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Chapter 10

Pennsylvania's Appalachian Bat Count: Trends from Summer Roost Surveys and a Comparison of Surveys Before and After the Arrival of White-nose Syndrome

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ABSTRACT

Pennsylvania's colonial-roosting bats provide a valuable ecological service as major predators of night-flying insects. A viable bat population provides economic, environmental, and recreational (viewing) benefits. Since 1989, the Pennsylvania Game Commission has organized surveys of bats at summer roost sites across the state, with the primary objective of evaluating the welfare of bat maternity colonies. These surveys primarily assess numbers of little brown myotis (*Myotis lucifugus*) and big brown bats (*Eptesicus fuscus*). From 1989 through 2014, 2,731 surveys were conducted at 420 sites from 65 of Pennsylvania's 67 counties, and one county in New Jersey. Generally, yearly counts, reported as a percentage of all-time record maximum counts, increased from 1989 through 1999, then remained fairly steady through 2010, followed by a steep decline through 2014. Counts in 2014 show an overall decline of 89.5% from all-time record maximum counts. The 2009–2014 period has been characterized by the devastating effects of White-nose Syndrome (WNS) on Pennsylvania's bats. A comparison of counts from 43 sites between the pre-WNS (2003–2008) and WNS periods (2009–2014) revealed an 87.2% decline. Likewise, nine little brown myotis roosts linked to a WNS-affected hibernaculum in central Pennsylvania, intensively monitored by Pennsylvania Game Commission staff, suffered declines ranging from 83% to 100% from 2009 to 2014. Monitoring summer bat populations is increasingly important as a way to assess the impact of this disease.

KEY WORDS — bats, citizen science, *Eptesicus fuscus*, *Myotis lucifugus*, population trends, summer roosts, White-nose Syndrome

Since 1989, the Pennsylvania Game Commission (PGC) has organized surveys of bats at summer roost sites across the state, with the primary objective of evaluating the welfare of bat maternity colonies. These surveys, originally called the Summer Bat Concentration Survey, and more recently the Appalachian Bat Count (and hereafter referred to as the Appalachian Bat Count), are carried out by volunteers, PGC staff, and staff from other state agencies and conservation organizations. Nearly all summer roost surveys have been of bats using man-made structures. Consequently, the surveys primarily assess numbers of little brown myotis (*Myotis lucifugus*) and big brown bats (*Eptesicus fuscus*), the 2 species that most commonly use man-made structures for summer roosts in Pennsylvania (Williams and Brittingham 2006). Summer roost surveys are but one valuable piece of the monitoring puzzle that also includes surveys of hibernacula, spring emergences, fall swarms, and summer netting and acoustic surveys (Loeb et al. 2015).

White-nose Syndrome (WNS) is an emerging infectious disease affecting hibernating species of bats. Caused by the fungus *Pseudogymnoascus* [=*Geomyces*] *destructans* (*Pd*; Gargas et al. 2009, Lorch et al. 2011, Minnis and Lindner 2013), biologists estimate that the disease has been responsible for the deaths of over six million bats across eastern North America. First observed in caves near Albany, New York, in the winter of 2006–2007, the disease has since spread to 29 states and 5 Canadian provinces as of September 2016 (Blehert et al. 2009; U.S. Fish and Wildlife Service 2016). Confirmation of the disease in Pennsylvania occurred during the winter of 2008–2009 (G. Turner and C. Butchkoski, Pennsylvania Game Commission, unpublished report). Mortality is associated with WNS at winter hibernacula. All significant bat hibernacula across Pennsylvania are now considered to be infected (G. Turner, unpublished report). Although bats typically clear the fungus during the summer months, the fungus can persist in the soil of caves and mines for long periods of time, potentially causing bats to become repeatedly exposed each year (Lorch et al. 2013, Hoyt et al. 2014, Langwig et al. 2015). Monitoring of summer roosts has been an essential tool to measure the impacts of the disease on bat populations (Dobony et al. 2011, Loeb et al. 2015). Here we document Appalachian Bat Count survey data from 1989–2014 and evaluate the impact of WNS by: 1) a comparison of counts before and after the arrival of WNS; and 2) an examination of counts from 9 little brown myotis roosts linked to a WNS-affected hibernaculum.

