SUCCESS OF BRANDENBARK™, AN ARTIFICIAL ROOST STRUCTURE DESIGNED FOR USE BY INDIANA BATS (*MYOTIS SODALIS*)[1]

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Abstract. The federally endangered Indiana bat (*Myotis sodalis*) is a concern for development projects in nearly half of the United States. The species roosts and rears young under exfoliating bark of trees, which has put it at risk for incurring adverse impacts from most projects that require tree clearing throughout its summer range. Project proponents generally incorporate avoidance and minimization strategies into the planning process. These strategies, however, are not always compatible with project goals and objectives, and mitigation is often required to offset adverse impacts to the Indiana bat. BrandenBark™ is an artificial roost structure that mimics the natural roosting habitat of Indiana bats. To date, 69 BrandenBark™ structures have been installed in 7 states (IL, KY, LA, OH, PA, TN and WV). Of these, 59 (86%) structures have been used by 6 species of bats, including northern long-eared bats (proposed for federal listing) and little brown bats (under status review); however, the majority of use (85%) has been by maternity colonies of Indiana bats confirmed by radio telemetry, capture, or genetic analysis of guano. Of the structures used by Indiana bats at Fort Knox Military Installation (n=21) in north-central Kentucky, 120 emergence counts have been conducted with an average of 81.3±7.1 bats per roost. Although the roost area under BrandenBark™ is slightly warmer ($\overline{X}$ = 24.6±7.2°C [SD]) than that of natural bark ($\overline{X}$ = 23.1±6.5°C), the temperature difference between BrandenBark™ and ambient ($\overline{X}$ = 2.1±2.7°C) is less variable than the temperature difference between natural bark and ambient ($\overline{X}$ = 3.9±4.0°C), possibly indicating a more stable thermal environment. However, both roost types are warmer than corresponding ambient temperatures. BrandenBark™ provides instant long-lasting habitat commensurate with natural roosts, is easy to install and monitor, and does not require the purchase of additional land for placement when used as a mitigation option.

Key words: bark roosting bat

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Introduction

The Indiana bat (*Myotis sodalis*) was first described by Miller and Allen in 1928. The species was formally listed as an endangered species on March 11, 1967 by the United States Fish and Wildlife Service (USFWS). Its distribution includes most of the eastern United States from Oklahoma, Iowa, and Wisconsin east to Vermont, and south to northwestern Florida (Barbour and Davis, 1969; Hall, 1981; Kurta and Kennedy, 2002; USFWS 2007).

On their summer grounds, Indiana bats typically roost under the exfoliating bark of trees during the day (Kurta and Kennedy, 2002). Many Indiana bats exhibit fidelity to summer roost areas and even specific trees from year to year (Gardner and Gardner, 1992; Gumbert et al., 2002). Early studies indicated that floodplain forests were the primary habitats for Indiana bats (Humphrey et al., 1977), but with additional research it was discovered that this species also uses upland habitats (Britzke et al., 2003; Gumbert 2001; Kiser and Elliott, 1996; MacGregor et al., 1999; Sewell et al., 2006). Most known maternity roosts have been located in or near wooded areas with full or partial solar exposure to the roost site. Females bear one young in May or June (USFWS 2007). Maternity colonies typically roost under the exfoliating bark of dead trees, occasionally live trees, and to lesser extent, tree cavities (Callahan, 1993; Gardner et al., 1991; Kurta and Williams, 1992). In some cases, Indiana bats have been observed using anthropogenic structures such as attics, barns, and utility poles as maternity roosts (Butchkoski and Hassinger, 2002; Chenger, 2003; Hawkins et al., 2008; Hendricks et al., 2004; Mann et al., 2006; pers. obs., 2013).

Although Indiana bats have occasionally been observed using non-tree roosts, they are at risk for incurring adverse impacts from projects requiring tree clearing throughout the summer range. While avoidance and minimization measures are the primary recommendation for reducing impacts to Indiana bats, these measures are not often compatible with development plans. Therefore mitigation is often required to offset adverse impacts. As mitigation for the removal of bat habitat, multiple attempts have been made to design an artificial bat roost that is effective at consistently attracting bats. Many artificial roosts were designed to be similar to anthropogenic structures already used by other species of bats such as window shutters, roof tiles, attic spaces, barns, and abandoned houses (BCI 2013).

