Notes of the *Southeastern Naturalist*, Issue 18/3, 2019

Spring Migration Behavior of a *Perimyotis subflavus* (Tri-colored Bat) from Tennessee

Stephen T. Samoray[1,*], Shelby N. Cotham[1], and Mark W. Gumbert[1]

Abstract - On the nights of 27, 28, and 29 April 2018, we used aerial radio-telemetry to track a female *Perimyotis subflavus* (Tri-colored Bat) as she migrated a straight-line distance of 243 km from a cave in southern Tennessee to a roost in Peachtree City, GA. To our knowledge, this represents the longest and most detailed spring migration track recorded for this species and places the Tri-colored Bat in the category of regional migrant.

Introduction. In the eastern US, *Perimyotis subflavus* (Cuvier) (Tri-colored Bat) was once considered a common species throughout its range (Barbour and Davis 1969, Damm and Geluso 2008, Fujita and Kunz 1984) and therefore was less researched than federally endangered species such as *Myotis sodalis* Miller and Allen (Indiana Bat) or *M. grisescens* Howell (Gray Bat). However, populations of Tri-colored Bats have declined significantly since the discovery of White-nose Syndrome (WNS) in 2006 (Powers et al. 2015, Turner et al. 2011). WNS is caused by the fungus *Pseudogymnoascus destructans* and causes mortality in hibernating bats (Ingersoll et. al 2016). Due to drastic population declines from WNS, the Tri-colored Bat is currently petitioned for listing (USFWS 2017) under the Endangered Species Act (ESA 1973, as amended). Researchers are now attempting to answer many life-history questions about Tri-colored Bats including understanding migratory behavior.

Methods. We captured Tri-colored Bats from a solution cave in the Cumberland Plateau physiographic region of Franklin County, TN, ~5.5 km south of the city of Pelam. Biologists from Copperhead Environmental Consulting, Inc., Arnold Air Force Base, and The University of the South entered the cave on 27 April 2018 and hand-captured 2 Tri-colored Bats. They recorded biological and morphometric data (e.g., sex, age class, reproductive condition, mass, and forearm length; Table 1) and banded each bat with a Tennessee Wildlife Resources Agency (TWRA) 2.4-mm, uniquely numbered, aluminum-lipped band (Porzana Ltd, Icklesham, East Sussex, UK). They also fitted the bats with model LB-2X-T, 14-d radio-transmitters (Holohil Systems Ltd., Carp, ON, Canada) weighing 0.30 g. Researchers captured bats under US Fish and Wildlife Service permit number TE94849B-0 following the American Society of Mammologists' guidelines for the safe/proper handling

Table 1. Data collected for 2 adult female *Perimyotis subflavus* (Cuvier) (Tri-colored Bat) hand-captured and radio-tagged on 27 April 2018 from a cave in Franklin County, TN. NR = non-reproductive, RFA = right forearm, and TWRA= Tennessee Wildlife Resource Agency. Reference for wing damage index is Reichard and Kunz (2009).

Reproductive status	Mass (g)	RFA (mm)	Wing damage index	Band prefix	Band #	Frequency
NR	6.50	35.0	0	TWRA	A03130	172.152
NR	6.25	34.0	0	TWRA	A03136	172.213

[1]Copperhead Environmental Consulting, Inc., 471 Main Street, Paint Lick, KY 40461. [*]Corresponding author - ssamoray@copperheadconsulting.com.

