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Winter Activity of the Sonoran Desert Tortoise (*Gopherus morafkai*) in Central Arizona

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ABSTRACT. – **Little is known regarding the activity of desert tortoises during winter, especially for the Sonoran Desert Tortoise (*Gopherus morafkai*). We observed adult, juvenile, and hatchling *G. morafkai* active during November, December, January, and February at 3 field sites in upland Sonoran Desert in central Arizona. At 1 site all individuals under observation ($n = 36$), including males, females, and hatchlings, emerged from hibernacula to drink during the first heavy (> 20 mm) rainfall event (December); at all 3 sites, females were observed active (basking, foraging) during winter much more frequently than were males.**

The ability to take advantage of favorable conditions for food and water is an ecological necessity for tortoises occupying arid environments (Peterson 1996; Loehr et al. 2009). While many species of tortoises occupy subterranean shelters when surface conditions are suboptimal (Gregory 1982; Zimmerman et al. 1994), they may occasionally leave those shelters to utilize temporally restricted resources. Loehr (2012) noted increased winter basking in *Homopus signatus* (Speckled Tortoise), which allowed them to opportunistically forage following winter rainfall events. On the opposite end of the thermal spectrum, surface activity for *Chersina angulata* (Angulate Tortoise) is typically lowest in the hot part of the summer, although they will become surface active if water is available (Ramsay et al. 2002). There are demographic consequences to the use of these temporally restricted resources (Huey and Berrigan 2001). While tortoises may gain osmotic (Nagy and Medica 1986; Peterson 1996) and reproductive (Averill-Murray 2002; Lapid et al. 2004) advantages via activity at suboptimal temperatures, such activity may also entail increased risk of mortality from rapidly declining temperatures (Kuzmin 2002) and increased exposure to predation (Riedle et al. 2010).

The Mohave Desert Tortoise (*Gopherus agassizii*) is generally thought to be inactive throughout the winter, although hatchlings have been observed basking, and rarely feeding, in seminatural enclosures (Wilson et al. 1999). Occasional observations of winter activity in adults have been documented, but the consensus among most workers is that adult tortoises rarely emerge from their hibernaculum from November through February (reviewed by Rautenstrauch et al. 1998 for *G. agassizii* and by Bailey et al. 1995 for *Gopherus morafkai* [Sonoran Desert Tortoise]). A parallel perspective concerns drinking:

until the observations of Medica et al. (1980), it was assumed that tortoises did not drink free-standing water. Medica et al. (1980) documented drinking by tortoises in the Mohave Desert, but only during the spring and summer months, though at what they described as ''suboptimal temperatures'' (i.e., 9°–15°C rather than 28°–34°C). Duda et al. (1999) stressed that summer rainfall was critical to populations of *G. agassizii*, implying they did not emerge to drink during winter rains. Nagy and Medica (1986) indicated that tortoises do not emerge from refuges from November to March and, given that the majority of rainfall in even the eastern Mohave Desert falls during the winter months, this requires that tortoises obtain rainwater during infrequent summer storms.

As described above, the majority of prior work on winter activity in desert tortoises has focused on *G. agassizii* in the Mohave Desert. Even fewer reports exist on winter activity in the recently described Sonoran Desert Tortoise (*G. morafkai*; Murphy et al. 2011). As *G. morafkai* is pending final listing under the Endangered Species Act (US Fish and Wildlife Service 2010), knowledge of their behavior during winter in the Sonoran Desert will be important to management practices. Variation in rainfall regimes, with predominantly winter rainfall in the Mohave Desert vs. summer rains in the Sonoran Desert, greatly influences timing of activity in both species (Averill-Murray et al. 2002) and might have significant consequences for activity during winter.

We initiated a radio-tracking study of *G. morafkai* in the Union Hills near Phoenix, in central Arizona, and subsequently observed activity in December and January during winter (2011–2012). We also observed 2 individuals repeatedly moving over 400 m to a rocky waterfall (catchment) prior (~ 24 hrs) to the initiation of rainfall events from April through November 2012. These observations suggested that rainfall events were critical to tortoise activity and, in light of the winter activity we observed, we hypothesized that rainfall might stimulate emergence even during colder winter months. We present data herein of two kinds: first, observations of activity of *G. morafkai* from our study in the Union Hills from 2011 through early 2013; second, observations from 2 other radio-tracking studies of *G. morafkai* at Sugarloaf Mountain (1991–1993, 1996–2005) and the Florence Military Reservation (2000–2004). The latter are long-term radio-tracking studies from which we could extract data on activity during winter months to provide perspective on the frequency of such behavior across the Sonoran Desert of central Arizona.

