



Indiana bat maternity roost preference within Midwestern United States upland oak-hickory forests

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Previous Indiana bat maternity colony studies

- Early 2000's & Before
 - Focus on microhabitat characteristics
 - Sloughing bark
 - Canopy opening
 - Tree height
 - Tree diameter
 - Live/Dead status
 - Some landscape characteristics
 - Distance from forest edge
 - Distance to water
- To Present
 - Landscape variables
 - MaxEnt
 - Look at both?
 - Multiple Spatial Scales
 - Still hold up across different sites?

The background of the slide features a silhouette of a bat in flight against a light blue sky. A dark, horizontal branch or wing structure is visible in the lower half of the image. The text and list are overlaid on a semi-transparent blue rectangular area.

Objective(s)

- Distinguish which roost tree features are most relevant to Indiana bat maternity roost tree selection among those collected
- Help forest managers determine what methods are most helpful to conserve/create Indiana bat habitat
 - More easily identify high quality Indiana bat summer roosting habitat
 - Conservation Measures

Study Sites

- 19 maternity roost trees
 - Iowa
 - Lucas (Stephens State Forest)
 - Van Buren
 - Illinois
 - LaSalle
 - Ford

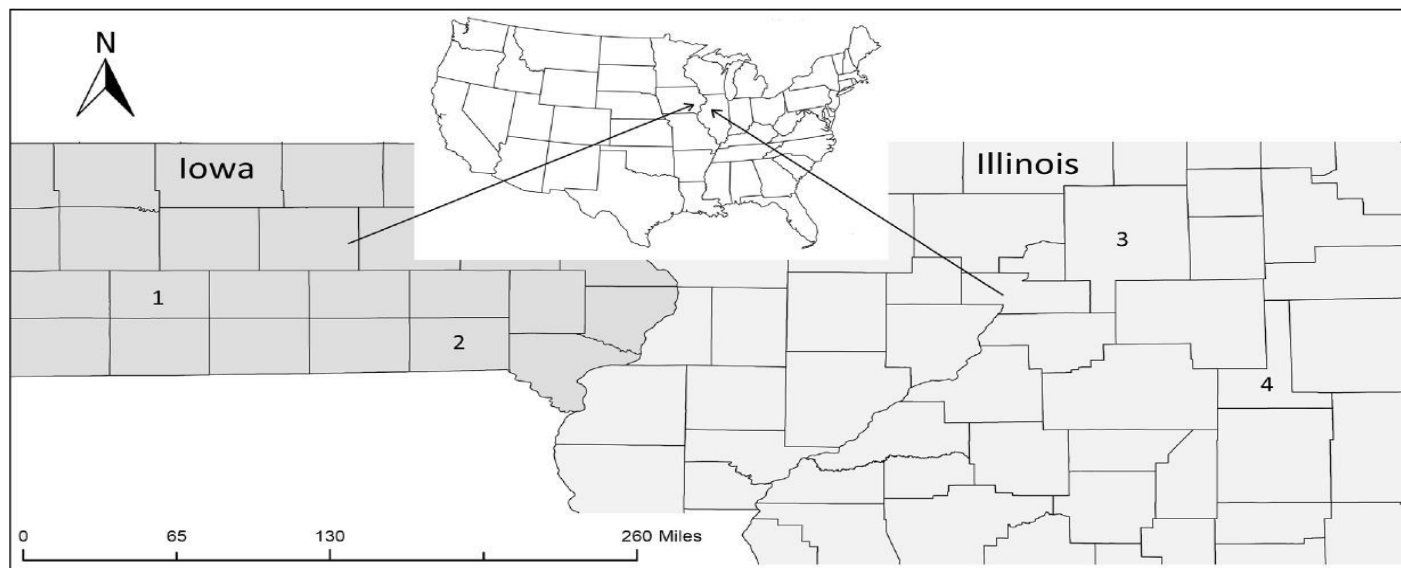


Fig. 1. Study site locations in Iowa and Illinois, USA: 1. Lucas County, 2. Van Buren County, 3. LaSalle County 4. Ford County.

Methods

- Variables Examined
 - Tree Diameter (cm)
 - Tree Height (m)
 - Tree Species
 - Available Bark (%)
 - Canopy Coverage (%)
 - Tree Status (live/dead)
 - Distance to nearest hibernaculum (km)
 - Distance between maternity colonies (km)
 - Distance to nearest water body (km)
 - Amount of forested habitat within 1.5km (potential maternity colony roosting habitat)
 - Distance to forest edge (km)

Statistical Analysis

- MATLAB
 - QR decomposition
 - Singular value decomposition (SVD)
 - Selected variables of most informative features
 - >95% of Frobenius norm and eliminated others
 - Eliminated variables
 - Correlations?

