variable-sized home ranges to which they attempt to return if displaced either accidently or after making long distance movements due to nesting, overwintering, or exploration (Dodd 2001). The extent to which *T. ornata* adheres to this general pattern of space use at its southwestern range margin is poorly known. The primary goal of this study is to describe the use of space by individual *T. o. luteola* in an apparent declining and poorly known population in southeastern Arizona.

MATERIALS AND METHODS

The study area was active ranchland located in the semi-arid grasslands of the Sulphur Springs Valley, 44 km SE of Willcox, Cochise County, Arizona at 1,400 m elevation. Vegetation consisted mainly of grasses and shrubs. Grasses included Love Grass (*Eragrostis*), Red Three-awn *Aristida*), Tabosa (*Pleuraphis*), Gramma (*Bouteloua*), Vine Mesquite (*Panicum*), and Sacaton (*Sporobolus*). Shrubs included Mesquite (*Prosopis*), Burro Weed (*Isocoma*), Catclaw (*Acacia*), and Russian Thistle (*Salsola*). Other plants include Mormon Tea (*Ephedra*), Yucca (*Yucca*), and Prickly Pear (*Opuntia*). Mounds of Bannertail Kangaroo Rats (*Dipodomys spectabilis*) were conspicuous landscape features and mound burrows served as the primary subterranean retreat for *T. o. luteola*. Most of the annual activity of *T. o. luteola* at the site occurs in a distinct 8–12 wk summer monsoon beginning in early July in which over 50% of the 31-cm annual rainfall occurs. However, monsoon rainfall is far from being uniformly distributed in space or time. Monsoon showers are typically small in diameter and move about in an apparent unpredictable and wandering fashion such that some areas receive abundant rainfall while nearby areas receive no rain (Michael Plummer, pers. obs.).

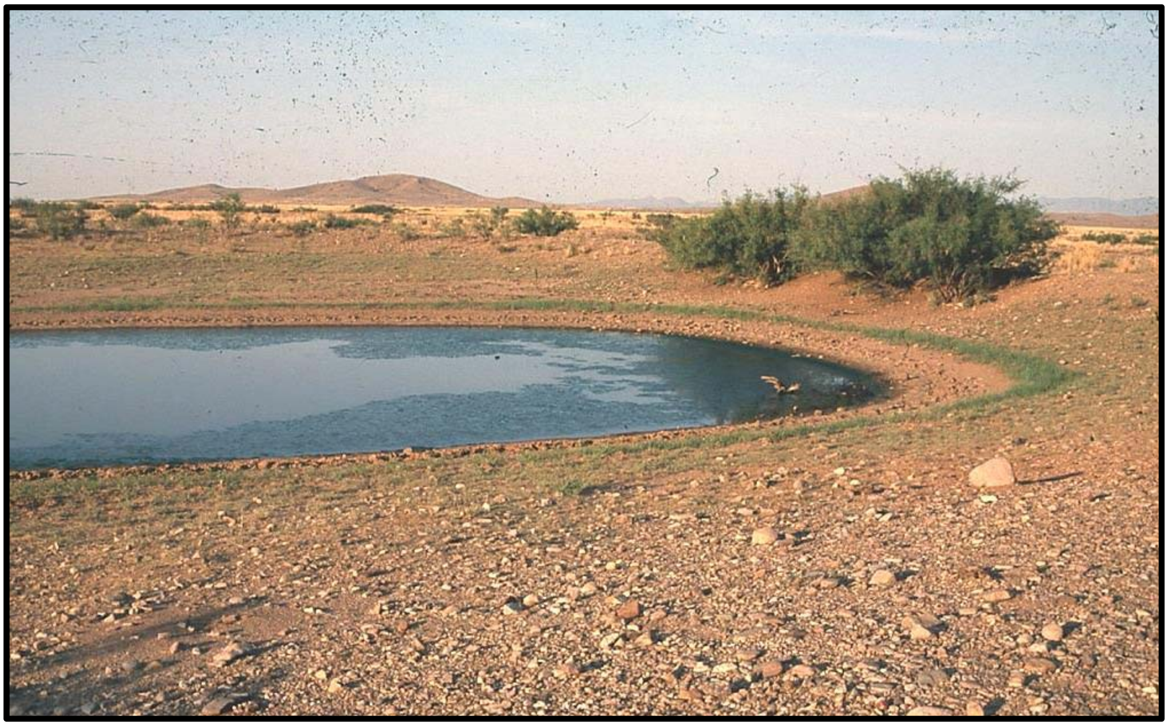

FIGURE 1. Stock tank in Cochise County, Arizona where turtles were initially collected from 2000-2002. The green ring indicates a higher previous water level.