Study Sites. — The Union Hills (UH) site lies on the northern edge of the Phoenix metropolitan area. The site is composed of a relatively low-elevation series of hills in a region of transition from creosote (*Larrea tridentata*)–bursage (*Ambrosia deltoidea*) flats to saguaro (*Carnegiea gigantea*)–palo verde (*Parkinsonia microphylla*)-dominated uplands. The hills rise to approximately 650 m elevation from a surrounding plain of about 350 m; geologically they comprise metavolcanic rocks with basaltic protoliths and various granitic rocks in lesser quantity. Within the UH site tortoises are rarely encountered away from the slopes and the incised arroyos draining those hills, which are dominated by plants associated with the Arizona Upland Subdivision of the Sonoran Desert (Turner and Brown 1982). The arroyos have numerous exposed caliche formations into which tortoises and other organisms (e.g., white-throated wood rats, *Neotoma albigula*) have excavated burrows that are used by tortoises for refuges during both winter and summer. Unsurprisingly, given the limited availability of large rock outcrops, tortoises at UH do not typically take refuge under rock overhangs as is commonly observed in other Sonoran Desert populations (Barrett 1990; Averill-Murray et al. 2002).

Sugarloaf (SL) occurs northeast of Phoenix on the Tonto National Forest. Elevations range from 549 to 853 m with steep, rocky slopes divided by many arroyos. The site contains vegetation classified in the palo verde-mixed cacti series of the Arizona Upland Subdivision of the Sonoran Desert (Turner and Brown 1982). Granitic boulders up to a 4-m diameter occur on many slopes, and tortoises predominantly shelter in excavated burrows or natural cavities below rocks and boulders. Caliche caves are absent at the site.

The Florence Military Reservation (FMR) is located southeast of metropolitan Phoenix. Florence Military Reservation, similar to the UH site, contains both the Arizona Upland and Lower Colorado River Valley subdivisions of the Sonoran Desert (Turner and Brown 1982). Elevations range from 450 to 610 m with geology characterized by gently sloping to flat alluvial fans in the north that have been mostly filled in by unconsolidated to weakly consolidated silts, sands, clay, and gravel from the Mineral and Tortilla mountains to the east. The alluvial fans are bisected by deeply incised washes on the eastern portion of the reservation. Tortoises were strongly associated with the deep washes and caliche caves as well as with a single, 10.9-ha volcanic hill (Riedle et al. 2008).

Field Methods. — The focus of this article is centered on a radio-tracking study we initiated at UH in the fall of 2011, which continued through 2013. We also extracted information on the activity of individuals tracked during the winter months (November–February) from 15 winters encompassed in data sets from SL and FMR. Work at SL spanned 1991 through 2005, except for 1994–1995, and at FMR from 2000 through 2004. We attached radio transmitters (< 5% body mass; Advanced Telemetry Systems, AVM Instrument Co., Telonics, or Wildlife Materials) to the anterior carapace using epoxy. We generally tracked tortoises once per week at SL and FMR and minimally twice per week (sometimes daily) at UH during December, January, and February each year. While tracking tortoises at UH, we also made opportunistic observations regarding emergence during rainfall of 9

Figure 1. Subject no. 21 basking at the Union Hills site with a clean beak (January, left image) and with a stained beak (February, right image) suggestive of feeding during the prior month.

individuals marked but untagged; at the other 2 sites only the behavior of radio-tagged individuals was recorded.

We analyzed records of activity by evaluating the status (in a refuge, basking, moving, feeding, drinking) of all individuals tracked from 1 December through 15 February 2012–2013 at UH and 1 November to 1 March each year at SL and FMR. Basking was defined as a stationary position with 2 or 4 limbs extended laterally, the plastron resting on the ground, and the head extended (eyes closed in many instances). Recent feeding was indicated by green, moist coloration along the margins of the mouth (beak); during the winter months, especially after drinking, the margins of the mouth are typically clean (Fig. 1). Recent movements of individuals were sometimes inferred from disturbance to the entrance of a refuge, by a clean, recently ''washed'' carapace (due to activity in rainfall), and by other indirect indicators (e.g., tracks, urate deposits at the entrance). Finally, all individuals overwintering within refuges during 2012–2013 at UH were categorized as occupying deep ($>$ 500-mm) caliche tunnels and slits or superficial refuges (shell visible; pallets or shallow tunnels $<$ 250 mm deep). We used Fisher's exact test to assess variation in behavior by sex (sex bias in basking, feeding, refuge type selection, etc., during winter months).