Results

Table 1

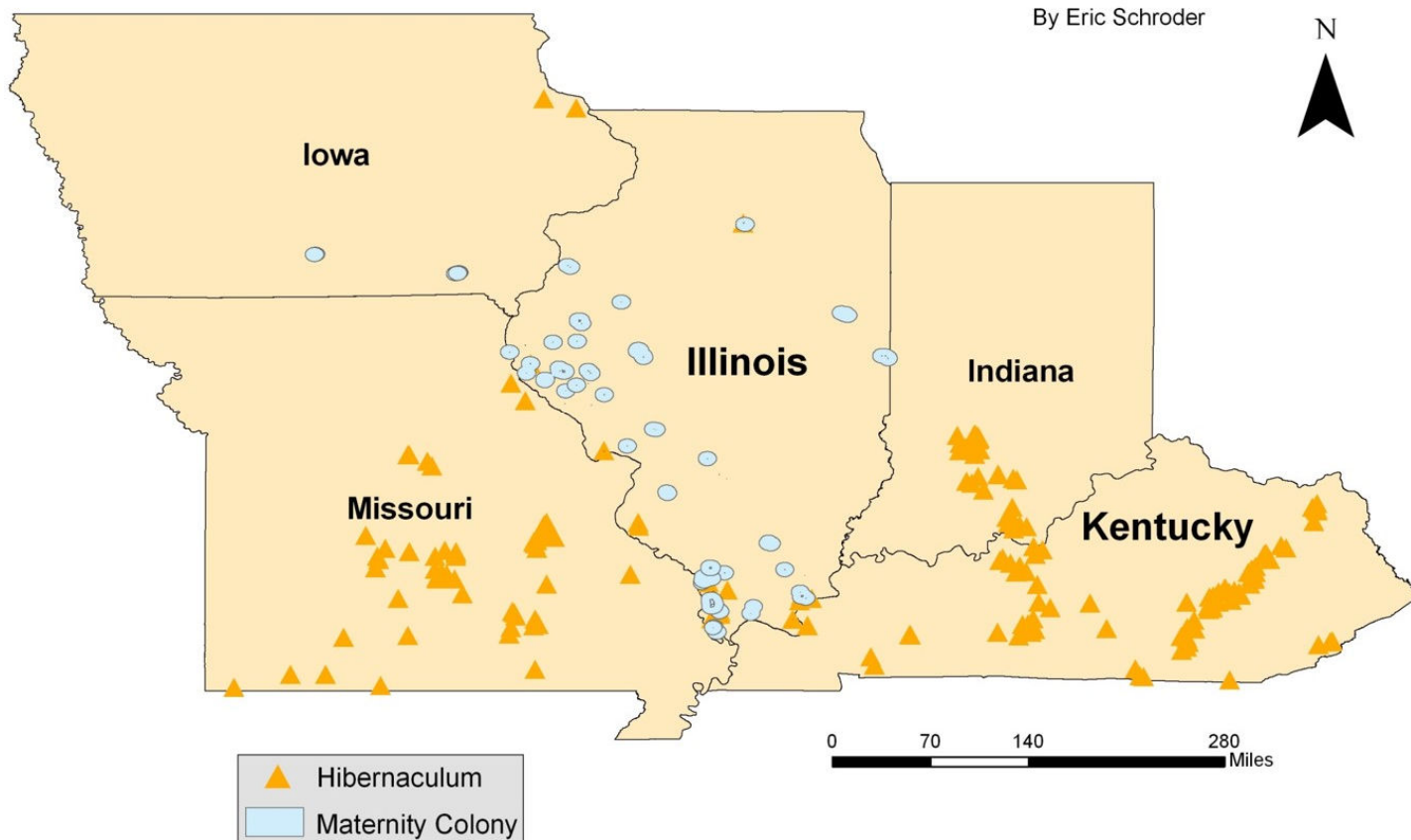
Descriptive statistics for maternity roost habitat variables related to the 19 studied summer maternity colony habitats of Indiana bats (*Myotis sodalis*) in Illinois and Iowa upland oak-hickory (*Quercus-Carya*) forests.

Feature	Label	Mean	Median	SD	Range
Tree height (m)	X_1	13.49	14.02	3.09	8.23–17.68
Distance to forest edge (m)	X_2	69.34	62.07	50.69	0–196.44
Distance to water (m)	X_3	464.74	400	279.81	0–880
Diameter (cm)	X_4	45.99	41.40	19.69	15.24–104.14
Bark cover (%)	X_5	36.63	34.17	20.16	1.71–71.44
Canopy opening (%)	X_6	46.25	33.75	29.99	7.5–100
Distance between maternity colonies (km)	X_7	100.92	90.07	22.10	49.7–131.89
Distance to nearest hibernaculum (km)	X_8	137.95	122.45	66.35	1.85–227.16
Potential maternity colony habitat (km ²)	X_9	3.13	2.49	1.20	1.87–5.46

- Most common tree species utilized: Shagbark hickory (*Carya ovata*) (10)
- Other species: Elm (2), Black Walnut (*Juglans nigra*) (2), Red Oak (*Quercus rubra*) (3), Black Locust (*Robinia pseudoacacia*) (1), Black Oak (*Quercus velutina*) (1)

Indiana Bat Maternity Colony Home Ranges in Iowa and Illinois with Regional Hibernacula

By Eric Schroder



Information was provided by the United States Census Bureau, the Federal Aviation Administration, the Illinois Natural Heritage Database, the Iowa Department of Natural Resources, the United States Fish and Wildlife Service, and the Illinois Institute for Rural Affairs

Results

- Six principle factors
 - Tree species
 - Tree height
 - Distance from maternity roost to forest edge
 - Distance from maternity roost to water
 - Roost tree diameter
 - % of exfoliating bark

Table 2

Variance impact factors (VIFs) between Indiana bat maternity roost tree attributes selected by a feature selection algorithm (rows 1–5) and correlation between landscape-scale variables (rows 6–8).