I initially captured all turtles by hand at an approx. 0.1-ha stock tank designated Turtle Tank (TT; Fig. 1). I used binoculars to search for turtles visiting TT each day during the typical 3-h morning surface activity period of *T. o. luteola* at this site (0600–0900; Plummer 2003). After a brief period of observation, I captured and marked each turtle individually by filing a unique combination of notches in the marginal scutes. I attached a Model SM1 (AVM Instrument Company, Ltd., Colfax, California, USA) radiotransmitter to the posterior-most marginal scutes of 13 turtles with stainless steel wire (Plummer 2003). Transmitter masses were well below the recommended 10% of body mass for reptiles.

I began to systematically observe and mark turtles at TT on 1 August 2000. I began attaching transmitters on 19 July 2001 and tracked turtles from 19 July - 9 October 2001 and 6 July - 12 September 2002. Transmitters remained on individual turtles for the duration of the study. I captured each turtle at the beginning of each field season to either replace the transmitter battery (2001 and 2002) or to remove the transmitter and release the turtle at the termination of the study (1 August 2003). While tracking, I made occasional focal observations through binoculars on the behavior of turtles during their movements.

I used Biotas™ version 1.03.1a (Ecological Software Solutions LLC, Hegymagas, Hungary) to plot telemetry relocations and calculate 95% Minimum Convex Polygon (MCP) home ranges for turtles with at least 20 telemetry relocations. I also used Biotas™ to measure the longest axis of home ranges and to identify sojourns as temporary movements that exceeded the length of the greatest home range axis beyond the home range boundary. I used Google Earth™ version 7.1.1.1888 (Google Inc., Mountain View, California, USA) to generate an aerial photograph of the study area, to determine compass headings, and to measure distances (meters) on the image with the ruler tool. I checked the data for normality and equality of variances and used appropriate parametric (t-tests) and non-parametric (Mann-Whitney and Wilcoxon) tests with SYSTAT 13 (SYSTAT Software, Inc., Chicago, Illinois, USA). I used Oriana version 4.02 (Kovach Computing Services, Pentraeth, Isle of Anglesey, Wales, U.K.) for circular statistical analysis (Rayleigh test) to determine if telemetry relocations were directional relative to TT. I calculated mean compass headings for turtles that demonstrated significant directionality. Alpha was set at ≤ 0.05 for all tests. Descriptive statistics are presented as mean ± SE.

RESULTS

I marked 39 individual turtles that visited TT and recaptured them a total of 75 times over four years. Eighteen turtles were observed visiting TT in 2000, 17 in 2001, 12 in 2002, and 17 in 2003. The number of turtles

TABLE 1. Movement characteristics of five male and six female Desert Box Turtles (*Terrapene ornata luteola*) in desert grassland habitat in SE Arizona and the results of Rayleigh tests of random distribution relative to Turtle Tank (TT) from 2000–2003. Shown are 95% Minimum Convex Polygon home ranges, maximum length of MCP home ranges, mean daily movement, and temporary movements outside of MCP home ranges (sojourns). Mean compass headings for turtles showing significant directionality are relative to the center of TT.

ID	Sex	No. Telemetry Locations	No. Years tracked	95% MCP (Ha)	Max HR Axis (m)	Mean Daily Movement (m/d)	Sojourn Length (m)	Mean Compass Heading (°)	Rayleigh Test *Z*	Prob.
AMN	M	66	2	11.8	574	146	1,179	-	1.24	0.289
AJW	M	64	2	34.6	821	238	977	308	7.56	< 0.001
AKM	M	58	2	8.3	380	105	-	-	0.43	0.648
ALU	M	46	2	7.4	427	136	781	301	9.05	< 0.001
AKW	M	42	1	5.9	368	81	-	159	9.90	< 0.001
AJU	F	34	2	5.1	296	192	1,469	7	13.73	< 0.001
ALN	F	65	2	3.6	347	105	1,485	-	1.31	0.271
AMV	F	21	1	4.3	313	111	431	249	14.53	< 0.001
ALO	F	24	1	8.6	668	142	1,141	-	0.84	0.923
CIX	F	20	1	5.4	480	129	-	255	18.92	< 0.001
AJN	F	70	2	12.8	484	103	-	-	1.08	0.340

seen at TT per day ranged from 1–4. Duration of TT visits averaged 9 ± 1.5 min (range 2–17 min). Behaviors at TT consisted of drinking, soaking, and foraging along the shoreline. Turtles were wary when approaching TT and quickly retreated if they detected my presence.