STUDY AREA

From 1989–2014, 430 sites have been registered in the PGC's Appalachian Bat Count database, and surveys have been conducted at 420 of these (Fig. 1). The 420 surveyed sites are distributed across 65 of Pennsylvania's 67 counties, with Montour and Philadelphia being the only counties not represented; a single site in Sussex County, New Jersey, near the Pennsylvania border, has also been included since 2012. Sites include 139 bat boxes,

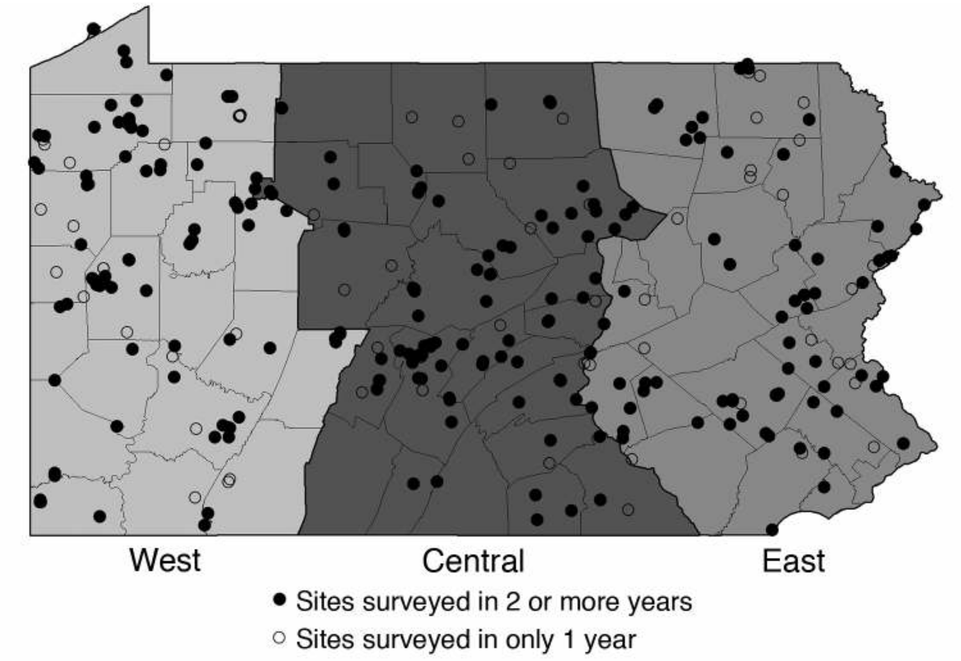

Figure 1. Locations of Appalachian Bat Count survey sites (1989–2014) and the 3 regions (West, Central, East) used for regional population trend analysis. Sites surveyed in 2 or more years contribute to the population trend analysis and are marked with solid circles. Sites surveyed in only 1 year are marked with open circles.

95 occupied houses, 65 barns, 24 bat condos (large bat houses designed to hold thousands of bats), 24 churches, 23 utility buildings, 10 bridges, 9 unoccupied houses, 2 trees, 22 other structures, and 7 sites where the structure type was not reported. Examples of other structures include garages, old schoolhouses, park pavilions, and park bath houses.

METHODS

Surveyors for Pennsylvania's Appalachian Bat Count were asked to find a structure housing bats and to conduct an external roost count. This involved counting bats from the exterior of the structure as they emerged at dusk. Surveys were conducted between late May and August when the temperature was above 15.6° C (60° F) and winds were 3 or less on the Beaufort scale (≤19 kph). Tallies of exiting bats started with the departure of the first bat and continued until bats ceased to exit. Bats returning to the site during the count were not recounted.

Although external roost counts were recommended, surveyors occasionally counted roosting bats by examining the interior of the roosting structure. We estimate that approximately 10–15% of surveys were conducted by counting roost interiors. These interior roost counts were most often conducted at bat boxes where a light could be shined into the box.