Prior to this study, two artificial roosts were designed to partially mimic the conditions of exfoliating bark on dead trees: the rocket-box bat house (MacGregor and Dourson, 1996) and Artificial Fiberglass Bark, an isopthalic polyester resin reinforced with fiberglass (Wesco Enterprises, Rancho Cordova, CA; Chambers et al., 2002). Of these, only the Artificial Fiberglass Bark had the potential to provide the necessary visual cues (e.g., exfoliating bark, bole size, etc.) that Indiana bats likely use when searching for a suitable roost. Both have been occupied by several bat species at many locations with varying degrees of success (Chambers et al., 2002; Whitaker et al., 2006). Indiana bats have rarely been documented using artificial roosts (however, see Carter et al., 2001; Roby, 2011; Whitaker et al., 2006).

Maternity colonies of Indiana bats have been documented using non-natural roosts in 9 areas: the Indianapolis Airport in central Indiana, Camp Atterbury also in Indiana, and at colonies in central Kentucky, Pennsylvania, Iowa, Missouri, Ohio, upstate New York, and in southern Illinois. A total of 3,204 artificial roost structures of 9 different types were installed as mitigation and for research within a large Indiana bat maternity colony at the Indianapolis Airport in central Indiana from 1992-1996 (Whitaker et al., 2006). The use of these structures by Indiana bats was minimal with documentation of sporadic use by juvenile males until 2003 when 2 pregnant Indiana bats were tracked to a bird-house style bat box with 27-65 bats emerging from the roost (Ritzi et al., 2005). Double chambered rocket boxes placed near known maternity roosts in southern Illinois received infrequent use by Indiana bats in late summer (Carter et al., 2001). However at Camp Atterbury 80 kilometers southeast of the Indianapolis Airport, a small percentage of rocket boxes were used by a maternity colony of Indiana bats 5 years after they were installed (Roby, 2011). Within an Indiana bat maternity colony in central Kentucky, Artificial Fiberglass Bark was placed on a previously identified maternity roost tree that had lost its natural bark. This artificial roost was used by 2 pregnant female Indiana bats for 4 days, during which a single emergence count recorded 9 bats leaving the roost (EKPC, 2005; Hawkins et al., 2008). Maternity colonies of Indiana bats were found using the attic of a church in northern Pennsylvania (Butchkoski and Hassinger, 2002) and a barn in Iowa (Chenger, 2003). In addition, a reproductive colony was found roosting behind the siding of a suburban house in upstate New York (A. Mann, 2007 pers. comm., ESI). Reproductive Indiana bats have been observed roosting in utility poles (structures that more closely resemble natural Indiana bat roosting habitat than other anthropogenic structures) in Missouri (Hendricks et al., 2004) and

Ohio (Rockey, 2015; pers. obs.). Low success of previous artificial bat roosts designed for Indiana bats is likely due to the lack of required temperature regimes and visual cues necessary to attract a species that prefers exfoliating bark of dead trees (USFWS, 2007). Even though anthropogenic structures and artificial roosts are occasionally used by Indiana bats, there has been limited success in the purposeful deployment of artificial roosts, especially those intended for Indiana bat maternity colonies.

In 1999, an Indiana bat maternity colony was discovered on the Fort Knox military installation in north-central Kentucky, on what is now the Wilcox Firing Range. In order to mitigate for the habitat loss associated with construction of the range, the Department of Defense entered into an agreement in 2002 with the USFWS to enhance Indiana bat habitat on the installation. One of the enhancement measures included the establishment of the Indiana Bat Management Area (IBMA) within the installation. Consisting of 605.6 hectares east of Wilcox Range and the Salt River in the northeast corner of the installation, the IBMA is managed specifically for Indiana bats as part of the mitigation agreement.