A total of 13 turtles were tracked over 1–2 years, but two transmitters failed early during the course of the study. As a result, movement analyses were based on data from 11 turtles (five males; six females) each with at least 20 telemetry fixes (Table 1). The majority of turtle movements were in well-defined overlapping 95% MCP home ranges that were highly variable in size and averaged 9.8 ± 2.63 ha (range 3.6–34.6 ha; CV = 89%) in area and 469 ± 49.0 m (range 296–821 m; CV = 35%) in the longest axis (Table 1). Home ranges of 10 turtles included TT proper; the 95% MCP home range of the 11th turtle was within 150 m of TT (Fig. 2A). Home range area did not differ between the sexes ($U = 23.0$, df = 1, $P = 0.140$) nor between turtles tracked two years (11.9 ± 3.98 ha) compared to turtles tracked one year (6.1 ± 0.91 ha; $U = 9.00$; df = 1, $P = 0.345$). Daily movement averaged 135 ± 13.6 m and did not differ between years (paired $t = 1.52$, df = 21, $P = 0.18$) or sexes ($t = 0.762$, df = 9, $P = 0.47$).

Long-distance movements beyond the turtles' home ranges averaged 1,066 m (SD = 142 m, min/max = 431/1,485 m) and were made within a single day by seven individuals (three males; four females; Table 1). The average long distance one day sojourn was eight times the distance of the overall average daily movement. Sojourn length did not differ between the sexes ($t = 0.50$; df = 5, $P = 0.64$). The path taken by one female during a sojourn exhibited minimal tortuosity and often followed portions of cattle paths. Her emigration and immigration paths were essentially identical. She gained > 5% in body mass during her sojourn.

The SE quadrant around TT contained the fewest fixes pooled for all turtles (SE = 9.3%; NE = 34.5%; SW = 38.0%; NW = 18.2%). Six of 11 turtles (three males; three females) exhibited significant directionality relative to TT (Table 1) but only one turtle (AKW) had a mean compass heading in the SE quadrant (Table 1; Fig. 2B). The SE quadrant contained a lower-lying wash, several human structures, disturbed areas associated with an old corral, and a junction of primitive dirt roads within approx. 600 m of TT (Fig. 2C).

DISCUSSION

A portion of the home ranges of 10 of 11 radiotracked turtles captured at TT encompassed TT, whereas the 11th turtle maintained a home range near TT. Assuming the remaining 28 turtles observed at TT but not radiotracked also maintained home ranges at TT, a minimum of 39 turtles regularly used TT. Because stock tanks are artificial human structures, the relationship between turtles and TT is likely a facultative response of turtles living in a hot, semiarid environment in which most of the sparse annual rainfall is restricted to a few weeks of the year.

Several factors could affect home range size at the study area including the presence or absence of free water. For example, the 95% MCP home ranges of *T. o. luteola* in a nearby study measured 9 ha for turtles having home ranges within 2 km of a permanent water source but only 2.8 ha when home ranges were distant from a permanent water source (Hall and Steidl, unpubl. report). The small home ranges distant from a water source are comparable in area to the MCP home ranges of *T. o. luteola* in a study located 350 km NE of TT on the Sevilleta National Wildlife Refuge in New Mexico (1.6 ha; Nieuwolt 1996). Whether Nieuwolt's (1996) study site contained a permanent water source is unknown but an examination of that study site on Google Earth (1996 imagery) revealed the nearest stock tank to be approx. 1,200 m outside the study site