To complement summer count data, in April 2009, a spring migration study was conducted at Seawra Cave in Mifflin County. WNS was detected at the cave that winter. The original goal of this study was to radio-track female Indiana myotis (*Myotis sodalis*) to summer roosts and monitor WNS effects through the summer and following years. Trapping occurred on 13, 15, 16, and 17 April using various sizes of harp traps (Tuttle 1974). Since no suitable Indiana myotis were captured for the study, 16 female little brown myotis were radio-tagged as surrogates. Radio-tagged bats were fitted with a 0.4 g Holohil LB-2N (Holohil Systems Ltd, Ontario, Canada) transmitter with a 21-day battery. A small patch of fur was removed from the mid-dorsal region using scissors. The transmitter was then glued to the bat's skin with Skin-Bond® cement. The animals were kept active in a smooth-sided metal container until arrival of aircraft. Bats were released the same evening and followed to summer roosts with ground crews and aircraft. Eleven of the 16 were successfully found in summer roosts at 11 different locations in Juniata (n = 1), Mifflin (n = 7), Snyder (n = 2), and Union (n = 1) counties. One Mifflin County roost was in a shagbark hickory tree, the remaining roosts were in buildings. Distance from the cave to summer roosts ranged from 3.5–48.5 km. Unfortunately, the tree roost fell down before a count could be conducted. Another site was dropped in 2010 due to insignificant counts (≤15 bats) and landowner modifications to the site. The remaining 9 sites have been counted regularly since 2009, providing an opportunity to evaluate WNS effects on summer roosts.

Data Analysis

Population Trends. — Due to the extensive use of volunteers in the survey, and because of time constraints, the majority of sites were not monitored consistently across the study period (1989–2014), making direct comparisons among years challenging. For each site, we used the maximum count within each year (yearly maximum) and the maximum count over the entire study period (all-time maximum) to summarize colony size. While we considered using the maximum count in a site's first survey year or a site's average of yearly maximum counts for the analyses, these measures were not used for the following reasons: 1) the survey relies on volunteers with varying levels of experience, thus any single count may be hampered by an observer's inexperience in conducting emergence counts, unfamiliarity with the site (where the bats exit the structure, where to stand to best view the emergence, etc.), or an insufficient number of observers to watch all exit points; 2) the first year of a count may be especially susceptible to these factors, and therefore may be biased towards low counts; and 3) the average of yearly maximum counts may also be skewed by years in which these factors impacted survey results.

In a given year, we averaged yearly maximums across the set of sites surveyed that year ($AVG_{YEAR\ MAX}$) and averaged all-time maximums for those same sites ($AVG_{ALL\text{-}TIME\ MAX}$). We then divided $AVG_{YEAR\ MAX}$ by $AVG_{ALL\text{-}TIME\ MAX}$ and report it as a percentage. A value of 100% would therefore indicate that the yearly maximums for the set of sites surveyed that year were equal to the all-time maximums of that set. The percentage is graphed by year to illustrate trends.

In order to ensure that we were not including counts conducted outside of the recommended survey window, we restricted our analysis to those surveys conducted between May 15 and August 1. Sites which were surveyed in only one year of the study were excluded from further analysis.

We also examined regional population trends by classifying sites into 3 Pennsylvania regions (West, Central, East; Fig. 1) and subsequently following the same methods described for the overall population trend. In this analysis, the West region is defined to include all counties from the Ohio state line to the eastern borders of Warren, Forest, Jefferson, Indiana, Cambria, and Somerset counties. The Central region extends from the West region to the eastern borders of Tioga, Lycoming, Union, Snyder, Juniata, Perry, Cumberland, and York counties. The East region includes all counties east of the aforementioned regions to the New York, New Jersey, and Delaware state lines (Fig. 1). We present regional population trends from 2007–2014, a period in which sample sizes were sufficient to examine regional data, and also of interest because of the emergence of WNS.