Feature	Selected Y/N	Regressed covariates	Multiple R ²	VIF
Tree height (X_1)	Y	X_2, X_3, X_4, X_5	0.189	1.233
Distance to forest edge (X_2)	Y	X_1, X_3, X_4, X_5	0.253	1.339
Distance to water (X_3)	Y	X_1, X_2, X_4, X_5	0.391	1.642
Diameter (X_4)	Y	X_1, X_2, X_3, X_5	0.328	1.488
Exfoliating bark (X_5)	Y	X_1, X_2, X_3, X_4	0.442	1.792
Distance between maternity colonies (X_7)	N	X_2, X_3, X_8, X_9	0.772	4.378
Distance to nearest hibernaculum (X_8)	N	X_2, X_3, X_7, X_9	0.872	7.794
Potential maternity colony habitat size (X_9)	N	X_2, X_3, X_7, X_8	0.927	13.755

Discussion

Table 1

Descriptive statistics for maternity roost habitat variables related to the 19 studied summer maternity colony habitats of Indiana bats (*Myotis sodalis*) in Illinois and Iowa upland oak-hickory (*Quercus-Carya*) forests.

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- Six principle factors
 - Tree species
 - Tree height
 - Distance from maternity roost to forest edge
 - Distance from maternity roost to water
 - Roost tree diameter
 - % of exfoliating bark
- Supports previous studies
- Conservation Measures
- Forest Management
- Biases
 - Distance to water
 - Fragment forests

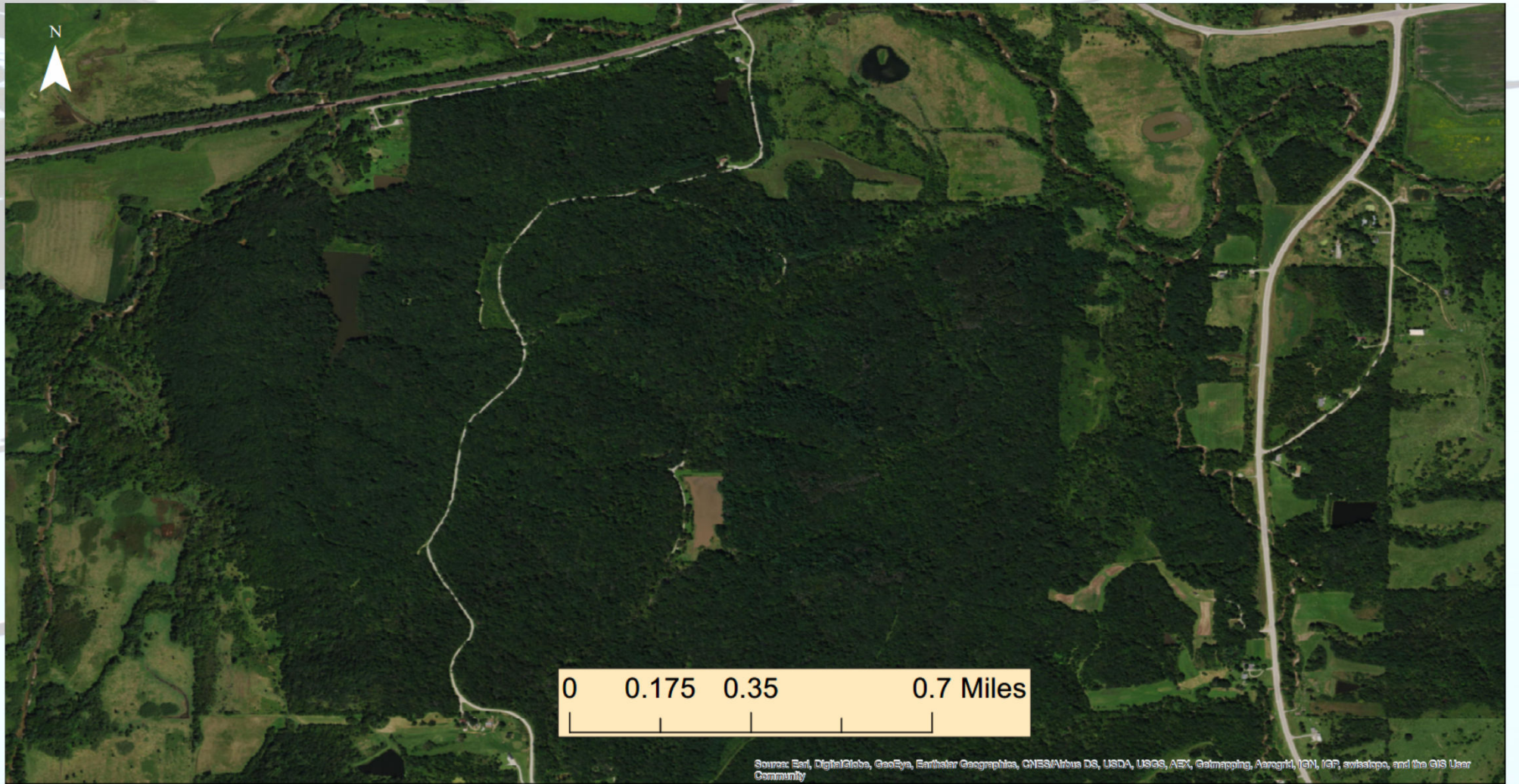
- Not Important
 - Canopy coverage
 - Shagbarks (live or dead)
 - Distance to nearest hibernaculum
 - Potential maternity colony habitat