We obtained air temperatures (high/low) and daily rainfall from 3 weather stations at the northern, eastern, and southern boundaries of UH (Maricopa County Flood Control District) and for individual tortoises at basking sites using a Schultheis (Weber & Miller) Quick Recorder thermometer. For basking events at UH, we recorded shaded air temperature within 1 m of the tortoise at $\sim$ 1 m above ground and on the ground within 0.5 m of the tortoise (shaded). Finally, we shaded the carapace of the tortoise and pressed the bulb of the thermometer gently against the shell to obtain a rough estimate of shell temperature.

Results. — At the UH site during 2011–2012 and 2012–2013, we observed 32 (23 with radio tags; 9 marked) adult tortoises at overwintering refuges from early December through mid-February: 13 males and 19 females. Of those individuals, most were in caliche tunnels and slit caves from 0.75 to 4.0 m deep (12 males, 10 females); 10 were in superficial (exposed) refuges, either wood rat nests or pallets under shrubs (1 male, 9 females). Hence, females were significantly more likely to occupy superficial refuges than were males (Fisher's exact test: $P = 0.024$).

We assessed basking and feeding events during radio-tracking surveys for 23 tortoises with radio-tags (14 females, 9 males) throughout winter months (December–February) during 296 visits to UH. During December (106), January (92), and early February (98), we documented 28 basking events by 9 females and 1 male. This was a minimum rate of 9% basking during winter visits, at air temperatures of 8°–22°C (mean = 15.4°C, $n = 23$) and ground temperatures of 24°–30°C (mean = 27.1°C, $n = 23$). Basking individuals were typically females ($n = 9$ of 14 total females; 70%) and rarely males ($n = 1$ of 9 total males; 12%); overall, females were significantly more likely to bask than were males at UH ($p = 0.029$). Seven of the 9 females in superficial refuges were observed basking. Air temperatures during basking events ranged from 8°C to 22°C and were typically warm, sunny days with highs above 20°C. It is important to note that we did not systematically survey during warm afternoon periods, so our observations are conservative estimates of the frequency of this behavior. Seven individuals were observed with green beaks indicative of recent feeding (6 females, 1 male); observations of subject no. 21 during January (clean

Table 1. Observations of Sonoran Desert Tortoises during winter (November–February) at Sugarloaf.

Year	No. of individuals	No. of records	In shelter	In open	Basking	Drinking	Foraging	Walking
1991–1992	9	94	72	22	0	0	0	3
1992–1993	9	37	37	0	0	0	0	0
1996–1997	12	190	183	7	3	1	0	0
1997–1998	20	318	310	8	2	0	0	1
1998–1999	19	307	299	8	2	0	2	0
1999–2000	20	320	312	8	2	0	1	2
2000–2001	22	330	301	29	19	0	2	0
2001–2002	20	336	326	10	0	0	0	1
2002–2003	23	334	305	29	13	0	2	4
2003–2004	19	299	289	10	6	0	0	1
2004–2005	19	245	234	11	5	0	0	3
Total		2810	2668	142	52	1	7	15
%			0.949	0.051	0.019	0.000	0.002	0.005

beak) and February (green beak) 2013 suggest this individual fed during the interim (Fig. 1).

We observed a single hatchling (50-mm midline carapace length at first observation, 2 January 2013) over a 3-mo period (2 January through 31 March 2013) at UH. It was basking consistently, morning after morning in sequence (e.g., 2–6 February), at much lower temperatures than were adults (minimum air temperature of 4°C) and on overcast mornings at earlier hours (0900 hrs at 5°C). The beak was green whenever visible.

At the UH site, the fall of 2012 (October and November) was dry (< 1.0 mm rainfall) until a large complex of Pacific fronts moved through the state from 14 to 17 December. During the early morning of 14 December, 12 mm of precipitation was recorded. When we tracked 17 individuals on that day, 15 were out of their refuges, in arroyos, many resting in pools of standing water; the other 2 were at their winter refuge but with clean, wet shells; and other aspects of the refuge (e.g., shifts in debris, deposition of urates outside) indicative of recent activity were observed. We also observed 2 unmarked hatchlings (midline carapace length = 40 mm) active in washes near pooled water on the initial day after rainfall. Over the course of the next 48 hrs, we tracked 24 tagged and 12 marked individuals (21 females, 15 males); most (22) were observed out during continuing rainfall, and all that were only observed at their refuge exhibited signs of recent activity. A total of 24 mm of rainfall was recorded at UH during the 72 hrs of activity, and air temperatures during the day ranged from 5°C to 14°C.

