

Indiana Myotis

Myotis sodalis (Miller and Allen, 1928)

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CONTENT AND TAXONOMIC COMMENTS

The Indiana (or social) myotis (*Myotis sodalis*) is a monotypic species (Hall 1981). Before the Indiana myotis was described, several authors identified specimens as the little brown myotis (*M. lucifugus*). Cases of misidentification were described by Miller and Allen (1928) and Mumford and Cope (1964). The literature on the life history, ecology, and management of the Indiana myotis is reviewed by Thomson (1982), Menzel et al. (2001), and Kurta and Kennedy (2002).

DISTINGUISHING CHARACTERISTICS

The Indiana myotis is a small-to-medium-sized bat. Measurements are: total length, 70.8–90.6 mm; tail, 27–43.8 mm; hind foot, 7.2–8.6 mm; forearm, 36–40.4 mm; weight, 5–11 g. The color of the dorsal pelage varies, but is often dull brownish-gray to dark pinkish-gray. Individual dorsal hairs are tricolor. The ventral pelage is lighter and appears pinkish-white. The bat is most easily confused with the little brown myotis and southeastern myotis (*M. austroriparius*) from which it can be distinguished by its short, almost inconspicuous toe hairs and a small but noticeable keel on the calcar (Menzel et al. 2002). The dental formula is: I 2/3, C 1/1, P 3/3, M 3/3 = 38 (Figure 1).

CONSERVATION STATUS

The Indiana myotis has a global rank of Imperiled (NatureServe 2007). It is also Imperiled in Alabama, and Arkansas, and is Critically Imperiled in Kentucky, Oklahoma, South Carolina, Tennessee and Virginia. In North Carolina, the status of the bat is Under Review. The U. S. Fish and Wildlife Service (U. S. Department of Interior 2007) lists the Indiana myotis as Endangered. A recovery plan for the species has been published (U. S. Fish and Wildlife Service 1983) and a revised draft is available (U. S. Fish and Wildlife Service 2007).

DISTRIBUTION

The Indiana myotis occurs widely across much of the eastern half of the United States from Iowa and Oklahoma east to Vermont and south to Alabama (Figure 2). In part, its range is linked to the distribution of limestone caverns used as winter hibernacula

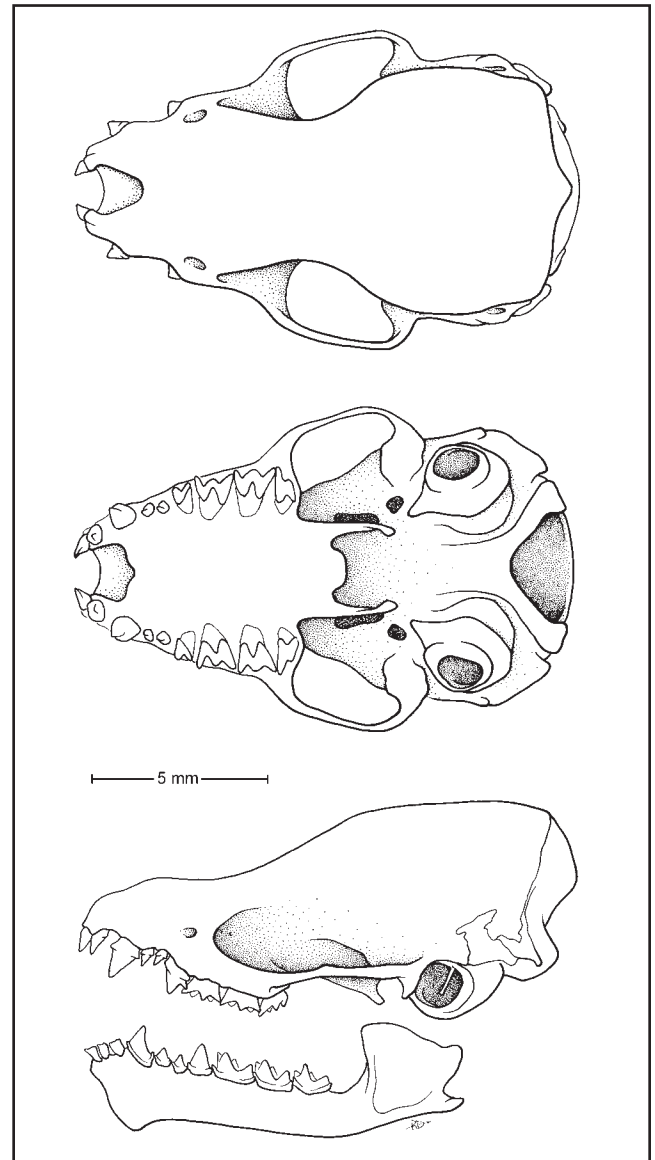


Figure 1. Dorsal, ventral, and lateral view of cranium and lateral view of mandible of *Myotis sodalis* from Bath County, Virginia (USNM 268520, male).

