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USE OF GOPHER TORTOISE BURROWS BY FLORIDA MICE (*PODOMYS FLORIDANUS*) IN PUTNAM COUNTY, FLORIDA

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Abstract.—In the sandhills of Florida, the Florida mouse (*Podomys floridanus*) lives in burrows of the gopher tortoise (*Gopherus polyphemus*). We excavated five tortoise burrows utilized by *Podomys* in sandhills in Putnam County. The mice inhabited the upper 2 m of the burrows. Small vertical tunnels ("chimneys") provided a secondary entrance to the burrow system and allowed occupation of burrows after the main entrances collapsed. Mice also used pockets and narrow tunnels attached to the side of the main burrow. We consider the extensive association of the mouse with these burrows an adaptation that allowed the mice to live in the hostile environment of the sandhills.

Blair and Kilby (1936) first noted an association between Florida mice (*Podomys floridanus*) and burrows of the gopher tortoise (*Gopherus polyphemus*). They recorded eight mice in five tortoise burrows in an old field near Gainesville, Florida, and saw one mouse enter a small side hole about 2 m from the burrow's entrance. Johnson and Layne (1961) and Milstrey (1987) also noted that *Podomys* inhabited tortoise burrows. In preliminary studies in Putnam County, Eisenberg (1983) reported higher trapping success for *Podomys* at the mouths of burrows (33%) than on transects (0.4%). We also observed in Putnam County that, when released, mice usually ran down tortoise burrows; they rarely climbed trees or sought other refuges, such as fallen logs or the base of trees. For example, Jones (unpubl. data) tallied escape responses for 18 *Podomys* trapped on a grid in 1987-88. Of the 35 responses where the destinations of the mice were observed, 25 (71%) entered tortoise burrows through the main entrance or through chimneys. Presumably, the

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use of tortoise burrows is of adaptive significance. Hallinan (1923) and Hansen (1964) described the shape and dimensions of *Gopherus* burrows, but did not discuss structures used by rodents. The only description of subterranean structures used by *Podomys* was that by Layne (in press), who described nests, nest chambers, and small tunnels found in two tortoise burrows in Alachua County.

In 1986, Franz and C. K. Dodd, Jr. excavated an inactive tortoise burrow and observed *Podomys* in a U-shaped tunnel connected to the main burrow (see Fig. 1A). They also noted a narrow vertical tunnel (which we called a chimney) opening to the surface more than a meter past the burrow entrance. As reported in this paper, we excavated and mapped four additional burrows, in order to describe the parts of tortoise burrows that are modified and utilized by Florida mice.

Study Area and Methods

We examined tortoise burrows on the Katharine Ordway Preserve-Swisher Memorial Sanctuary, Putnam County, Florida. About one-third of this 37 km^2 preserve consists of high pine sandhills dominated by longleaf pine and turkey oak. The climate, flora, and fauna of sandhills on the preserve were described by Eisenberg (1983), Franz (1986), Gates and Tanner (1988), and Dodd and Charest (1988). At Ordway, *Podomys* has been trapped at several locations, all on sandhills or on the margins of sandhills in old pastures or xeric oak forests.

Using criteria established by Auffenberg and Franz (1982), we selected two active burrows (i.e., where soil was disturbed by tortoise), one inactive (where the entrance was open but the soil undisturbed), and one old burrow (where the main entrance had collapsed), all of which appeared to have chimneys. Tortoise burrows were excavated by removing the upper layers of soil with shovels. We constantly watched for chambers and tunnels connecting to the tortoise burrow. During excavation we mapped the tortoise and mouse burrows using 50-meter cloth tape measures, compasses, and plumb lines. Data recorded included: compass bearings of tortoise burrows and adjacent structures constructed by mice; width, depth, and length of the burrows and other structures; presence of crickets and other animals; and presence of leaf litter, acorn hulls, or other evidence of *Podomys floridanus*.

Results

The first excavated burrow system consisted of a main tunnel, a U-shaped passageway, and a chimney that opened to the surface. One *Podomys* was visible in the passageway and chimney during excavation. All four additional burrows showed evidence of recent use by mice, as indicated by the presence of tracks, acorn hulls, and the animals themselves. Dimensions of these burrows and associated structures are summarized in Table 1. A curving chimney was found in each of the additional tortoise burrows that we excavated (Figs. 1-2). Each chimney had a surface diameter of 3 cm, and two were partially plugged with sand (Figs. 1D and 2). The old, closed burrow had the most extensive mouse-tunnel system of the five burrows examined (Fig. 2). In the two deepest

Table 1. Dimensions (meters) of burrows number 2 (active), 3 (inactive), 4 (old), and 5 (active), and chimneys. Two bearings indicate a curve in the main burrow.