Indiana bat maternity use was first documented in the IBMA in 2005 (Martin et al., 2006). At that time, the Fort Knox Natural Resources Branch began work to establish and then monitor habitat enhancements within the IBMA and on other areas of the base. In 2008 as part of the effort to enhance Indiana bat habitat within the IBMA, we began to design an artificial roost structure that could provide the necessary thermal conditions and visual cues likely needed to attract a species that prefers roosting under exfoliating bark of dead and dying trees. Here we present the results of deploying this artificial roost habitat and report its success as a viable habitat enhancement and mitigation product.

Methods

The study area is located approximately 48 kilometers southwest of Louisville, Kentucky on the Fort Knox Military Installation in Bullitt and Hardin counties. Testing of multiple artificial roost types resulted in the development of BrandenBark™, a product specifically designed to mimic the exfoliating bark of natural Indiana bat roost trees. BrandenBark™ utilizes the realistic polyurethane elastomeric Flex-Bark© created by Replications Unlimited (Hazelwood, MO), but has been modified to allow bats to grip and hang from the undersurface of the bark. Bark patterns are available that mimic a variety of tree species, including many species known to be used by Indiana bats. A typical BrandenBark™ structure is composed of an untreated 7.6 m utility pole that is placed 1.5 m into the ground and packed with gravel. The portion below ground is treated prior to placement with a non-toxic, environmentally safe polymer coating developed by American Pole and Timber (Houston, TX) to help prevent decay. A sheet of BrandenBark™ measuring approximately 1.0 m at the top, 1.1 m at the bottom, and 1.3 m long is attached to the pole using screws. This shape allows the bark to be wrapped around the top of each pole with a gap at the bottom allowing bats to access under the bark with the top of the sheet securely fastened to the pole. In order to help document bat use, guano traps constructed of wooden supports and window screen are attached to each pole approximately 1 m above the ground (Fig 1). To determine if BrandenBark™ provides suitable habitat for Indiana bat maternity colonies, we installed the bark on untreated utility poles in the IBMA near known maternity roosts that had degraded in quality, i.e., lost considerable roosting bark or fallen over. BrandenBark™ roosts were also installed along a gas line right-of-way on the western side of the installation in an area where Indiana bats had not been documented but where habitat appeared to be suitable for roosting and foraging. In total, 21 BrandenBark™ structures were installed over 4 years. Six to 10 structures were generally clustered in groups within close proximity to one another (within an area of 0.2 – 1.0 ha).

Figure 1. Representative photo of a BrandenBark™ roost structure

BrandenBark™ structures were considered occupied if guano was present within the trap, bat vocalization (squeaking) was heard from the roost, bats were visible under the bark, bats were observed exiting the roost, or bats were radio-tracked to the roost. Extent of use was determined by conducting emergence counts or using mist-nets to capture bats exiting roosts. To confirm use of multiple structures, select reproductive female and/or juvenile Indiana bats captured exiting BrandenBark™ were outfitted with radio-transmitters (0.36-0.42 g LB-2 or LB-2X, Holohil Systems, Ontario, Canada) and tracked for 8-10 days. Eighty-two transmitters were placed on 76 adult females and 6 juvenile Indiana bats over the 4-year period (radio-transmitters were attached to some bats more than once). Roosting activities of these bats were monitored during the maternity season from 2009 – 2012 (15 May – 15 August; USFWS, 2007) and/or post-maternity season (16 August – 15 October 2011).

Temperature data loggers (iButton®, Maxim Integrated, San Jose, CA) were placed in several BrandenBark™ structures to compare roost temperature between BrandenBark™ and: 1) ambient temperature, and 2) temperature under natural bark on suitable roost trees. Ambient temperature was recorded by placing a data logger on the north facing side of a non-roost tree at each focus area. All data loggers were set to record temperature every 2 hours from 1 April 2010 through September 2010 (or until storage space expired). Due to the unequal variance in the data set, non-parametric Kruskal-Wallis tests were completed using XLSTAT-Pro v2014.6.01 (Addinsoft, Paris, France) to determine differences in temperature among BrandenBark™, natural bark, and ambient readings. Results are reported as mean ± standard deviation.