The White-nose Syndrome Era. — Clinical signs of WNS, including mass mortality of bats, were first confirmed in Pennsylvania during the winter of 2008–2009 (G. Turner and C. Butchkoski, unpublished report). To analyze differences in summer roost counts of bats since confirmation of WNS, we selected counts from the 6-year period prior to WNS confirmation (pre-WNS period; 2003 through 2008) and the 6-year period after confirmation of WNS (WNS period; 2009 through 2014). We selected all sites from which we had at least 2 years of data within each of the pre-WNS and WNS periods. For sites with more than 2 years of data, we selected the most recent 2 years within each period for our analysis. Thus, each site contributed 2 counts for the pre-WNS period and 2 counts for the WNS period. These counts were averaged within their respective categories to obtain one count value for each location and sampling period. Shapiro-Wilkes normality tests were performed to determine whether parametric tests could be utilized. As all data were not normally distributed, we used the non-parametric paired-sample Wilcoxon signed-rank test to determine whether median count values significantly differed between the pre-WNS and WNS sampling periods. All statistical analyses were performed using the package IBM SPSS Statistics v20 (International Business Machines Corp., Armonk, NY) and a significance value of $\alpha = 0.05$ was adopted.

RESULTS

From 1989–2014, 2,731 surveys were conducted at 420 sites, an average of 6.5 surveys per site, including multiple surveys per year. In order to assess trends, sites that are surveyed in multiple years are necessary, and sites that are surveyed over a long period of time are especially valuable. Of the 420 sites for which we have survey data, 297 were surveyed in multiple years, including 109 surveyed 5–10 years, 21 surveyed 11–20 years, and 3 surveyed more than 20 years (Fig. 2). Counts ranged from 0–22,642 bats, but the majority of sites had fewer than 500 bats (Fig. 3).

Population Trends

Our full dataset included 2,731 surveys. From this dataset, 505 surveys were from outside of the May 15–August 1 survey window and were excluded, leaving 2,226 surveys for the trends analysis. Sample sizes ranged from 4 sites in 2000 to 168 sites in 2014 (Fig. 4). Generally, average yearly maximums ($AVG_{YEAR\ MAX}$) as a percentage of average all-time maximums ($AVG_{ALL\text{-}TIME\ MAX}$) increased from 1989 through 1999, remained fairly steady through 2010, and then declined drastically through 2014 (Fig. 4). The 2014