	Main burrow			Chimney			
No.	Diameter at entrance	Bearing (degrees)	Total length	Distance to entrance	Diameter at entrance	Length	Entrance to burrow
2	.27	303 (270)	6.1	2.44	.03	.85	1.45
3	.21	71	—	1.56	.03	—	.45
4	.11	141 (99)	5.97	1.52	.03	1.00	.63
5	.29	261	3.72	1.35	.03	.40	.80
Means	.22		5.26	1.72	.03	.75	.83

tortoise burrows excavated (Fig. 1B and 1D), no mouse sign occurred below a depth of 2 m.

Besides the chimney, there were several other structures that probably were utilized by mice. These included U-shaped tunnels, short blind tunnels, and small pockets or chambers that opened onto the side or ceiling of the tortoise burrow. Some of the pockets possibly were constructed by crickets (*Ceuthophilus* sp.). We occasionally saw crickets inside these structures, and camel crickets (*Ceuthophilus latibuli*) are known to construct small tunnels (Gentry and Smith 1968). In the old tortoise burrow, where the main entrance was blocked, the mice not only maintained the chimney (and possibly the pockets), but also constructed an elaborate system of interconnecting tunnels; in so doing they modified parts of the original tortoise burrow.

Although we discovered no mouse nests, we found grass in the chimney of one active tortoise burrow (Fig. 1B). The closed burrow (Fig. 2) had oak leaves (mostly *Quercus geminata* and *Q. hemisphaerica*) and wiregrass lining the floor and walls at the distal end of the modified tortoise burrow. We captured two subadult mice at this burrow, and an adult escaped during the excavation. In addition to *Ceuthophilus* and *Podomys*, we encountered wolf spiders (*Geolycosa* and *Lycosa*), unidentified opiliones, gopher crickets, and *Gopherus* during our excavations.

DISCUSSION

In high pine sandhills, the Florida mouse is associated closely with burrows of the gopher tortoise. At Ordway, many individuals typically show fidelity to one or two tortoise burrows (Jones unpubl. data). Because we have monitored some tortoise burrows at Ordway since 1983, we have been able to recognize small holes used by mice as remnants of

preexisting tortoise burrows, even when the main entrance to the old burrow was no longer evident.

Perhaps the most obvious function of burrow use by Florida mice is to provide a refuge, since sandhills are among the most xeric habitats in northern Florida. Burrow temperatures remain fairly constant through the year relative to air temperatures, with temperature decreasing at a rate of 0.9°C/m (Douglass and Layne 1978; Speake 1981; Franz unpubl. data). Burrows also provide a refuge from fire. Sandhill vegetation is fire-adapted; conversion to a xeric hardwoods/mixed pine association begins after about 50 years without fire (Myers 1985).

King et al. (1964), Wolfe (1970), and Layne (1969, in press) described the nests built by *P. floridanus*. *Podomys* used less nesting material and built smaller, flatter nests compared to *Peromyscus gossypinus* and *P. polionotus*. Two *Podomys* burrows excavated by Layne (in press) in sandhills in Alachua County were lined with vegetation in a manner similar to the burrow we found lined with oak and wiregrass leaves (Fig.

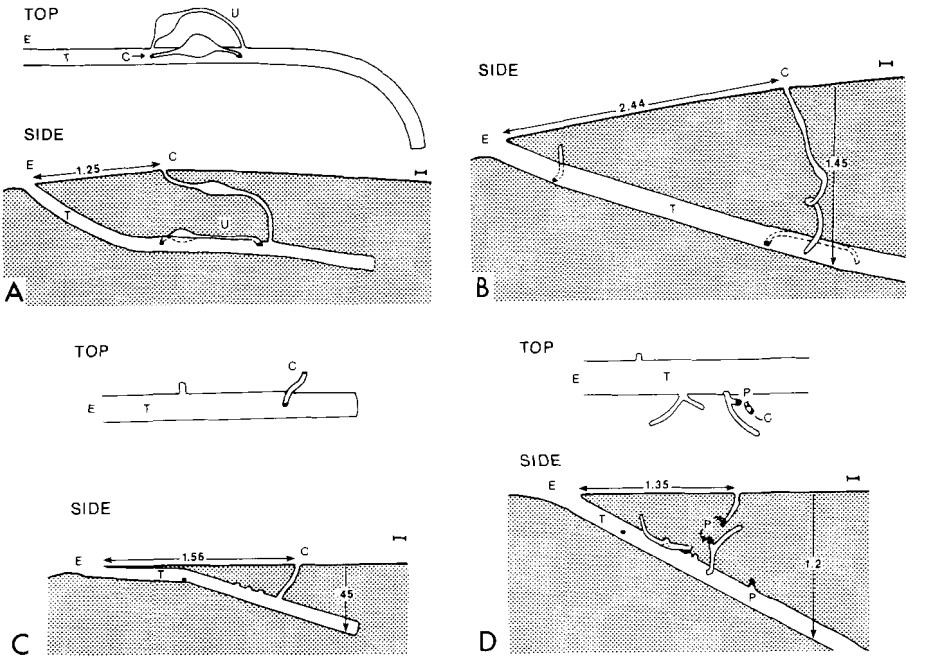

Figure 1. Inactive (A, C) and active (B, D) tortoise burrows excavated on the Ordway Preserve. Measurements are shown in meters; the bar represents 10 cm. Abbreviations are as follows: C = chimney, E = entrance to tortoise burrow, P = plug, T = tortoise burrow, and U = U-shaped tube.

