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Habitat Structures Associated with Juvenile Gopher Tortoise Burrows on Pine Plantations in Alabama

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Little is known of the basic ecology of juvenile gopher tortoises, *Gopherus polyphemus*, as they are often inconspicuous to human observers. Although young gopher tortoises are secretive, they are extremely vulnerable to predation and experience high mortality due to their small size and soft shells (Alford, 1980; Wilson, 1991; Butler and Sowell, 1996). Gopher tortoises construct burrows that provide some protection from predation and desiccation. The extent to which young gopher tortoises construct their own burrows or use other refugia varies. Most gopher tortoise nests are found on burrow mounds and hatchlings emerge in late summer or early fall (Landers et al., 1980). Hatchlings may remain inside adult burrows or bury under sand or leaf litter near the burrow mound and first construct burrows the following spring (Douglass, 1978). Small individuals have been shown to take refuge in adult burrows (Brode, 1959; Carr, 1963). However, Allen and Neill (1953) found that 10 hatchlings excavated their own burrows (< 77 cm in length) and Butler et al. (1995) demonstrated that most hatchlings excavated their own burrows within one day of hatching. Hatchling tortoises may construct burrows by enlarging existing burrows dug by other animals (e.g., beetles, rodents) (Auffenberg, 1969; Tom, 1994; Butler et al., 1995).

Active and abandoned small tortoise burrows fill with soil rapidly compared to adult burrows and this erosion may be accelerated by heavy rains (Guyer and Hermann, 1997). Soil erosion requires frequent burrow maintenance by gopher tortoises. Therefore, it should be advantageous for juvenile tortoises to construct burrows in places that provide the greatest protection from both predators and soil erosion. Immovable habitat structures (e.g., logs, roots, stumps) may stabilize the soil around burrows against erosion and also decrease the ability of predators to dig tortoises out of their burrows. Some structures (e.g., understory vegetation) may function to camouflage burrows from detection by mammalian or avian predators. In this study I test the hypothesis that juvenile gopher tortoise burrows are commonly associated with habitat structures and compare the use of structures between adult and juvenile tortoises.

Methods. — I conducted this study at four sites within mature slash pine (*Pinus elliottii*) plantations in the Conecuh National Forest (CNF), Covington Co., south-central Alabama (see Aresco and Guyer, 1999, for a full description of

Figure 1. Representative habitat structures observed at gopher tortoise burrows in the Conecuh National Forest, Alabama. **Top**: Juvenile burrow located at a pine log (7 cm burrow width). **Bottom**: Adult burrow located at a tree stump (25 cm burrow width).

study area). On the CNF, gopher tortoises 1–9 yrs of age may fall within the size range (5.8–13 cm carapace length) of the juvenile stage (Aresco and Guyer, 1998). Burrow width is tightly correlated with carapace length (CL) of the resident tortoise (Martin and Layne, 1987; Wilson et al., 1991). Therefore, I classified burrows as either juvenile (< 14 cm in opening width) or adult based on the width of burrow entrances. In most cases, these were confirmed by actual captures via live traps. A few of the smallest burrows (< 6 cm in opening width) were constructed by hatchlings (0–1 yrs; 4.8–5.5 cm CL), but for the purposes of this study these were pooled with juvenile burrows.

I defined habitat structures as logs (fallen trees), stumps, fallen tree limbs, upright tree trunks, and shrub stems (minimum diameter of 3 cm) located within 25 cm of a burrow entrance (Fig. 1). I recorded the presence or absence of habitat structures at all active juvenile tortoise burrows ($n = 38$, mean width = 8.3 cm, SD = 2.7, range = 5–13 cm), at all active adult tortoise burrows ($n = 64$, mean width = 23.7 cm, SD = 3.9, range = 16–32 cm), and at random non-burrow sites ($n = 60$). Location of random points was determined by covering a map of each study site with a numbered grid and using a random numbers table to generate two coordinates. Random points were all at least 10 m from the nearest tortoise burrow. I used G^2 log-likelihood ratio tests to detect differences in habitat structure associations among adult and juvenile tortoise burrows and random non-burrow points.

Results. — Juvenile tortoise burrows were associated with habitat structures more often (61%) than were adult tortoise burrows (13%) or random non-burrow points (10%) ($G^2 = 35.9$, df = 2, $p < 0.0001$) (Table 1, Fig. 2). Pairwise comparisons indicated that juvenile tortoises burrows differed from random points ($G^2 = 29.1$, df = 1, $p < 0.0001$) and adult tortoise burrows ($G^2 = 26.1$, df = 1, $p < 0.0001$) in their association with habitat structures. In contrast, number of structures observed at adult tortoise burrows were not different from those at random points ($G^2 = 0.194$, df = 1, $p = 0.66$). Juvenile gopher tortoise burrows were most often associated with logs (26%) and fallen tree limbs (21%) (Fig. 2). Most habitat structures associated with burrows were located immediately behind the burrow entrance (61% of 23 juvenile burrows, 75% of 8 adult burrows), thereby covering the first portion of the burrow itself.