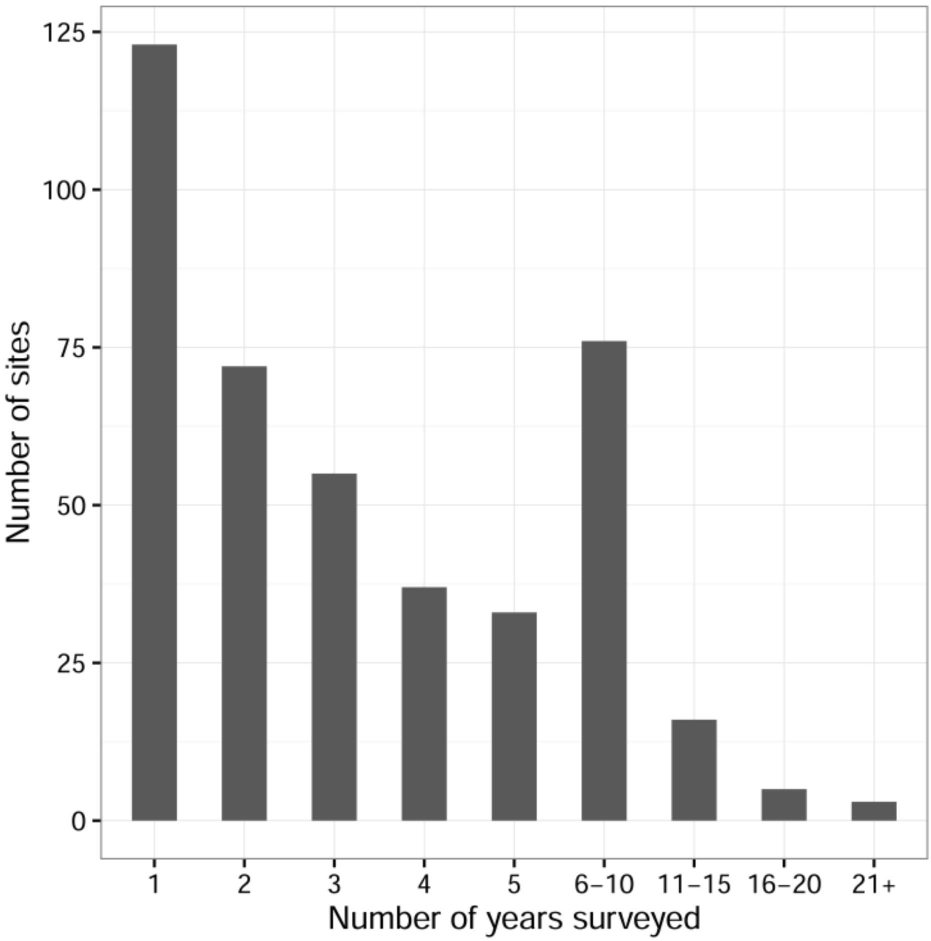

Figure 2. Distribution of sites by number of years surveyed during the study period (1989–2014).

percentage (10.5%) was the lowest on record, equivalent to an 89.5% decline from all-time record maximum counts.

Our examination of regional population trends reveals a pattern of steep declines in the Central and East regions beginning in 2007–08, whereas the West region shows increasing counts from 2007–2011, followed by a steep decline through 2014 (Fig. 5).

The White-nose Syndrome Era

Bat count data from 43 sampling sites were included in the comparison between the pre-WNS and WNS periods, and were not normally distributed for either sampling period ($P < 0.001$). Therefore, a non-parametric, pairwise analysis was performed. The median bat roost count during the pre-WNS sampling period was 411 (range 6.5–13,700) while the

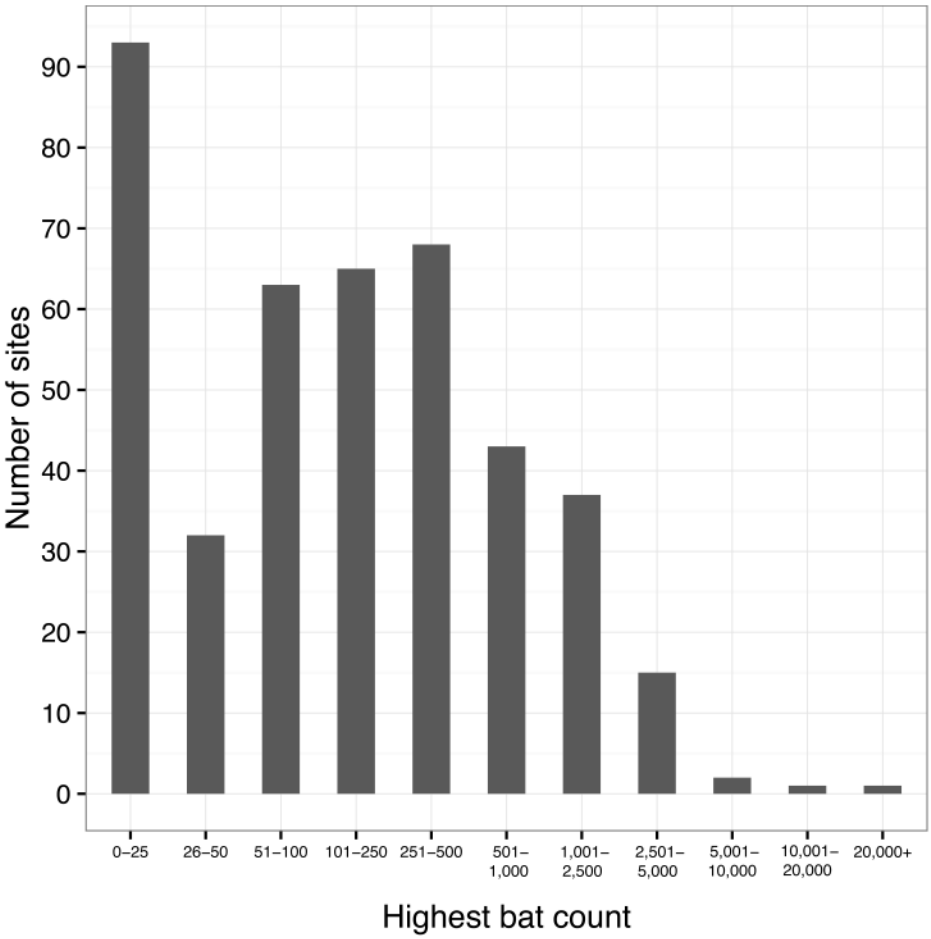

Figure 3. Distribution of sites by highest recorded bat count, 1989–2014.