Results

Over the course of our study at Fort Knox (2011-2014), Indiana bats selected BrandenBark™ structures on a regular basis. Of the 191 roost visits (combination of emergence counts and mist-netting), bats were observed under BrandenBark™ 146 times (76.4%). Indiana bats typically occupied BrandenBark™ structures within a few months after installation and sometimes within days or weeks. For example, of the 5 roosts installed on 27 February 2012, 4 had multiple species of bats (including Indiana bats) using them by 7 May 2012, and the fifth was used by 8 June 2012.

Emergence counts were conducted at BrandenBark™ structures throughout the year, but the majority of the counts were during the maternity season. Of the 120 emergence counts conducted at 21 BrandenBark™ structures housing reproductive Indiana bats, there was an average of 81.3±7.1 bats per roost. This includes 11 counts when no bats exited and a high count of 451 individuals emerging from a single BrandenBark™ structure (Roby and Gumbert, 2014). If emergence counts that yielded no bats are removed, the mean rises to 89.5±7.4 bats per roost. The high count of 451 bats emerging from a single roost exceeds the previous record of 384 bats exiting a roost tree at Camp Atterbury, Indiana (Kiser et al., 2002) and represents the second highest emergence count ever recorded from a known Indiana bat roost tree (n = 475; Roby and Gumbert, 2014).

To date, 6 bat species have been confirmed (via capture and in-hand identification) to roost in BrandenBark™ structures at Fort Knox. Eighty-five percent of the bats captured emerging from BrandenBark™ at Fort Knox were Indiana bats. Little brown bats (*Myotis lucifugus*) represented 18% of captures, whereas northern long-eared bats (*M. septentrionalis*), evening bats (*Nycticeius humeralis*), tricolored bats (*Perimyotis subflavus*), and big brown bats (*Eptesicus fuscus*) represented less than 1% each. Most capture events consisted of a single species emerging from a particular roost, but interspecies cohabitation did occur on occasion, including both little brown bats and evening bats roosting with Indiana bats. In fact, a pregnant female evening bat was captured emerging from a BrandenBark™ roost that was housing a maternity colony of Indiana bats.

Temperature data were collected from BrandenBark™ roosts housing reproductive female and juvenile Indiana bats and at suitable natural bark roosts that were not documented Indiana bat roosts. Trends indicate that temperatures in all 4 roosts (2 natural and 2 BrandenBark™) were warmer than ambient, but BrandenBark™ temperatures were slightly warmer ($\overline{X}$ = 24.6±7.2°C) than natural bark ($\overline{X}$ = 23.1±6.5°C). The temperature difference between BrandenBark™ and ambient ($\overline{X}$ = 2.1±2.7°C) was less variable than the temperature difference between natural bark and ambient ($\overline{X}$ = 3.9±4.0°C, Fig. 2).

