

FIRST FOSSIL RECORD OF *EUDERMA MACULATUM* (CHIROPTERA:  
VESPERTILIONIDAE), EASTERN GRAND CANYON, ARIZONA

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The spotted bat (*Euderma maculatum*) is widely distributed across western North America from southern British Columbia and Montana to southern California, and southeast through New Mexico and western Texas to Querétaro, México (Easterla, 1970; Schmidly and Martin, 1973; Watkins, 1977; Leonard and Fenton, 1983; Navo et al., 1992). Spotted bats appear to roost in cracks and small crevices in cliff walls, and have been documented hibernating or roosting on walls within caves (Poché and Bailie, 1974; Leonard and Fenton, 1983; Wai-Ping and Fenton, 1989). Hardy (1941) reported at least 4 hibernating *Euderma* in Crocodile Cave near Kanab, Kane Co., Utah, and Parker (1952) discussed the observation of a single spotted bat in a cave near Barstow, San Bernardino Co., California. Spotted bats are known to forage in nearly all habitats throughout the elevation range from low-desert to coniferous forest (Priday and Luce, 1999). In northern Arizona, Rabe et al. (1998) and Siders et al. (1999) revealed that *Euderma* preferred to forage in open areas surrounded by ponderosa pine. One *Euderma* was tracked 38 km from the montane foraging area to a limestone cliff roost at about 700 m elevation, ca. 200 m from the Colorado River (Siders et al., 1999).

A limestone cave located on Navajo Nation lands adjacent to the Marble Canyon region of Grand Canyon National Park, Coconino Co., in northern Arizona was explored in 1995 through 1997 for its natural history contents. The precise location of the cave is withheld at the request of the Navajo Nation. Qualified researchers may obtain more information by writing to DGM. The cave is located at 1,530 m elevation on the rim of the Marble Canyon platform, and is adjacent to the Colorado River corridor and associated side canyons. The biotic community surrounding the cave is Great

Basin Desertscrub as defined by Turner (1982). The cave extends ca. 160 m underground, has a ceiling height of 15–30 m, and has an opening that is ca. 4 × 13 m at its greatest measures. The walls and ceiling of the cave are lined with cracks within the limestone that are typically less than 10 cm in width. Twenty bat carcasses of at least 5 species (*E. maculatum*, 11 specimens; *Eptesicus fuscus* (big brown bat), 2; *Corynorhinus townsendii* (*Plecotus*; Townsend's big-eared bat), 1; *Myotis thysanodes* (fringed myotis), 1; *M. yumanensis* (Yuma myotis), 1; and unidentifiable, 4) have been found on the floor of the cave at various locations and have not been removed.

Present-day use of this cave by spotted bats was investigated using roost counts and netting sessions between September 1995 and October 1997. The goals of these investigations were to verify day-roosting by spotted bats, estimate the number of bats and seasonal use, and determine roost locations within the cave. Roost counts were performed on 11 November 1995, 9 May and 28 October 1996, and 24 July 1997; netting sessions were conducted on 12 September 1995, 16 August 1996, and 2 October 1997. We determined that between 6 and 9 spotted bats day-roosted within the ceiling cracks of the cave between at least May (6 individuals) and early October (9 individuals). No *Euderma* emerged from the cave during roost counts on 28 October and 11 November; however, several small non-audible bats were observed at the cave entrance immediately after sundown on both dates. Spotted bats emerged from this cave singly or in pairs, typically each separated by 1 to 9 min. Emergence began 15 to 30 min after sundown, lasted for ca. 30 min, and usually included 1 to several bats flying back into the cave. We captured 11 spotted bats on 16–17 August at the cave entrance from 2100h to 0500h; 9 were adult males, and 2 were adult



FIG. 1—Dorsal view of mummified carcass of the spotted bat, *Euderma maculatum*, from a cave near Grand Canyon, Arizona. Preserved hair shows the spotted pattern characteristic of the species. Right ear was removed for radiocarbon analysis.

females. Also during the August netting session, spotted bats were heard overhead, outside the cave, during all hours of the night. We recorded peaks in activity (number of passes per hour) from 2100h to midnight, and again during the 0400h.

Eleven carcasses of spotted bats were found in various states of preservation in at least 3 locations from 100 to 160 m within the cave. Figure 1 illustrates a particularly well-preserved *Euderma* mummy found wedged into a wall crevice ca. 0.5 m above the cave floor at 137 m from the cave entrance. The position above the cave floor apparently permitted total desiccation of the specimen by circulating air, leaving the hair and delicate wing membranes intact. Preserved hair on the body clearly identifies the specimen as *E. maculatum*. This specimen was removed from the cave wall in May 1995 for radiocarbon analysis, and is deposited in the United States Geological Survey's Biological Survey Collection, Museum of Southwestern Biology, University of New Mexico

(MSB 122645); a photograph of the specimen is archived at the Navajo Natural Heritage Program, Window Rock, Arizona.