Manuscript Editor: David Jachowski

of wild animals (Sikes 2016). To track the bats during spring migration, we used a Cessna 172 Skyhawk fitted with FAA-approved (Form FAA 337–Major Repair and Alteration) aircraft strut-mount assemblies (Advanced Telemetry Systems Inc., [ATS] 1997, Isanti, MN) with two 172-3FB 4-element ATS Yagi directional antennas (model #13886; ATS). The aerial crew consisted of a pilot and a navigator. The pilot maintained an altitude of ~455 m above ground level, while the navigator monitored the transmitter signal through an ATS programmable datalogging receiver (model R4500S) and recorded bat locations on mapping software (DeLorme Topo North America 9.0, Yarmouth, ME) approximately every 5 min. A 2-person ground crew used a 5-element Yagi directional antenna (Wildlife Materials, Inc., Murphysboro, IL) mounted to an extendable pole to track migrating bats in conjunction with the aerial team, or independent of the aerial team when the plane was grounded due to inclement weather or during refueling stops. Researchers tracked bats nightly until spring migration was considered completed. Based on past experience tracking Indiana Bats (Roby et al. 2019), we considered the spring migration completed after an individual bat foraged in the same general area for 1 full night during acceptable migration weather (i.e., temperatures above 10 °C, wind speeds <10.3 m/s, and no precipitation) and returned to a previously used roost tree. We plotted time-stamped bat location fixes in ArcGIS v10.5.1 (ESRI, Redlands, CA) to determine the distance and speed of bat flight.

Observations. Both radio-tagged bats foraged within the staging area (i.e., within 5 km; Roby et al. 2019) of the cave after release. After ~45 minutes, the bat carrying transmitter 172.213 (Bat 213) began moving south. The plane could only track 1 bat at a time; thus, the tracking crews focused on this bat for the remainder of the study. We tracked Bat 213 for 4.5 h until weather and fuel restrictions forced the plane to land. During this period, Bat 213 traveled ~90.4 km at an average speed of 19.9 km/h. On the morning of 28 April, the aerial crew flew a search pattern along the bat's last known trajectory and located her day roost in Dekalb County, AL, on the shore of Weiss Lake, a straight-line distance of 127 km from the cave. On the evening of 28 April, Bat 213 foraged in the vicinity of her roost for 40 min and then traveled southeast for a total of 124 km at an average speed of 29.7 km/h to a location ~7 km south of Peachtree City, GA. She foraged here from 23:30 h to 01:00 h. Tracking stopped at 01:00 h when Bat 213 appeared to be stationary. On the night of 29 April, the aerial crew tracked her while she foraged for 2 h, and they considered this the end point of the spring migration. We feel confident about this conclusion, as the bat was found by the ground crew on 30 April just 210 m northwest of the final foraging point recorded by the plane on 29 April. This roost was in a clump of dead hardwood leaves hanging from a branch of a 68.8-cm diameter-at-breast-height *Pinus echinata* Mill. (Short-Leaf Pine). The roost was 13 m high and ~1.5 m from the trunk of the tree. A team from the US Fish and Wildlife Service Georgia Field Office and the Georgia Department of Natural Resources conducted a follow-up survey of this tree on 7 May and determined that the bat had dropped the transmitter. Although the transmitter was not recovered, the strongest signal was from the ground ~30 m east of the roost tree. Bat 213 traveled a total straight-line distance of 243 km from the cave to this roost tree (Fig. 1).

Discussion. Fleming and Eby (2003) defined 3 categories of bat migration based on migration distance. Sedentary species move <50 km, regional migrants travel 100–500 km, and long-distance migrants may move over 1000 km. While seasonal movements of Tri-colored Bats throughout the year are unclear (Cryan and Barclay 2009, Fraser et. al 2012, Fujita and Kunz 1984), early banding studies recorded movements as far as 136 km (Griffin 1940). Other literature has classified the Tri-colored Bat as a regional migrant that visits swarming sites as early as August, hibernates over winter in a central hibernaculum,

and disperses to summer maternity colonies (Davis 1966, Fujita and Kunz 1984, Schwartz and Schwartz 2001). In a more recent study, Fraser et. al (2012) used stable isotope analysis to conclude that some male Tri-colored Bats in Ontario followed a latitudinal migration pattern more typical of long-distance migrants such as *Lasiurus cinereus* Beauvois (Hoary Bats) and *L. borealis* Müller (Eastern Red Bats). Therefore, Tri-colored Bats should be considered a partial (some, but not all, members of the species migrate) and a differential (migratory patterns vary by sex or age) migrant (Hobson and Norris 2008). However, Fraser et al. (2012) did not report migration distances; in fact, the only previously reported study to actively track a migrating Tri-colored Bat took place in Wisconsin in 2017 using ground-based telemetry only. Contact with the bat was not maintained over the entire migration track, but a final roost area was located ~44 km (straight-line distance) from the release site (J.P. White, Wisconsin Department of Natural Resources, Madison, WI, pers. comm.).