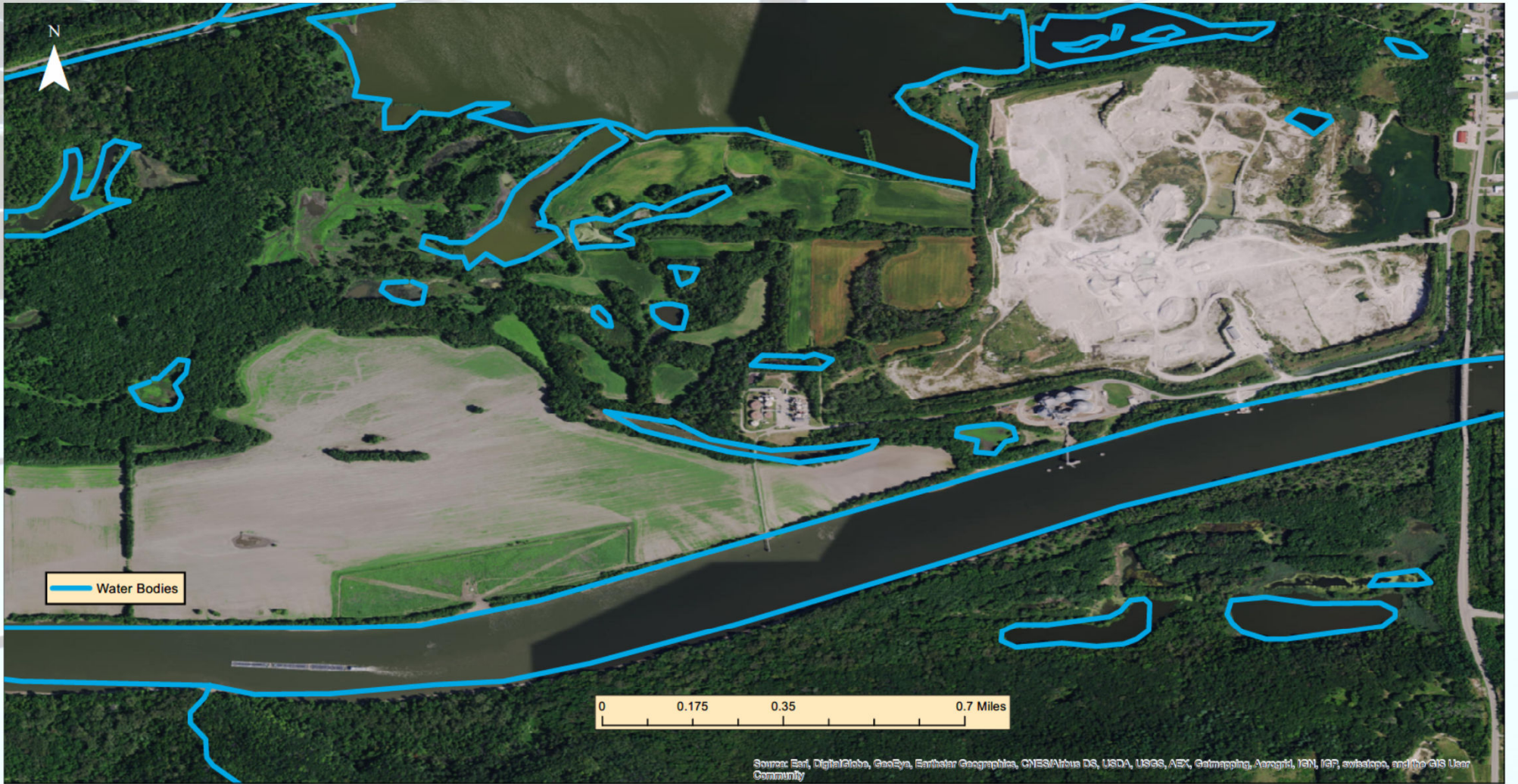
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, Aero, Galmapping, AerialGrid, IGN, IGN, swisstopo, and the GIS User Community