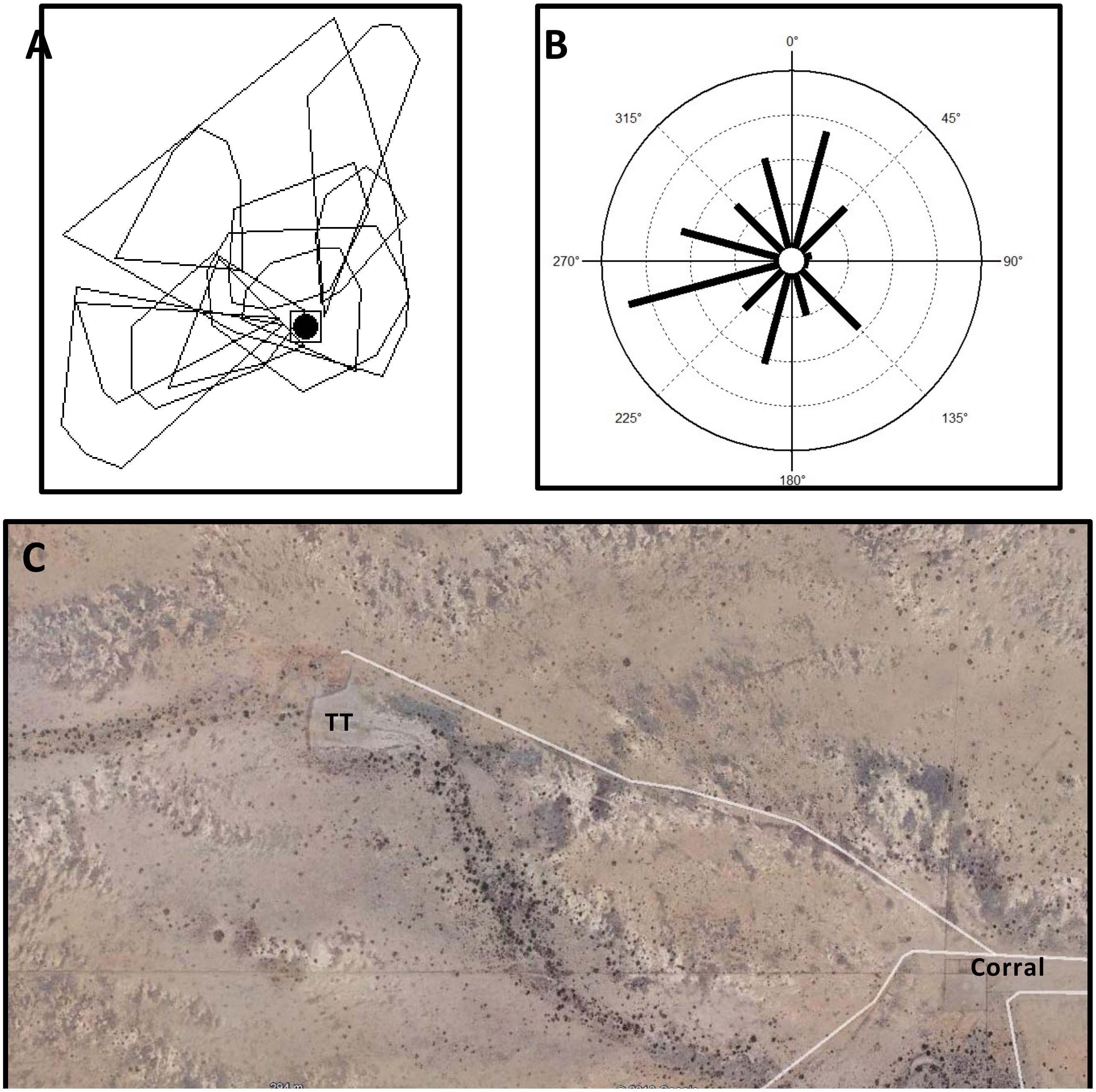

FIGURE 2. A) 95% MCP home ranges of 11 Desert Box Turtles (*T. o. luteola*) relative to one another and to TT (closed circle in square); B) Circular histogram showing percentage of compass headings of daily movements for six *T. o. luteola* (three males; three females) that demonstrated significant directionality in their movements relative to TT. C) Aerial view of Turtle Tank (TT; dry in this photograph) and surrounding area. Light lines identify primitive dirt roads.

boundaries. Another factor that could affect home range size is habitat degradation, which has been reported to increase home range size of *T. o. ornata* in Wisconsin (Curtin 1997). The Sulphur Springs Valley has been subjected to long-term drought, suburbanization, livestock overgrazing, and invasion by exotics (especially Mesquite), which has resulted in severe degradation of native desert-grassland habitats in many areas (Bailey 1994; Rosen et al. 1998). Finally, the duration of tracking may affect home range size in turtles. For example, home ranges of *Emydoidea blandingii* calculated from data collected over several years were larger than annual home ranges (Schuler and Thiel 2008). In this study, I could not detect a difference in home range size for *T. o. luteola* based on data collected over one year vs. those collected over two years, suggesting that *T. o. luteola* individuals move through their entire home range each year. Alternatively, I may have had insufficient statistical power to detect an existing difference due to a low sample size.