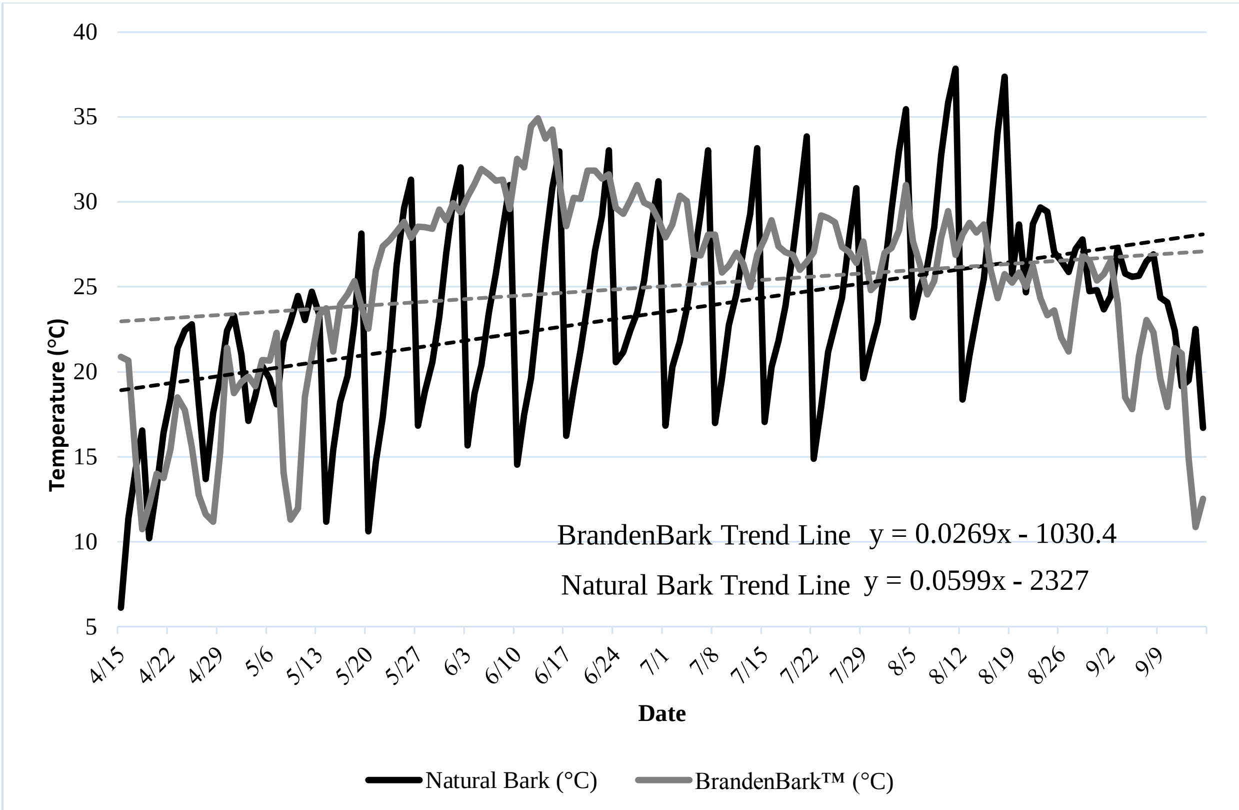

Figure 2. Temperature data collected from natural and BrandenBark™ roosts used by reproductive female Indiana bats.

Discussion

The capture of 190 adult female (150 reproductively active) and 97 juvenile Indiana bats emerging from BrandenBark™ structures over 6 years clearly indicates maternity use of BrandenBark™ structures. In addition, 40 reproductive adult female and 7 juvenile little brown bats were also captured emerging from BrandenBark™ structures during our study indicating their use of BrandenBark™ structures as maternity habitat. The success of BrandenBark™ as a suitable roost for bark roosting bats, Indiana bats in particular, may be attributed to several factors. Previous studies (Speakman and Thomas, 2003; Studier and O'Farrell, 1972) reported that female myotine bats in late pregnancy and their pups are poor thermoregulators, leading Barclay and Kurta (2007) to surmise that the "roost microclimate and its impact on thermoregulation are the primary factors involved in roost selection by forest-dwelling bats." However, this hypothesis has not been tested. Confirmed maternity use of BrandenBark™ demonstrates that the roost microclimate therein is sufficient to support the growth of bat pups.

In addition, the fact that these roosts provide a more stable microclimate than natural roosts may allow bats to use the structures during cooler temperatures (e.g., spring and fall).

Other research (Britzke et al., 2006; Gumbert, 2001; Sewell and Adams, unpubl. data) has shown that bats choose different types of roosts based on the time of year. This is likely due to the lower ambient temperatures prior to and after the maternity season and the bats' need to reduce energy expenditure. Indiana bats have been documented in BrandenBark™ structures on Fort Knox as early as mid-April (Copperhead, unpubl. data) and as late as October (Roby, 2012). Changes in ambient summer temperatures appear to affect roost use by Indiana bats. Roby (2011) reported that when ambient summer temperatures reached 32°C at Camp Atterbury, Indiana, the majority of Indiana bats in a maternity colony roosting in a rocket box dispersed into the woods, choosing natural roosts of mainly live shagbark hickories (*Carya ovata*). The reverse occurred at Fort Knox when bats congregated in a BrandenBark™ roost and in a crevice roost (i.e., crack in the bole of a snag, rather than under bark) when the ambient daytime temperature dropped dramatically (from 33°C-23°C) in mid-summer (Roby and Gumbert, 2014). BrandenBark™ structures provide an additional roosting resource when placed within the home range of bark roosting bats and the thermal stability helps provide suitable roosting habitat during different times of the year, including outside the maternity season (Roby, 2012).