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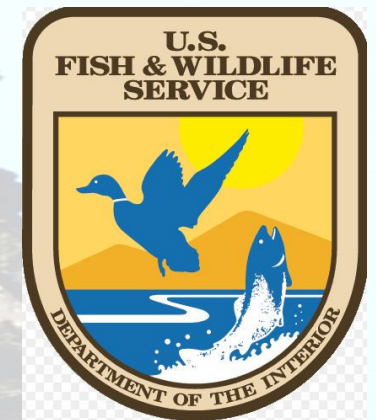
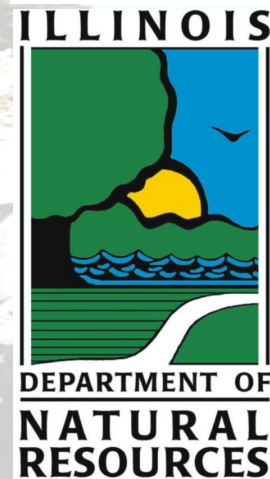


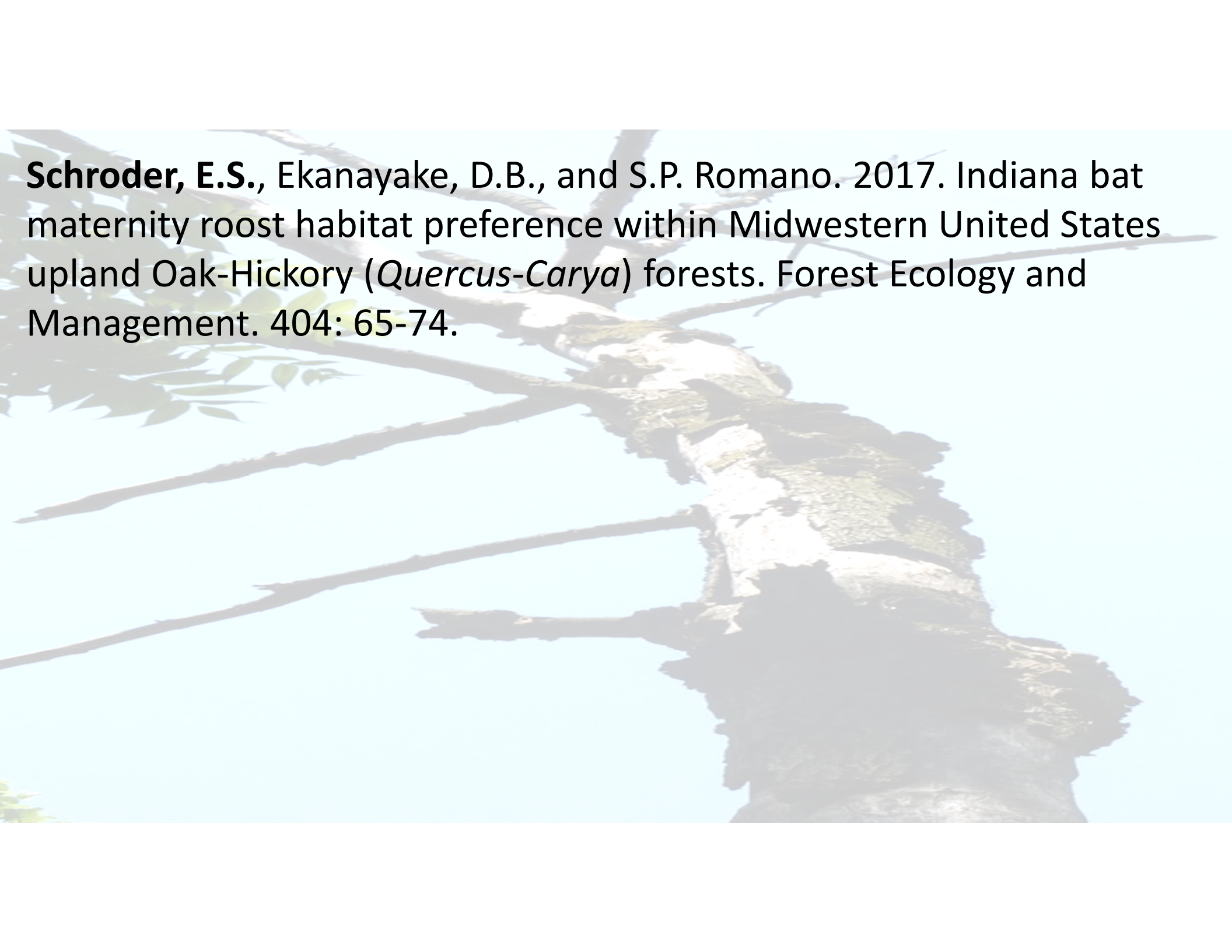
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Literature Cited