(Hall 1962). During the summer, the range extends beyond the karst areas into the mid-Mississippi and upper-Ohio River Valleys north to Iowa, southern Michigan and southern Wisconsin (Mumford and Cope 1964, Hall 1962, Barbour and Davis 1969, Gardner and Cook 2002). Over half of known Indiana myotis utilize 9 Priority I hibernacula caves or mines

(i. e., those containing >30,000 wintering individuals) in Indiana, Kentucky, and Missouri (Humphrey 1978, Richter et al. 1978, U. S. Fish and Wildlife Service 2007, Clawson 2002). The remaining bats occupy approximately 330 Priority II and III hibernacula throughout winter range in the lower Midwest and upper Midsouth, as well as along the Appalachian Mountains from Alabama north to Vermont (Humphrey 1978, Dunn and Hall 1989, Menzel et al. 2001, Clawson 2002, U. S. Fish and Wildlife Service 2007).

In the South, scattered caves and mines serving as Indiana myotis hibernacula occur in western Virginia, northern Arkansas, northern Alabama, and throughout Kentucky and Tennessee east of the northward bend of the Tennessee River (U. S. Fish and Wildlife Service 2007, Harvey 2002). Kentucky and Tennessee contain over 100 hibernacula (Harvey et al. 1991). Small numbers of Indiana myotis hibernate in eastern Oklahoma (Saughey et al. 1990) and scattered records of hibernating individuals have been reported for western North Carolina, northwestern South Carolina, northwestern Georgia, northeastern Mississippi, and the Florida Panhandle near the Alabama and Georgia borders (Penny 1950, Jennings and Layne 1957, Golley 1962, Golley 1966, Kennedy et al. 1974, Jones and Carter 1989).

During spring post-hibernation emergence and summer maternity season, male Indiana myotis often remain locally near hibernacula sites (Ford et al. 2002, Harvey 2002, Whitaker and Brack 2002). Most maternity activity and summer distribution of females occurs outside of the South, north of the Ohio River and west of the Appalachians (Hall 1962, Humphrey 1978, Gardner and Cook 2002, Harvey and Britzke 2002), although maternity activity in Kentucky along the Ohio and Mississippi rivers has been known for some time (Harvey et al. 1991). Recent surveys have documented maternity activity and female distribution in the vicinity of the Great Smoky Mountains in North Carolina and Tennessee (Harvey 2002, Harvey and Britzke 2002). Lactating females and juveniles indicative of maternity activity have been reported in the Cumberland Mountains and Plateau of eastern Kentucky (Garner and Cook 2002, B. Palmer-Ball, Kentucky State Nature Preserve Commission, personal communication) and southwestern Virginia (Virginia Department of Game and Inland Fisheries 2003), and along the Allegheny Mountains and Plateau in north-central and southwestern of West Virginia (Owen et al. 2001, Beverly and Gumbert 2004). Relative to maternity activity in the Midwest, observations in the Appalachians seem to be ephemeral with little year-to-year fidelity (Carter 2006).

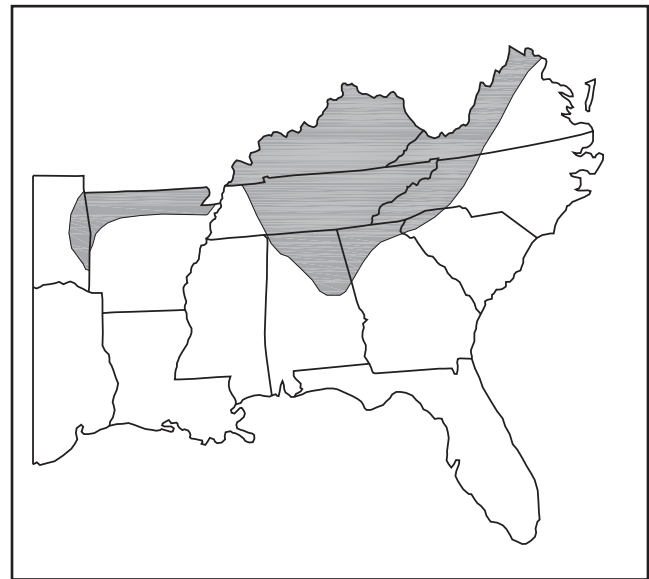


Figure 2. Distribution of *Myotis sodalis* in the South.

ABUNDANCE STATUS

In the 1960s, populations of Indiana myotis were estimated at 750,000 individuals; by the middle 1990s, this estimate declined to approximately 380,000 (Clawson 2002). Approximate overwinter hibernacula numbers by state include Alabama (250), Arkansas (2,500), Kentucky (60,000), Tennessee (10,000), and Virginia (1,000). Georgia, Mississippi, North Carolina, and South Carolina have overwintered small numbers from year to year less than 100 bats (Clawson 2002, U. S. Fish and Wildlife Service 2007). In the summer months, a foraging population density in Kentucky was measured at 11–17/ha (Humphrey et al. 1977). Although endangered, the Indiana myotis may be locally common near winter hibernacula during the fall “swarm” period.