Other types of artificial roosts have resulted in varying degrees of success. Indiana bat use of most artificial roost types designed for species that roost under exfoliating bark has been limited, and those structures that have been used by maternity colonies have often taken several years before significant use was documented (Roby, 2011; Whitaker et al., 2006). BrandenBark™ was occupied by maternity colonies within months of installation, occasionally within a matter of days. In addition to the thermal stability of BrandenBark™, we also believe it provides the necessary visual cues for selecting summer roosts on the landscape. The lack of data/observations and occupancy timeframe for Indiana bats using anthropogenic structures and other tree mimics appears to support this belief.

It is likely that the availability of maternity roosts may be a limiting factor for the persistence of Indiana bats (USFWS, 2007). Since its introduction to the United States in 2006 (Blehart et al., 2009), it has been estimated that more than 5.5 million bats had been killed by White-Nose Syndrome (WNS) in 25 states (Froschauer and Coleman, 2012). With WNS causing mass mortality during hibernation, protecting summer habitat is becoming more crucial for the survival of the species. In order to ensure that Indiana bat summer habitat is available while still allowing developers to provide for the needs of a growing human population, mitigation options that provide immediate and long lasting maternity roosts are necessary. The results of this study indicate that BrandenBark™ provides a tool that appeals not only to Indiana bats but to other bat species experiencing population declines, including the northern long-eared bat which is currently under consideration for federal listing.

In addition to all of the mitigation benefits, BrandenBark™ structures require minimal effort to install and monitor. A typical installation can be completed by 3 people in less than an hour. Long term monitoring can be conducted by installing guano traps, a noninvasive monitoring method that can be conducted by any personnel. The guano can also be genetically analyzed to determine species use (Walker et al., 2015). If more precise monitoring is required, emergence counts and mist-netting to capture bats can be conducted.

Although BrandenBark™ has proven to be a useful tool for habitat enhancement for bats, future research is necessary to answer several questions about the interactions of bats with these structures. Such interactions could be tested by altering the appearance, size, and shape of the bark, using natural trees rather than utility poles for attaching bark, and varying the diameter at breast height of the poles. Such tests could help identify the exact appeal that BrandenBark™ structures has to bats. How different are the temperature regimes of different areas under the bark; for example, how much warmer is it at the top of the bark versus near the bottom? How often will bats select BrandenBark™ roosts when placed near other artificial structures? In terms of bat behavior and health, how often does roost switching occur compared to natural roosts? Does the permanence of the structures affect home range sizes as opposed to colony shifting with a changing forest structure? These and many more questions are still yet to be investigated, but preliminary results with one of the largest known maternity colonies of Indiana bats have been very positive and encouraging.

Literature Cited

Barbour, R.W. and W. Davis. 1969. Bats of America. The University Press of Kentucky, Lexington, Kentucky.

Barclay, R.M.R. and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Pages 17-59 in Bats in Forests: Conservation and Management. (M.J. Lacki, J.P. Hayes, and A. Kurta, eds.). Johns Hopkins University Press, Baltimore, Maryland.

BCI (Bat Conservation International). 2013. Designing Better Bat Houses. *Batcon.org*. Bat Conservation International, Spring 1993. Web. 20 May 2013.

Blehart, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Colman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat white-nose syndrome: An emerging fungal pathogen? Science 323, 227. 28 July 2008; accepted 30 September 2008. Published online 30 October 2008; 10.1126/science.1163874

Britzke, E. R., M. J. Harvey, and S. C. Loeb. 2003. Indiana bat, *Myotis sodalis*, maternity roosts in the southern United States. Southeastern Naturalist 2(2):235-242.

Britzke, E.R., A.C. Hicks, S.L. Von Oettingen, and S.R. Darling. 2006. Description of spring roost trees used by female Indiana bats (*Myotis sodalis*) in the Lake Champlain Valley of Vermont and New York. American Midland Naturalist 155:181-187.

Butchkoski, C.M. and J.D. Hassinger. 2002. The ecology of Indiana bats using a building as a maternity site. Pages 130-142 *In* The Indiana Bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Callahan, E.V. 1993. Indiana bat summer habitat requirements. M.S. Thesis. University of Missouri, Columbia. 84 pp.