The Tri-colored Bat has been described as a weak flier (Barbour and Davis 1969) and the bat's relatively small size and wing aspect ratio are more suited for maneuverability than speed (Findley et. al 1972, Fleming and Eby 2003, Norberg and Rayner 1987). Based on this characterization, we expected that this species would migrate distances closer to the 136 km distance described by Griffin (1940). However, we found that Tri-colored Bats are capable of traveling as far as 243 km during a 2-night period at average speeds similar to those found in *Tadarida brasiliensis* Geoffroy (Brazilian Free-Tailed Bat; McCracken et. al 2016). Our data are consistent with previous findings (Davis 1966, Fujita and Kunz 1984, Griffin 1940, Schwartz and Schwartz 2001) and indicate that Tri-colored Bats should be classified as regional migrants.

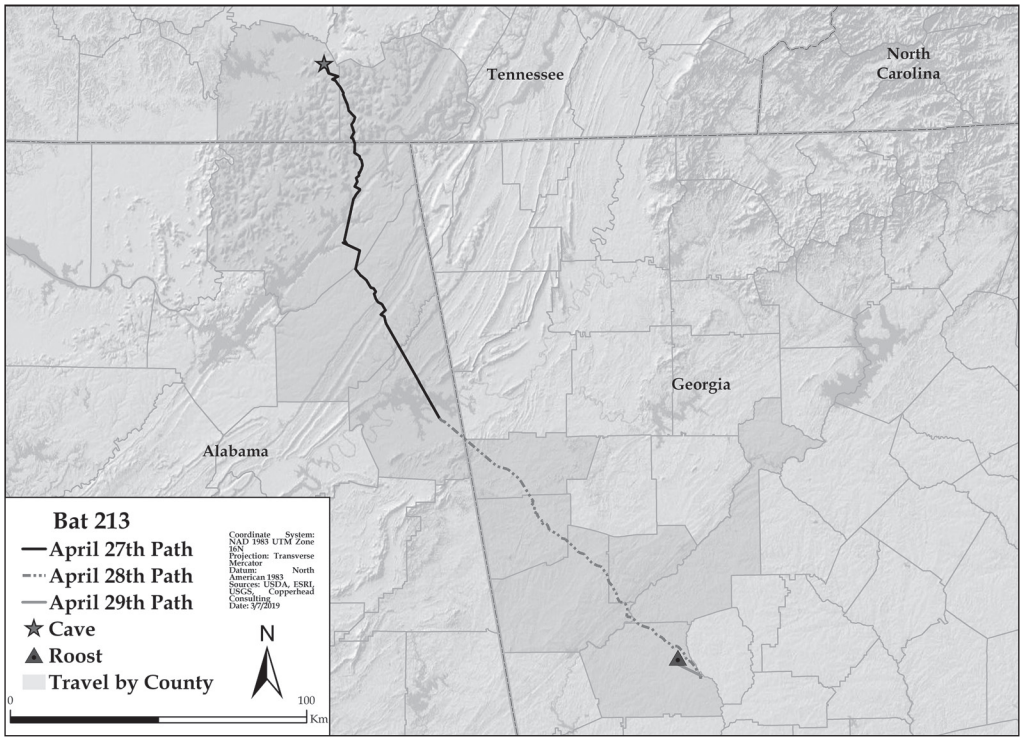

Figure 1. The migration track of Bat 213 during the nights of 27, 28, and 29 April 2018. Bat 213 was a female *Perimyotis subflavus* (Tri-colored Bat) fitted with a radio-transmitter at a cave in Franklin County, TN, and tracked 243 km to a roost near Peachtree City, GA.

Acknowledgments. This work was funded by Arnold Air Force Base with assistance from Shannon Allen (AAFB) and John Lamb (AECOM). We thank Amy Turner (The University of The South) for landowner coordination, Pete Pattavina and Laci Pattavina for field assistance in Georgia, and all the Copperhead Consulting field crews who assisted with this research. We also thank Copperhead Consulting's Piper Roby and Richard Borthwick for their editorial comments and the reviewers and editors for their time and expertise. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government.