The right ear of the specimen was removed and submitted to Beta Analytic Incorporated (Florida) for radiocarbon analysis using the accelerator mass spectrometer technique. Pretreatment of tissue followed standard procedures including an acid/alkali/acid wash. Hot acid washes removed any potential carbonate contamination. Alkali pretreatment reduced the 100 mg specimen to 7.9 mg. Analysis of the ear tissue (Beta-83102;  $^{13}\text{C}/^{12}\text{C}$  ratio =  $-23.2\text{‰}$ ) indicates the age of the mummy to be  $9,180 \pm 50$  radiocarbon years old ( $^{14}\text{C}$  years B.P.; calendar calibration of BC 8,130; = about 10,500 calibrated [cal.] years old; Stuiver and van der Plicht, 1998). This directly radiocarbon-dated specimen represents the first non-modern sample of *E. maculatum*, and dates to the early Holocene.

There is no indication that *Euderma maculatum* was living in North America north of Mex-

ico during the Wisconsin Glaciation (ca. 80,000 to 11,000 years B.P.), or if it was, it was exceedingly rare and, to this date, is not known in the fossil record (Kurtén and Anderson, 1980; Harris, 1985). The bat is not known from any of the Grand Canyon Pleistocene locations (Mead, 1981), or from other likely fossil localities in the arid Southwest such as Papago Springs Cave, southeastern Arizona (see review in Czaplewski et al., 1999).

The Wisconsin glacial climate of northern Arizona and surrounding region was quite different than today. There was, in general, a strong summer cooling and a dominant winter precipitation regime (Betancourt et al., 1990). Fossil plants recovered in dry-preserved woodrat middens (nesting and debris pile deposits; *Neotoma* sp., Rodentia) and pollen from lake sediments indicate a Wisconsin Glaciation (Oxygen Isotope Stage [IS] 3; 50,000–27,500 cal. year B.P.) mean annual temperature 3–5°C lower and annual precipitation 35–60% greater than today; IS 2 [27,500–14,040 cal. year B.P.] was 5°C cooler (Betancourt et al., 1990; Anderson et al., 2000). Monsoonal flow during IS 3 and IS 2 would have been inhibited from the southern Colorado Plateau by, among other things, the southerly position of the jet stream in summer and a heavy spring snowpack over the Colorado Plateau preventing summer heating and thermally-induced low-pressure upstream (Anderson et al., 2000). The transition from IS 2 to IS 1 (ca. 14,000 cal. year B.P., or about 12,000 <sup>14</sup>C year B.P.) marks a drastic change in the weather pattern and witnessed major reorganization of the vegetation on the southern Colorado Plateau (Anderson et al., 2000). Among other plant species, the appearance in low-desert regions of catclaw acacia (*Acacia greggii*), velvet mesquite (*Prosopis velutina*), and summer ephemerals by 9,900 <sup>14</sup>C year B.P. suggests that greater precipitation with reliable summer rainfall prevailed at this time. The final demise of the glacial winter rainfall regime in the Southwest occurred by ca. 9,000 <sup>14</sup>C year B.P. [ca. 10,200 cal. year B.P.], with the onset of hot summers (Van Devender, 1990). It may be that *E. maculatum* was unable to roost/live as far north as the Grand Canyon until the summer temperatures and rainfall patterns had established the modern regime ca. 10,000 to 9,000 <sup>14</sup>C year B.P. [ca. 11,000–10,200 cal. year B.P.]. The fossil

specimen presented here dating to 9,180 <sup>14</sup>C year B.P. [ca. 10,500 cal. year B.P.] is consistent with this model. Additional specimens and radiocarbon analyses are needed to further refine the chronology for the arrival of *Euderma* in the arid Southwest.

**Resumen**—Un espécimen momificado de un murciélago moteado (*Euderma maculatum*) fue recuperado de una caverna en las tierras de la nación Navajo adyacentes al Gran Cañón del norte de Arizona. Una muestra de la oreja fue datada por radiocarbono alrededor del año 9.180 <sup>14</sup>C antes de la presente era (o alrededor de 10.500 años calibrados). Este es el primer record de un fósil de la especie. Ya que no hay otros fósiles que aparezcan en depósitos de la era glacial del suroeste de los Estados Unidos, concluimos que *E. maculatum* no vivía en esa región en aquel tiempo. Al parecer, *E. maculatum*, viviendo en México entonces, no pudo migrar tan al norte como el Gran Cañón para buscar refugios hasta que el clima se calentó. Esto no ocurriría sino hasta que las temperaturas de verano y las épocas de lluvia establecieran sus patrones modernos alrededor de los años 10.000 a 9.000 <sup>14</sup>C antes de la presente era (alrededor de los años calibrados 11.000 a 10.200 antes de la presente era).

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