Carter, T., G. Feldhamer, and J. Kath. 2001. Notes on summer roosting of Indiana bats. Bat Research News 42(4):197-198.

Chambers, C.L., V. Alm, M.S. Siders, and M.J. Rabe. 2002. Use of artificial roosts by forest-dwelling bats in northern Arizona. Wildlife Society Bulletin 30(4):1085-1091.

Chenger, J. 2003. Iowa Army Ammunition Plant 2003 Indiana bat investigation. Prepared by Bat Conservation and Management, Inc., Carlisle, PA. for Iowa Army Ammunition Plant, Middletown, IA.

(EKPC) East Kentucky Power Cooperative. 2005. Biological Assessment. Effects on the Indiana bat associated with construction of the proposed Little Mount 161 – 12.5kV distribution substation & 161kV transmission line tap. Unpublished report submitted to U.S. Fish and Wildlife Service, Kentucky Field Office, Frankfort, Kentucky.

Froschauer, A. and J. Coleman. 2012. "North American Bat Death Toll Exceeds 5.5 Million from White-nose Syndrome." *Whitenosesyndrome.org*. U.S. Fish & Wildlife Service, 17 Jan. 2012. Web. 2 Mar. 2015. https://www.whitenosesyndrome.org/sites/default/files/files/wns_mortality_2012_nr_final_0.pdf .

Gardner, J.W., J.D. Gardner, and J.E. Hoffman. 1991. Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Final report submitted to Endangered Species Coordinator, Region III, U.S. Department of the Interior, Fish and Wildlife Service, Twin Cities, Minnesota and Indiana/Gray Bat Recovery Team, U.S. Fish and Wildlife Service.

Gardner, J.D. and J.E. Gardner. 1992. Determination of summer distribution and habitat utilization of the Indiana bat (*Myotis sodalis*) in Illinois. Final Report, Project E-3. Illinois Department of Conservation, Springfield, Illinois, USA.

Gumbert, M.W., J.M. O'Keefe, and J.R. MacGregor. 2002. Roost fidelity in Kentucky. pp. 143-152 in The Indiana bat: biology and management of an endangered species. (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Gumbert, M.W. 2001. Seasonal roost tree use by Indiana bats in the Somerset Ranger District of the Daniel Bonne National Forest, Kentucky. M.S. Thesis, Eastern Kentucky University, Richmond, Kentucky. 136 pp.

Hall, E.R. 1981. The mammals of North America. 2 vols. John Wiley & Sons, New York.

Hawkins, J.A., P.L. Sewell, and M.W. Gumbert. 2008. Indiana bat survey and anthropogenic stimuli study conducted at US Army Garrison Fort Knox and Brashears Creek study sites during summer 2007. Final report prepared for R. Tibbitts (ICI, LLC), M. Brandenburg (Ft. Knox), and M. Hohmann (USACOE). 65pp.

Hendricks, W.D., R. James, L. Alverson, J. Timpone, M. Muller, N. Nelson, and J. Smelser. 2004. Notable roosts for the Indiana bat (*Myotis sodalis*). pp. 133-138. *In* Proceedings of Indiana bat and coal mining: a technical interactive forum. OSM, Alton, IL and Coal Research Center, SIU, Carbondale, IL.

Humphrey, S., A. Richter, and J. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. Journal of Mammalogy 58(3): 334-346.

Kiser, J.D. and C.L. Elliott, 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat (*Myotis sodalis*) during autumn in Johnson County, Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky, USA.

Kiser, J.D., J.R. MacGregor, H.D. Bryan, and A. Howard. 2002. Use of concrete bridges as night roosts. pp. 208–215 *In* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, TX.

Kurta, A. and J. Kennedy, (eds.) 2002. The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, Texas.

Kurta, A. and K. Williams. 1992. Roost habitat, microclimate, and behavior of the endangered Indiana bat, *Myotis sodalis,* in southern Michigan. Final report submitted to the Nongame Program, Michigan Department of Natural Resources, Lansing, MI.