Table 1. Summary data of habitat structures associated with juvenile ($n = 38$) and adult ($n = 64$) gopher tortoise burrows and random non-burrow points ($n = 60$) in the Conecuh National Forest, Alabama.

Habitat Structure	Juvenile Burrows		Adult Burrows		Random Non-Burrow Points	
	n	%	n	%	n	%
Log	10	26.0	3	5.0	4	6.7
Stump	1	2.6	3	5.0	0	0.0
Tree Limb	8	21.0	0	0.0	0	0.0
Tree Trunk	2	5.3	1	1.5	1	1.7
Shrub Stem	2	5.3	1	1.5	1	1.7
Total Structures	23	61.0	8	13.0	6	10.0
No Structures	15	39.0	56	87.0	54	90.0

Discussion. — Mammalian predators such as raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), and foxes (*Urocyon cinereoargenteus*) can easily excavate hatchling tortoises from their shallow burrows (Wright, 1982; Butler and Sowell, 1996). Raccoons apparently develop a "search image" for small tortoise burrows and can devastate local populations, excavating burrows by removing the roof, leaving the sides and floor undisturbed (Butler and Sowell, 1996). Young gopher tortoises that select burrow sites at and below structures such as fallen logs or tree limbs may thus be safer. In this study, 61% of juvenile burrow entrances had structures immediately be-

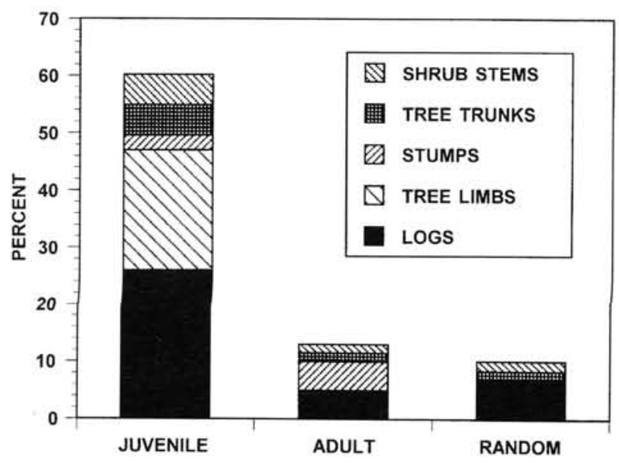

Figure 2. Percent of juvenile and adult gopher tortoise burrows and random non-burrow points associated with types of habitat structures in the Conecuh National Forest, Alabama.

hind them that could interfere with predator excavation behavior. In addition, structures that partially hide the burrow entrance and mound may decrease predation by raptors (e.g., *Buteo* ssp.) (Wilson, 1991). Therefore, in areas of high predation, selection may favor hatchling and juvenile tortoises that construct burrows at habitat structures. Tortoises abandoned burrows frequently in the CNF (Aresco and Guyer, 1999) and juveniles may continue to construct new burrows at habitat structures until they reach the subadult stage when a larger size and hardened shell protect them from most predators.

Small tortoise burrows erode and fill with soil more rapidly than large burrows (Guyer and Hermann, 1997). However, burrows constructed at logs, fallen tree limbs, or stumps will probably remain open longer as these structures can help maintain the integrity of the burrow entrance and walls by diverting surface water away from burrow entrances during heavy rain. Juvenile gopher tortoises have smaller home ranges and spend limited time above-ground as compared to adult tortoises (Wilson et al., 1994). Wilson (1991) found that predation on juvenile tortoises was greater during cooler months when tortoises basked for longer periods on their burrow mounds. An increase in the above-ground or near-surface activities of juvenile tortoises associated with repairing an eroded burrow or searching for a new burrow site may also cause greater exposure to predators.

Another possible explanation for the association between juvenile tortoise burrows and habitat structures may be related to the thermal ecology of juveniles. Small tortoises heat up more rapidly than adults and extremely high surface temperatures in xeric habitats may exceed the thermal tolerances of juveniles. Studies of the Bolson tortoise (*Gopherus flavomarginatus*) and the desert tortoise (*Gopherus agassizii*) have shown that hatchlings and juveniles prefer to excavate burrows under vegetation (e.g., cacti and shrubs) rather than in open areas (Burge, 1978; Berry and Turner, 1986; Tom, 1994). Such habitat structures may function to shade juvenile burrows and provide a more favorable microclimate at the burrow entrance and within the burrow (Judd and Rose, 1977).

Small gopher tortoise burrows in pine plantations may be especially susceptible to erosion and exposure to predators because of sparse ground cover vegetation. In natural longleaf pine habitats, a dense understory of herbaceous plants and wiregrass helps hide small tortoise burrows from detection by predators. The root structures of these plants also probably limit burrow erosion. I recommend that some logs, fallen tree limbs, and stumps be left on the ground in pine plantations as these structures may promote higher survivorship of juvenile gopher tortoises.

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