Home range sizes in this study should not be compared to those reported for *T. o. luteola* in an earlier study at this site in which data were collected over a brief period and calculated with a method designed to yield an index of relative home range sizes rather than absolute sizes (Plummer 2003).

As reported in an earlier study (Plummer 2003), surface activity and movements were enhanced by local rainfall. Movements appeared to be mostly associated with foraging and were made primarily on bare soil in sparsely vegetated areas. Although the sinuous paths of daily movements appeared to have no directional predisposition (Claussen et al. 1997; Plummer 2003), turtles were familiar with their home ranges and aware of their location because they typically returned to the burrow from which they began their early morning and late afternoon foraging episodes (Plummer 2003).

While foraging, turtles maintained a high level of vigilance and quickly responded to disturbances by ceasing movement and extending their legs and sometimes their neck vertically in apparent surveillance behavior (Plummer 2003). Similar behavior, followed by a quick retreat, was observed at TT when turtles detected my presence.

Temporary sojourns, commonly reported for *T. o. ornata* and its close relative *T. carolina*, may result from feeding and nesting forays, exploratory movements, movements to and from overwintering or nesting sites, and movements due to environmental perturbations (Dodd 2001). The most plausible functions for sojourns in my study were feeding forays and exploratory movements. Sojourn movements associated with overwintering and environmental perturbations were non-factors and the weight gain of one female followed during her sojourn is inconsistent with a nesting function.

Differences in habitat, elevation, relief, and vegetation were difficult to detect around most of TT. However, the SE quadrant contained a slightly lower wash area with more dense vegetation. The non-random distribution of radiotelemetry fixes suggests turtles may have responded to the slight differences in habitats around TT. Furthermore, the paucity of turtle fixes in the SE quadrant, which contained several human-disturbed areas, suggests avoidance of degraded habitats.

Conservation.—All species and subspecies of *Terrapene* are of national concern in the U.S. and are listed in CITES Appendix II. *Terrapene o. luteola* is listed as imperiled (S2) or vulnerable (S3) in Arizona (NatureServe. 2013. NatureServe Explorer: An Online Encyclopedia of Life. Available from http://www.natureserve.org/explorer. [Accessed: 31 October 2013]). In a status assessment study in Arizona, Hall and Steidl (unpubl. report) reported that *T. o. luteola* may be locally common but has declined statewide. Together these results suggest that *T. o. luteola* may need to be considered for conservation management to assure future population viability. The results reported herein on home range size, home range fidelity, internal home range movements, and temporary movements out of the home range should be of value to science-based conservation efforts, especially to questions of how individual turtles use their habitat and how turtles might respond when involuntarily removed from their home ranges in repatriation, translocation, and relocation efforts (Dodd 2001; Hill et al. 2009, Refsnider et al. 2012). Nonetheless, additional biologically relevant information is still needed for a more complete understanding of the core area requirements of *T. o. luteola*. For example, data are needed on potential nesting migrations out of the home range and on the area necessary to buffer core habitat from the edge effects of surrounding land use (Semlitsch and Bodie 2003; Congdon et al. 2011).

Although individual *T. o. luteola* are clearly attracted to stock tanks, whether the attraction affects turtle behavior, physiology, and life history is unknown. Historically, water gained from foraging and drinking at monsoon rain pools provided sufficient water for survival and population growth; water available at stock tanks is the result of relatively recent human activities. Water supplementation is known to increase surface activity and food acquisition in the long-lived desert dwelling Gila Monster (*Heloderma suspectum*; Davis and DeNardo 2009) and increase growth in the Desert Tortoise (*Gopherus agassizii*; Field et al. 2007). Providing additional aquatic resources might similarly benefit individual turtles; however, there are no comparative data to support or refute these ideas.

The distribution of stock tanks could be an influential force shaping the metapopulation dynamics of *T. o. luteola* (Roe and Georges 2007; Roe et al. 2009) if stock tanks represent clumped resources for turtles and local population density is increased as a result. An understanding of these issues would require comparative population studies in areas with and without stock tanks. Developing comprehensive management strategies for *T. o. luteola* on ranchlands will require not only spatial information such as provided in this paper, but also an understanding of turtle population structure and how stock tanks might affect that structure.

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