Literature Cited

Barbour, T.W., and W.H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, KY. 286 pp.

Cryan, P.M., and R.M.R. Barclay. 2009. Causes of bat fatalities at wind turbines: Hypotheses and predictions. Journal of Mammalogy 90:1330–1340.

Damm, J.P., and K. Geluso. 2008. Use of a mine by Eastern Pipistrelles (*Perimyotis subflavus*) in east-central Nebraska. Western North American Naturalist 68:382–398.

Davis, W.H. 1966. Population dynamics of the Bat *Pipistrellus subflavus*. Journal of Mammalogy 47:383–396.

Endangered Species Act of 1973, as amended (ESA). 1973. Pub. L. No. 93-205, 87 Stat. 884. Available at http://www.fws.gov/endangered/esa-library/pdf/ESAall.pdf. Accessed 14 December 2018.

Findley, J.S., E.H. Studier, and D.E. Wilson. 1972. Morphologic properties of bat wings. Journal of Mammalogy 53:429–444.

Fleming, T.H., and P. Eby. 2003. Ecology of bat migration. Pp. 156–208, *In* T.H. Kunz and M.B. Fenton (Eds.). Bat Ecology. University of Chicago Press, Chicago, IL. 779 pp.

Fraser, E.E., L.P. McGuire, J.L. Eger, F.J. Longstaffe, and M.B. Fenton. 2012. Evidence of latitudinal migration in Tri-colored Bats, *Perimyotis subflavus*. PLOS ONE 7:e31419.

Fujita, M.S., and T.H Kunz. 1984. *Pipistrellus subflavus*. Mammalian Species 228:1–6.

Griffin D.R. 1940. Notes on the life histories of New England cave bats. Journal of Mammalogy 21:181–187.

Hobson, K.A., and D.R. Norris. 2008. Animal migration: A context for using new techniques and approaches. Pp 1–20, *In* K.A. Hobson and L.I. Wassenaar (Eds.). Tracking Animal Migration with Stable Isotopes. Elsevier Academic Press, London, UK. 268 pp.

Ingersoll, T.E., B.J. Sewall, and S.K. Amelon. 2016. Effects of white-nose syndrome on regional population patterns of 3 hibernating bat species. Conservation Biology 30:1048–1059.

McCracken, G.F, K. Safi, T.H. Kunz, D.K.N. Dechmann, S.M. Swartz, and M. Wikelski. 2016. Airplane tracking documents the fastest flight speeds recorded for bats. Royal Society Open Science 3(160398).

Norberg, U.M., and J.M.V. Rayner. 1987. Ecological morphology and flight in bats (Mammalia; Chiroptera): Wing adaptations, flight performance, foraging strategy, and echolocation. Philosophical Transactions of The Royal Society B Biological Sciences. 316:335–427.

Powers, K.E., R.J. Reynolds, W. Orndorff, W.M. Ford, and C.S. Hobson. 2015 Post-white-nose syndrome trends in Virginia's cave bats, 2008–2013. Journal of Ecology and The Natural Environment 7:113–123.

Reichard, J.D., and T.H. Kunz. 2009. White-nose syndrome inflicts lasting injuries to the wings of Little Brown Myotis *(Myotis lucifugus*). Acta Chiropterologica 11:457–464.

Roby, P.L., M.W. Gumbert, and M.J. Lacki. 2019. Nine years of Indiana bat (*Myotis sodalis*) spring migration behavior. Journal of Mammalogy advance article. DOI: 10.1093/jmammal/gyz104.

Schwartz, C.W., and E.R. Schwartz. 2001. The Wild Mammals of Missouri, 2nd Revised Edition. University of Missouri Press, Columbia, MO. 392 pp.

Sikes, R.S. and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97:663–688.

Turner, G.G., D.M. Reeder, and J.T.H Coleman. 2011. A five-year assessment of mortality and geographic spread of White-nose Syndrome in North American bats and a look to the future. Bat Research News 52:13–27.

US Fish and Wildlife Service. 2017. Petition to list Tricolored Bat under the endangered species act of 1973, as amended. Available online at https://www.regulations.gov/document?D=FWS-R5-ES-2017-0011-0001. Docket No. FWS-R5-ES-2017-0011.