PRIMARY HABITATS

The summer habitat requirements of the Indiana myotis are poorly known. Females and their young typically roost in maternity colonies located under loose, exfoliating bark of living and dead trees during June–July in bottomland and upland forest, and in residual trees in pastures, harvested stands, and suburban areas. Roosts usually receive full sunlight regardless of the sex and the geographic locale. Foraging often occurs along forested riparian areas (Cope et al. 1974, Humphrey et al. 1977, Kurta et al. 1993a,b; Callahan et al. 1997, Stihler 1998, Foster and Kurta 1999, Menzel et al. 2001, Belwood 2002, Whitaker and Brack 2002, Ford et al. 2005, Menzel et al. 2005). Approximately 25 tree species have been identified as maternity roosts (Menzel et al. 2001). Females

exhibit strong inter-annual fidelity for maternity sites (Kurta and Murray 2002). Although males often remain near hibernacula during summer (Henshaw and Folk 1966, Menzel et al. 2001, Harvey 2002, Whitaker and Brack 2002), many of the summer roosting habits of male bats are unknown. In the Allegheny Mountains of West Virginia, a male Indiana myotis roosted under exfoliating bark of large diameter (61 cm) shagbark hickory (*Carya ovata*) and sugar maple (*Acer saccharum*) in a close-canopied mature forest and a clearcut with residual trees, respectively (Ford et al. 2002). In southern Indiana, Brack (1983) found that 4 adult males roosted in moderately large diameter snags and trees (38 cm) in stands with 50% canopy closure. These included pine (*Pinus* spp.), shagbark hickory, white oak (*Quercus alba*), northern red oak (*Q. rubra*), and American elm (*Ulmus americana*).

During winter, Indiana myotis select caves and mines with noticeable airflow and temperatures that remain cool and stable (Henshaw 1965, Humphrey 1978, Menzel et al. 2001). When bats arrive at hibernacula between October–November, they begin the hibernation period in a relatively warm area deep within the cavern (Hall 1962, Myers 1964, Hassell 1967, Hardin and Hassell 1970, Kurta et al. 1996). The Indiana myotis may move nearer the cave entrance when temperatures cool. The Indiana myotis may arouse every 8–10 days; intra-hibernacula movements to favorable microclimates occur (Hardin 1967, Menzel et al. 2001). Many hibernation sites have mid-winter temperatures within 4–8°C (Hall 1962, Myers 1964, Humphrey 1978). Extremes of -1.6°–17°C have been reported (Barbour and Davis 1969, Humphrey 1978); however, those caves often report population declines (Tuttle and Kennedy 2002). Raesly and Gates (1986) found that Indiana myotis tend to occupy open cave ceilings where the ambient air and cave wall temperature were low, relative humidity was high, and airflow was great as compared to sites selected by other bat species. Guthrie (1933a) referred to Indiana myotis as the “cluster bat” because individuals pack together in tight groups or clusters on the ceilings of caves. These clusters have relatively high densities of bats (3000/m²; Hall 1962, Barbour and Davis 1969). This clustering behavior may buffer individuals from fluctuations in temperature (Clawson et al. 1980).

REPRODUCTION

Similar to other life history aspects, the reproductive ecology of Indiana myotis also is poorly known. Mating likely occurs during the fall swarm (Hall 1962), a behavior pattern in which many bats fly in and out of cave entrances from dusk to dawn (Poole 1932, Davis

and Hitchcock 1965, Fenton 1969, Cope and Humphrey 1977). Mating may also occur in winter or early spring (Guthrie 1933a, Hall 1962, Barbour and Davis 1969, LaVal and LaVal 1980). Females store sperm through winter; ovulation, fertilization, and implantation occur after the females leave the hibernacula in spring (Guthrie 1933b, Easterla and Watkins 1969, Thomson 1982). During gestation and lactation, females form small nursery colonies that typically do not contain males (Humphrey et al. 1977). Maternity roosts commonly are found in forested bottomland or riparian areas (Gardner et al. 1991, Callahan et al. 1997, Whitaker and Brack 2002); they also can occur in residual trees and snags in pastures and upland hardwoods (Kurta et al. 1993a,b; Whitaker and Hamilton 1998), and one colony has been reported in an abandoned church (Butchkoski and Hassinger 2002). Few maternity colonies are located in tree cavities; maternity roosts are found under exfoliating bark in large live trees and snags that receive maximum solar exposure (Cope et al. 1974, Humphrey et al. 1977, Kurta et al. 1993a,b; Rommé et al. 1995, Callahan et al. 1997, Menzel et al. 2001, Beverly and Gumbert 2004). Excellent summaries on maternity roost characteristics are presented by Gumbert et al. (2002), Kurta et al. (2002), Miller et al. (2002) and Whitaker and Brack (2002). The gestation period is unknown but parturition occurs in June or July. A single young is born (Easterla and Watkins 1969, Humphrey et al. 1977). Juveniles are weaned in 25–37 days (Humphrey et al. 1977). Volant young have been captured as early as mid-July (LaVal and LaVal 1980). The age at sexual maturity is unknown. Reported longevity is noteworthy, with individuals over 10 years recorded (Paradiso and Greenhall 1967, Humphrey and Cope 1977); one bat was recaptured 20 years after banding (LaVal and LaVal 1980).