At SL, we recorded 2810 observations of tortoises from November through February during the 11 winters of study (Table 1). The data set included up to 82 observations of 0–5 individual males (total = 342), up to 327 observations of 6–20 females (total = 2414), and up to 18 observations of 0–2 juveniles/subadults (total = 54) each winter. We found tortoises outside their burrows on a total of 142 occasions (5.1%; 21 males, 118 females, 3 subadults). Of observations that could be attributed to specific behaviors, 52 were basking (4 males, 47 females, 1 subadult), 15 walking (1 male, 12 females, 2 subadults), 7 foraging (1 male, 6 females), and 1 drinking (female). The balance of observations typically involved tortoises sitting motionless and aware of the observer, but the behavior prior to detection was uncertain. Overall, out-of-shelter observations were dominated by females during winter months at SL.

At FMR, we recorded 607 observations of tortoises from November through February during the 4 winters of study (Table 2). The data set included up to 127 observations of 4–8 individual males each winter (total = 299) and up to 119 observations of 6–8 females (total = 308). We found tortoises outside their burrows on a total of 9 occasions (1.5%; 1 male, 8 females). Of observations that could be attributed to specific behaviors, 3 were basking (all female) and 1 female showed evidence of recent drinking (muddy nares). Similar to SL, females were observed out of shelters during winter months much more commonly than were males at FMR.

Discussion. — Our results reveal a number of striking trends. First, primarily female Sonoran Desert Tortoises bask (70% of UH females in 1 yr) and feed (40%) during the winter months. As documented previously (Bailey et al. 1995), females occupy thermally variable sites, less buffered and more superficial relative to males in deep

Table 2. Observations of Sonoran Desert Tortoises during winter (November–February) at the Florence Military Reservation.

Year	No. of individuals	No. of records	In shelter	In open	Basking	Drinking
2000–2001	10	36	32	4	2	0
2001–2002	15	236	234	2	0	1
2002–2003	14	237	234	3	1	0
2003–2004	14	98	98	0	0	0
Total		607	598	9	3	1
%			0.985	0.015	0.005	0.002

tunnels and crevices; 9 of 10 individuals at the UH site overwintering in ''superficial'' sites were females. Second, tortoises of both sexes will emerge from (and return to) these winter hibernacula to drink at even low temperatures (8°–15°C). Last, hatchlings do emerge to drink and to bask on winter days at temperatures as low as 4°C but with ground temperatures as high as 30°C.

Basking events in December and January at UH always concluded with the individuals returning to the hibernaculum from which they emerged; however, in February individuals that emerged to feed spent at least 1 night in a pallet prior to returning to the original overwintering refuge. These individuals, all females save for 1 male, always possessed green beaks (Fig. 1), suggestive of feeding bouts during these brief excursions.

While previous researchers have generally assumed that *G. agassizii* remain inactive inside their burrows through the winter months (Nagy and Medica 1986; Rautenstrauch et al. 1998; Duda et al. 1999), populations now recognized as *G. morafkai* experience much different climatic conditions, leading to differences in activity and behavior (Van Devender 2002). We observed a disproportionately large number of females relative to males emerging from their hibernacula during winter months at all 3 sites; at UH, both sexes and even some hatchlings emerged to drink during the first major winter storm event, even though temperatures were suboptimal (Medica et al. 1980). Averill-Murray et al. (2002) noted that females typically left their hibernacula 1 mo earlier than did males, and this asynchronous timing of emergence has resulted in significant differences in seasonal mortality rates between sexes (Riedle et al. 2010). For female tortoises, the obvious question is: why leave your hibernaculum to bask and feed?

The diet of *G. morafkai* is osmotically stressful, leading to a dehydrated state during prolonged dry periods (Peterson 1996; Oftedal 2002). Ovarian follicles in *G. morafkai* do not mature until after a female has left hibernation, and maturation is dependent on availability of spring forage (Averill-Murray 2002). Opportunistic drinking when water is available in the winter may help maintain osmotic balance, allowing tortoises to forage immediately when they emerge from hibernation in February and March. We suggest that winter-drinking bouts may have a significant impact on the fitness of *G. morafkai* in the Sonoran Desert.

From a conservation standpoint, it is important to recognize that *G. morafkai* can be active in the winter more often than previously recognized. Guidelines developed for construction and mitigation projects based on information derived from *G. agassizii* stating that tortoises are not surface-active during the winter months would then be inaccurate for activities taking place in the Sonoran Desert of Arizona. Therefore, while winter activity is less common than during other seasons, it would be prudent to take measures to minimize potential impacts to tortoises during development projects in winter, especially given the likelihood of slow movement and a concentration of individuals in low areas where water collects. It is also critical to note that winter activity in *G. agassizii*, especially after rains, may be more common than has been assumed; detailed observations during rainfall events will be required to evaluate this hypothesis.

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