2). Layne (1969) suggested that the relatively poor nest-building abilities of *Podomys* indicated a long evolution of burrow use under warm, xeric climatic conditions.

We found no food caches or fecal deposits, although *Podomys* cached acorns and other food under laboratory conditions (Jones unpubl. data). Hulls of opened acorns were common in the tortoise burrow, in mouse tunnels and pockets, and occasionally on the apron at the burrow entrance. Nowhere were food remains as numerous as those observed in *P. polionotus* burrows by Gentry and Smith (1968).

The precise function of the curved chimneys is uncertain. The absence of a mound at the chimney entrance implies a lack of ventilation by convection, as reported for hillocked holes made by other fossorial mammals (Vogel et al. 1973). On the Ordway several species of snakes that are potential predators of Florida mice utilize tortoise burrows (Franz 1986; Timmerman 1989), and we believe that chimneys and the U-shaped

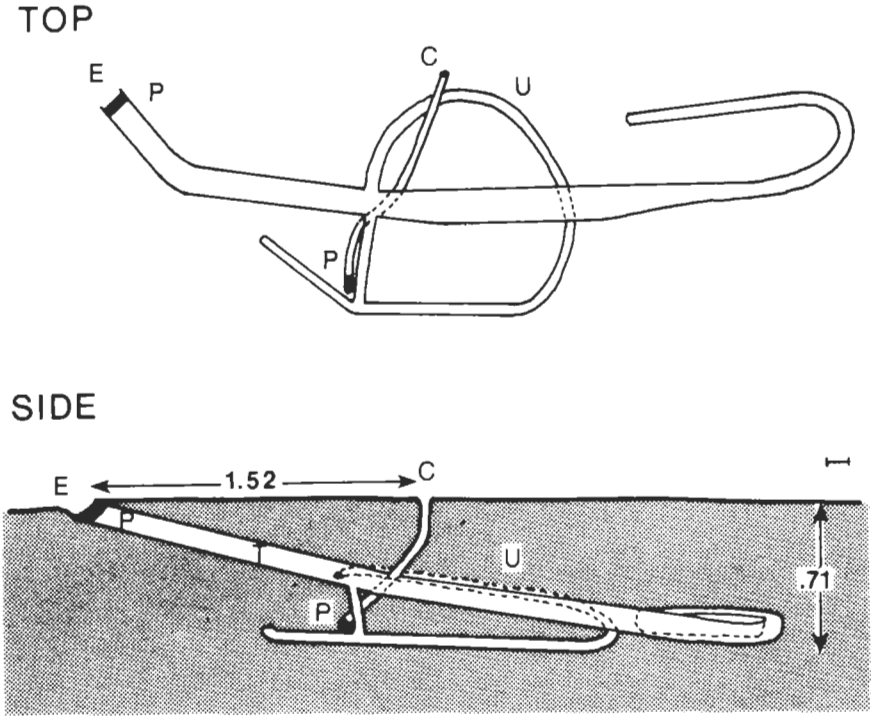

Figure 2. The old tortoise burrow excavated at Ordway. Abbreviations as for Figure 1.

tunnels might serve as escape tunnels similar to those described for other small mammals (Sumner and Karol 1929; Hayne 1936; Brown and Hickman 1973). *Podomys* are susceptible to cold weather (Layne 1969; pers. obs.), and perhaps the tunnels allow mice to move within a preferred temperature gradient, so they can stay at a higher temperature than used by *Gopherus* at the bottom of the burrow while still escaping ambient temperature extremes.

At other study sites, Layne (in press) observed *Podomys* using burrows constructed by other mammals (*P. polionotus*, *Sigmodon hispidus*, *Geomys pinetis*, and *Dasypus novemcinctus*). In the ecotone between mesic hammock and longleaf pine flatwoods, Starner (1956) trapped a Florida mouse in a small burrow that she thought might have been dug by the mouse and Lee (1968) reported that *Podomys* dug its own burrows in scrub ecotone. However, on the Ordway Preserve we had no evidence that *Podomys* dug its own burrows or inhabited logs or other shelters.

Jones (unpubl. data) trapped for more than 17,000 trapnights at tortoise burrows on three sandhills on Ordway and captured only one *P. gossypinus*. Clearly, rodents other than *Podomys* were only occasional visitors to tortoise burrows in these sandhills, although in other parts of Florida tortoise burrows in sandhills are used by *P. gossypinus*. The extensive use of gopher tortoise burrows by *P. floridanus* might be unique among rodents. Layne (1969) suggested that its restriction to nesting in burrows and poor nesting ability contributed to *Podomys*' relatively limited habitat use and geographic range. At the same time, we believe that the ability of this species to take advantage of gopher tortoise burrows contributes to its success in the xeric sandhill environment.

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