- Bergeson, S.M., Carter, T.C., Whitby, M.D. 2015. Adaptive roosting gives little brown bats an advantage over endangered Indiana bats. *Am. Midl. Nat.* 174: 321-330. <https://doi.org/10.1674/003-0031-1742.321>.
- Brack, V., Jr. 1983. The non-hibernating ecology of bats in Indiana with emphasis on the endangered Indiana bat, *Myotis sodalis*. Dissertation, Purdue University, West Lafayette, Indiana. 296 p.
- Brack, V., Jr. 2006. Autumn activity of *Myotis sodalis* (Indiana bat) in Bland County, Virginia. *Northeast Nat.* 13: 421-434. [http://dx.doi.org/10.1656/1092-6194\(2006\)13\[421:AAOMS\]2.0.CO;2](http://dx.doi.org/10.1656/1092-6194(2006)13[421:AAOMS]2.0.CO;2).
- Britzke, E.R., Harvey, M.J., Loeb, S.C. 2003. Indiana bat, *Myotis sodalis*, maternity roosts in the Southern United States. *Southeast Nat.* 2: 235-242. [http://dx.doi.org/10.1656/1528-7092\[2003\]002\[0235:1BMSMR\]2.0.CO;2](http://dx.doi.org/10.1656/1528-7092[2003]002[0235:1BMSMR]2.0.CO;2).
- Britzke, E.R., Hicks, A. C., Von Oettingen, S.L., Darling, S.R. 2006. Description of spring roost trees used by female Indiana bats (*Myotis sodalis*) in the Lake Champlain Valley of Vermont and New York. *Am. Midl. Nat.* 155: 181-187. [http://dx.doi.org/10.1674/0003-0031\[2006\]155\[0181:DOSTRU\]2.0.CO;2](http://dx.doi.org/10.1674/0003-0031[2006]155[0181:DOSTRU]2.0.CO;2).
- Businger, P., Golub, G. H. 1965. Linear least squares solutions by Householder transformations. *Numer. Math.* 7:269-276. <https://doi.org/10.1007/BF01436084>.
- Callahan, E.V. 1993. Indiana bat summer habitat requirements. M.S. Thesis. University of Missouri, Columbia. 84 pp.
- Callahan, E. V., Drobney, R. D., Clawson, R. L. 1997. Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri. *J. Mammal.* 78:818-825. <https://doi.org/10.2307/1382939>.
- Carter, T. C., Carroll, S. K., Hofmann, J. E., Gardner, J. E., Feldhamer, G. A. 2002. Landscape analysis of roosting habitat in Illinois. In: Kurta, A., Kennedy, J. (Eds.). *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin, Texas, pp. 160-164.
- Carter, T. C., Feldhamer, G. A. 2005. Roost tree use by maternity colonies of Indiana bats and northern long-eared bats in southern Illinois. *Forest Ecol. Manag.* 219:259-268. <https://doi.org/10.1016/j.foreco.2005.08.049>.
- Clark, B. K., Bowles, J. B., Clark, B. S. 1987. Summer status of the endangered Indiana bat in Iowa. *Am. Midl. Nat.* 118:32-39. <https://doi.org/10.2307/2425625>.
- Duda, R. O., Hart, P. E., Stork, D. G. 2001. *Pattern classification*, second ed. John Wiley & Sons, New York.
- Bogan, M., O'Shea, T. J., Ellison, L. (1996). Diversity and conservation of bats in North America. *Endangered Species Update*, 13(4), 5. <http://www.umich.edu/~esupdate/library/96.04-05/bogan.html> (accessed 5.11.2017).
- Foster, R., Kurta, A. 1999. Roosting ecology of the north bat (*Myotis septentrionalis*) and comparisons with the endangered Indiana bat (*Myotis sodalis*). *J. Mammal.* 80:659-672. <https://doi.org/10.2307/1383310>.
- Francis, J. G. F. 1961. The QR transformation a unitary analogue to the LR transformation—Part 1. *Comput. J.* 4:265–271. <https://doi.org/10.1093/comjnl/4.3.265>.
- Francis, J. G. F. 1962. The QR transformation—part 2. *Comput. J.* 4:332–345. <https://doi.org/10.1093/comjnl/4.4.332>.
- Gardner, J. E., Cook, E. A. 2002. Seasonal and geographic distribution and quantification of potential summer habitat. In: Kurta, A., Kennedy, J. (Eds.). *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin, Texas, pp. 9-20.
- Gardner, J. E., Garner, J. D., Hofman, J. E. 1991. Summer roost selection and roosting behavior of *Myotis sodalis*, Indiana bat, in Illinois. Illinois Natural History Survey Technical Reports, Champaign, Illinois. https://www.ideals.illinois.edu/bitstream/handle/2142/10371/inhscbv0199100000_opt.pdf?sequ (accessed 5.11.2017).
- Garner, J. D., Gardner, J. E. 1992. Determination of summer distribution and habitat utilization of the Indiana bat (*Myotis sodalis*) in Illinois. Illinois Natural History Survey Technical Reports, Champaign, Illinois. https://www.ideals.illinois.edu/bitstream/handle/2142/10287/inhscbv0199200002_opt.pdf (accessed 5.11.2017).
- Gu, M., Eisenstat, S. C. 1996. Efficient algorithms for computing a strong rank-revealing QR factorization. *SIAM J. Sci. Comput.* 17:848-869. <https://doi.org/10.1137/0917055>.