FOOD HABITS

The Indiana myotis feeds in forested riparian areas (Humphrey et al. 1977, LaVal and LaVal 1980, Kessler et al. 1981, Brack 1983, Menzel et al. 2005, Ford et al. 2005), upland forests, and woodlots (Easterla and Watkins 1969, LaVal et al. 1977, Brack 1983, Hobson and Holland 1995). Open pasture and cropland may be avoided (Menzel et al. 2001, Menzel et al. 2005). Foraging occurs 2 m above the forest floor to canopy height (30 m) in closed forests and selectively logged stands (Brack 1983, Callahan 1993). There is strong evidence suggesting Indiana myotis return to foraging areas annually (Menzel et al. 2001, Gumbert et al. 2002). During the summer months in Indiana, Whitaker (1972) reported stomach contents contained Hymenoptera (50%), Coleoptera (24%), and Homoptera (19%). Belwood (1979) and Murray and Kurta (2002) analyzed fecal pellets from a maternity

roost and found that females and their young had consumed insects representing 8 and 12 orders, respectively. Belwood (1979) found that lepidopterans comprised 57% of total prey taken over the entire season, increasing to 70% during lactation. Brack and LaVal (1985) found that a diversity of insects was consumed early in the season; however, lepidopterans were selected for disproportionately. Diptera and Coleoptera are other important components of the diet (Kurta and Whitaker 1998, Murray and Kurta 2002). When foraging or orienting, the Indiana myotis emits ultrasonic pulses that sweep downward from 96 to 40 kHz in relatively short (0.5–1.5 millisecond) bursts, an adaptation for foraging in closed habitats (Thomson 1982, O'Farrell 1999, Owen et al. 2004, Ford et al. 2005).

ASSOCIATED SPECIES

Indiana myotis usually cave roost in large, dense, single-species clusters. However, roosting can occur in association with the gray myotis (*M. grisescens*; Sealander and Young 1955), little brown myotis (Griffin 1940, Cope et al. 1974), northern long-eared myotis (*M. septentrionalis*; van Zyll de Jong 1979), southeastern myotis (LaVal 1967), big brown bat (*Eptesicus fuscus*; Fenton 1966), and eastern pipistrelle (*Pipistrellus subflavus*; Kunz and Schlitter 1968).

VULNERABILITY AND THREATS

Myotis sodalis is extremely vulnerable to natural and human-caused perturbations due to concentrated populations in few winter hibernacula. Cave flooding (Hall 1962, DeBlase et al. 1965) and extremely low temperatures (Humphrey 1978) have resulted in mortality. However, the major threat is human disturbance (Humphrey 1992). Human visitation to hibernacula that cause arousal can result in weight loss than impacts survival (Johnson et al. 1998). Population declines also have been related to changes in cave temperature and airflow regimes caused by cave entrance alterations or improper gating (Humphrey 1978, Menzel et al. 2001, Currie 2002, Tuttle and Kennedy 2002), and destruction of summer foraging and roosting habitat by deforestation and stream channelization (Humphrey et al. 1977, U. S. Fish and Wildlife Service 1983, Carter 2007).

MANAGEMENT SUGGESTIONS

Human entry into hibernacula should be prohibited from September–May (Brady 1985). Improperly designed gates or unnatural obstructions that alter cave humidity and temperature require modification. In some instances, cold-air dams or ventilation shafts can restore favorable conditions (Tuttle and Kennedy

2002). Johnson et al. (2002) provides a summary on hibernacula management. Conservation actions also include the protection of roost trees and forested habitats where maternity activity occurs (Bat Conservation International 2001). Land-clearing activities near hibernacula and important maternity areas can be restricted to the hibernation period to avoid direct harm to Indiana myotis. Trees with exfoliating bark such as shagbark hickory should be retained. Forest management techniques, including the use of prescribed fire, that promote multiple-aged stands with large residual trees and snags should be investigated (Gumbert et al. 2002, Krusac and Mighton 2002, Keyser and Ford 2006).

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