Mann, A., L.M. Gilley, and V. Brack, Jr. 2006. 2005 Summer mist net and radio-telemetry surveys for the federally-endangered Indiana bat for Phase 1 of the Millennium Gas Pipeline Project, Orand and Rockland Counties, New York. Unpublished report to Millennium Pipeline Company, Binghamton, New York. 78 pages plus appendices.

Martin, C.O., A.A. Lee, R.A. Fischer, M.P. Guilfoyle, M.W. Gumbert, P.L. Roby-Thomas, K. L. McDonald, and G.A. Shirk. 2006. Threatened and endangered species inventory 2004-2005: plant survey, seasonal bird surveys, mammal and herpetological surveys, and aquatic survey of Mill Creek and Otter Creek, Kentucky. Contract Report prepared for US Army Fort Knox by the Environmental Laboratory, US Army Engineer Research and Development Center, Vicksburg, MS.

MacGregor, J. and D. Dourson. 1996. Post bat house design. Daniel Boone National Forest, Winchester, KY.

MacGregor, J.R., J.D. Kiser M.W. Gumbert, and T.O. Reed. 1999. Autumn roosting habitat of male Indiana bats (*Myotis sodalis*) in a managed forest setting in Kentucky. In: Proceedings, 12th central hardwood forest conference (J.W. Stringer and D.L. Loftis, eds.); 1999 February 28-March 2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.: 169-170.

Ritzi, C.M., B.L. Everson, and J.O. Whitaker, Jr. 2005. Use of bat boxes by a maternity colony of Indiana myotis (*Myotis sodalis*). *Northeastern Naturalist* 12: 217-220.

Roby, P. 2011. Bat survey of Camp Atterbury with emphasis on roosting of Indiana bats and evening bats. Unpublished Report for AMEC, Lexington, KY.

Roby, P. 2011. Bat survey of Camp Atterbury with emphasis on roost of Indiana bats and evening bats. Final Report prepared for Martin Marchaterre, Lexington, KY. 234 pp.

Roby, P. 2012. Indiana bat 2011 autumn habitat use and migration from Ft. Knox to southern Indiana caves. Final Report prepared for Lee Andrews and Mike Armstrong, USFWS, Frankfort, KY. 27 pp

Roby, P. and M. Gumbert. 2014. Fort Knox Indiana bat maternity colony monitoring and northern long-eared bat survey. Unpublished report submitted to Lee Andrews and Mike Armstrong, USFWS-KFO, Frankfort, KY.

Rockey, C.D. 2015. Bat assemblage across the summer landscape of Kentucky, Ohio, Pennsylvania, and West Virginia. Poster presented at the meeting of the North American Joint Bat Working Group, 6 March 2015, St. Louis, MO.

Sewell, P., P. Roby, and M.W. Gumbert. 2006. Rare bat survey on the Cherokee National Forest, Tennessee. Final Report, U.S. Forest Service, Cleveland, Tennessee.

Speakman, J.R. and D.W. Thomas. 2003. Physiological ecology and energetics of bats. Pp. 430-490. *In*: Bat Ecology (T.H. Kunz and M.B. Fenton, eds.). The University of Chicago Press, Chicago, IL.

Studier, E.H. and M.J. O'Farrell. 1972. Biology of *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilioniadae)-I. Thermoregulation. Comparative Biochemistry and Physiology 41A:567-595.

Walker, F.M., C.H.D. Williamson, D.E. Sanchez, C.J. Sobek, and C.L. Chambers. 2015. Species from feces: A tool for genetically identifying bats. Paper presented at the meeting of the North American Joint Bat Working Group, 6 March 2015, St. Louis, MO.

Whitaker, J.O. Jr., D.W. Sparks, and V. Brack, Jr. 2006. Use of artificial roost structures by bats at the Indianapolis International Airport. Environmental Management 38:1 28-36.

USFWS (United States Fish and Wildlife Service). 2007. Indiana bat (*Myotis sodalis*) draft recovery plan: first revision. U.S. Fish and Wildlife Service, Fort Snelling, MN. 258 pp.

USFWS (United States Fish and Wildlife Service). 2012. White-nose syndrome: The devastating disease of hibernating bats in North America. Retrieved January 27, 2015.