- Hammond, K.R., O'Keefe, J.M., Aldrich, S.P., Loeb, S.C. 2016. A Presence-Only Model of Suitable Roosting Habitat for the Endangered Indiana Bat in the Southern Appalachians. *PloS one*. 11:e0154464. <https://doi.org/10.1371/journal.pone.0154464>.
- Hong, Y. P., Pan, C. T. 1992. Rank-revealing QR factorizations and the singular value decomposition. *Math. Comput.* 58:213-232. <https://doi.org/10.1090/S0025-5718-1992-1106970-4>.
- Humphrey, S. R., Richter, A. R., Cope, J.B. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. *J. Mammal.* 58:334-346. <https://doi.org/10.2307/1379332>.
- Johnson, J.B., Ford, W.M., Rodrigue, J.L., Edwards, J.W., Johnson, C.M. 2010. Roost selection of male Indiana *Myotis* following forests fires in Central Appalachian Hardwoods Forests. *J Fish Wildl Manag.* 1: 11-121. <http://dx.doi.org/10.3996/042010-JFWM-007>.
- Kurta, A., Bell, G. P., Nagy, K. A., Kunz, T. H. 1989. Water balance of free-ranging little brown bats (*Myotis lucifugus*) during pregnancy and lactation. *Can. J. Zool.* 67:2468-2472. <https://doi.org/10.1139/z02-086>.
- Kurta, A., Bell, G. P., Nagy, K. A. 1990. Energetics and water flux of free-ranging big brown bats (*Eptesicus fuscus*) during pregnancy and lactation. *J. Mammal.* 71: 59-65. <https://doi.org/10.2307/1381316>.
- Kurta, A., D. King, D., Teramino, J. A., Stribley, J. M., Williams, K. J. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. *Am. Midl. Nat.* 129: 132-138. <https://doi.org/10.2307/2426441>.
- Kurta, A., Murray, S. W., Miller, D. H. 2002. Roost selection and movements across the summer landscape. In: Kurta, A., Kennedy, J. (Eds.). *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin, Texas, pp. 118-129.
- Kurta, A. 2004. Roosting ecology and behavior of Indiana bats (*Myotis sodalis*) in summer. In Vories, K. C., Harrington, A. (Eds.). *Proceedings of Indiana bat and coal mining: a technical interactive forum*. US Department of Interior, Office of Surface Mining, Alton, IL and Coal Research Center, Southern Illinois University, Carbondale, pp. 29-42. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.732.4951&rep=rep1&type=pdf#page=45> (accessed 5.11.2017).
- Lacki, M. J., Cox, D. R., Dickinson, M. B. 2009. Meta-analysis of summer roosting characteristics of two species of *Myotis* bats. *Am. Midl. Nat.* 162:318-326. <http://dx.doi.org/10.1674/0003-0031-162.2.318>.
- LaVal, R. K., Clawson, R. L., LaVal, M. L., Caire, W. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. *J. Mammal.* 58:592-599. <https://doi.org/10.2307/1380007>.
- Menzel, M. A., Menzel, J. M., Carter, T. C., Ford, W. M., Edwards, J. W. 2001. Review of the forest habitat relationships of the Indiana bat (*Myotis sodalis*). U.S. Department of Agriculture, Forest Service, Northeastern Research Station, General Technical Report NE-284. https://www.fs.fed.us/neh/newtown_square/publications/technical_reports/pdfs/2001/gtrne284.pdf (accessed 5.11.2017).
- Miller, N. E., Drobney, R. D., Clawson, R. L., Callahan, E. V. 2002. Summer habitat in northern Missouri. In: Kurta, A., Kennedy, J. (Eds.). *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin, Texas, pp. 165-171.
- Mohlenbrock, R. H. 2006. *Forest trees of Illinois*. 9th Ed. Illinois Department of Natural Resources.
- Murray, S.W., Kurta, A. 2004. Nocturnal activity of the endangered Indiana bat (*Myotis sodalis*). *J. Zool.* 262:197-206. <https://doi.org/10.1017/S0952836903004503>
- Pauli, B. P., Badin, H. A., Haulton, G. S., Zollner, P. A., Carter, T. C. 2015. Landscape features associated with the roosting habitat of Indiana bats and northern long-eared bats. *Landscape Ecol.* 30:2015-2029. <https://doi.org/10.1007/s10980-015-0228-y>.
- Perry, R.W., Brandebura, S.C., Risch, T.S. 2016. Selection of tree roosts by male Indiana bats during the autumn swarm in the Ozark Highlands, USA. *Wildl. Soc. Bull.* 40: 78-87. <https://doi.org/10.1002/WSB.624>
- Phillips S. J., Anderson, R. P., Schapire, R. E. 2006. Maximum entropy modeling of species geographic distributions. *Ecol. Model.* 190:231-259. <https://doi.org/10.1016/j.ecolmodel.2005.03.026>.
- Powers, K. E., Reynolds, R. J., Orndorff, W., Ford, W. M., Hobson, C. S. 2015. Post-White-nose syndrome trends in Virginias cave bats, 2008-2013. *J. Ecol. Nat. Environ.* 7:113-123. <https://doi.org/10.5897/JENE2015.0507>.
- Racey, P. A. 1982. Ecology of bat reproduction. In: Kunz T.H. (Eds.). *Ecology of Bats*, Springer, US, pp. 57-104. https://doi.org/10.1007/978-1-4613-3421-7_2.
- Rockey, C.D., Stumpf, J.P., Kurta, A. 2013. Additional Winter Recoveries of Indiana Bats (*Myotis sodalis*) Banded During Summer in Michigan. *North. East. Nat.* 20:N8-N13.
- Royle, J. A., Chandler, R. B., Yackulic, C., Nichols, J. D. 2012. Likelihood analysis of species occurrence probability from presence-only data for modelling species distributions. *Methods Ecol. Evol.* 3:545-554. <https://doi.org/10.1111/j.2041-210X.2011.00182.x>.
- Silvis, A., R. W. Perry and W.M. Ford. 2016. Relationships of three species of White-nose Syndrome-impacted bats to forest condition and management. US Forest Service Southern Research Station General Technical Report. SRS-214, Asheville, NC. 57p
- Sparks, D. W. 2003. How does urbanization impact bats? Dissertation. Indiana State University. Terre Haute, Indiana.
- Sparks, D. W., Ritzl, C.M., Duchamp, J.E., Whitaker, J.O. 2005. Foraging habitat of the Indiana Bat (*Myotis sodalis*) at an urban-rural interface. *J. Mammal.* 86: 713-718. [http://dx.doi.org/10.1644/1545-1542\(2005\)086\[0713:FHOTIB\]2.0.CO;2](http://dx.doi.org/10.1644/1545-1542(2005)086[0713:FHOTIB]2.0.CO;2).
- Stewart, G. W. 1984. Rank degeneracy. *SIAM J. Sci. Stat. Comp.*, 5:403-413. <https://doi.org/10.1137/0905030>.
- Timpone, J.C., Boyles, J.G., Murray, K.L., Aubrey, D.P., Robbins, L.W. 2010. Overlap in roosting habits of Indiana Bats (*Myotis sodalis*) and northern Bats (*Myotis septentrionalis*). *Am. Midl. Nat.* 163: 115-123. <http://dx.doi.org/10.1674/0003-0031-163.1.115>.
- Thogmartin, W. E., King, R. A., McKann, P. C., Szymanski, J. A., Pruitt, L. 2012. Population-level impact of white-nose syndrome on the endangered Indiana bat. *J. Mammal.* 93:1086-1098. <http://dx.doi.org/10.1644/11-MAMM-A-355.1>.
- Thomas, J. W., Anderson, R. G., Maser, C., Bull, E. L. 1979. Snags, Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service. *Agriculture Handbook* 553, pp. 60–77.
- U.S. Fish and Wildlife Service (USFWS). 2016. Revised Programmatic Biological Opinion for the Transportation Projects in the range of the Indiana bats and Northern Long-Eared Bat. U.S. Fish and Wildlife Service, Bloomington, Minnesota. <https://www.fws.gov/Midwest/endangered/section7/fhwa/pdf/BOFWHAIbatAndNLERevisedDec2016.pdf> (accessed 5.11.2017).
- U.S. Fish and Wildlife Service (USFWS). 2015. 2015 Range wide Population, Compiled by Andy King (andy_king@fws.gov), U.S. Fish and Wildlife Service, Indiana. <https://www.fws.gov/midwest/Endangered/mammals/inba/pdf/2015IBatPopEstimate25Aug2015v2.pdf> (accessed 5.11.2017).
- U.S. Fish and Wildlife Service (USFWS). 2007. Indiana Bat (*Myotis sodalis*) Draft Recovery Plan: First Revision. U.S. Fish and Wildlife Service, Minnesota. https://www.fws.gov/midwest/endangered/mammals/inba/pdf/inba_fldrtrreclpn_apr07.pdf (accessed 5.11.2017).
- Weber, T. C., Sparks, D. W. (2013). Summer habitat identification of an endangered bat, *Myotis sodalis*, across its eastern range of the USA. *J. Conserv. Plan.* 9: 53-68.
- Watrous, K. S., Donovan, T. M., Mickey, R. M., Darling, S. R., Hicks, A. C., Oettingen, S. L. V. 2006. Predicting minimum habitat characteristics for the Indiana bat in the Champlain Valley. *J. Wildl. Manag.* 70:1228-1237. [http://dx.doi.org/10.2193/0022-541X\(2006\)70\[1228:PMHCF\]2.0.CO;2](http://dx.doi.org/10.2193/0022-541X(2006)70[1228:PMHCF]2.0.CO;2).
- Whitaker, J. O., Jr., Brack, V., Jr. 2002. Distribution and summer ecology in Indiana. In: Kurta, A., Kennedy, J. (Eds.). *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Austin, Texas, pp. 48-54.
- Wolcott, K. A., Vulinec, K. 2012. Bat Activity at Woodland/Farmland Interfaces in Central Delaware. *Northeast Nat.* 19:87-89. <http://dx.doi.org/10.1656/045.019.0107>.
- Yates, M. D., Muzika, R. M. 2006. Effect of forest structure and fragmentation on site occupancy of bat species in Missouri Ozark forests. *J. Wildlife Manag.* 70:1238-1248. [http://dx.doi.org/10.2193/0022-541X\(2006\)70\[1238:EOFSAF\]2.0.CO;2](http://dx.doi.org/10.2193/0022-541X(2006)70[1238:EOFSAF]2.0.CO;2).



Questions?