median count during the WNS sampling period was 52.5 (range 0–742.5; Fig. 6). The median counts for the 2 sampling periods were significantly different ($Z = 5.518$, $P < 0.001$), representing an 87.2% decline between the 2 periods.

PGC staff monitored 9 little brown myotis roosts linked to Seawra Cave, a hibernaculum first known to be affected with WNS in the winter of 2008–2009. In 2014, 97% and 95% declines were observed in pre-volant (before pups are able to fly) and volant (after pups are able to fly) counts, respectively, when compared to 2009 (Table 1). The site declines across the 9 sites ranged from 83% to 100%, although sites 0934C1 and 0944C5 appear to have stabilized (Table 1). One of the site declines was due to the eviction of bats from the building in 2011, but even with this site excluded there were still 96% and 94% declines in pre-volant and volant counts, respectively. Big brown bats have colonized some of these sites in 2013 and 2014, making it more difficult to estimate declines in

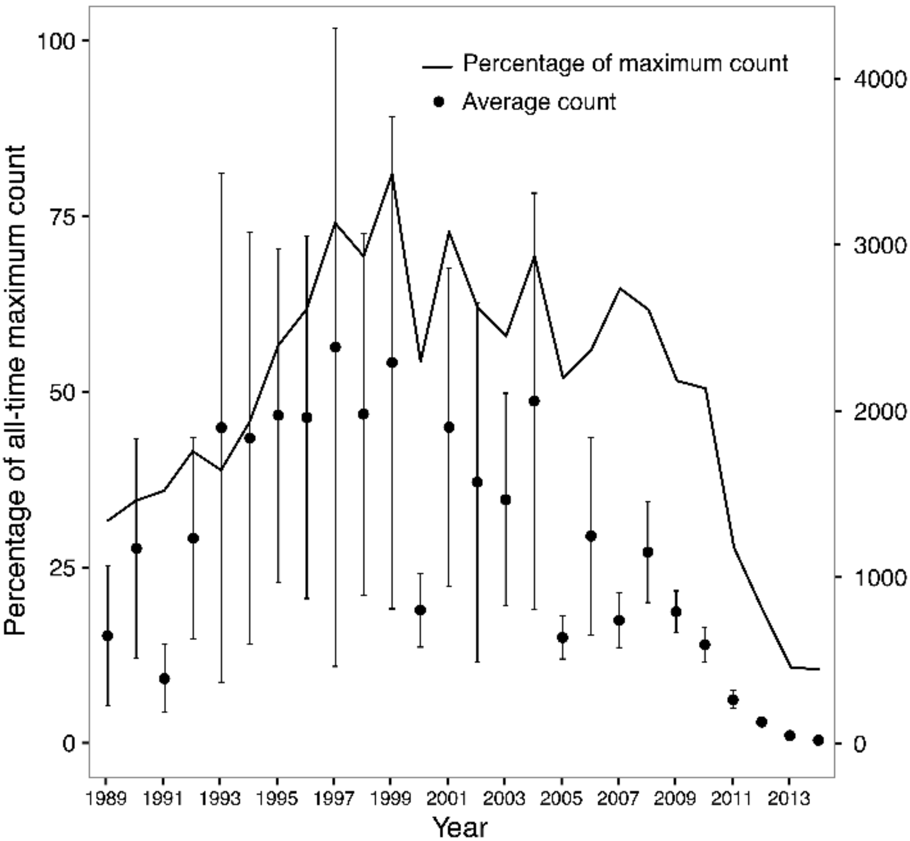

Figure 4. Percentage of yearly maximum counts in relation to all-time (1989–2014) maximum counts (yearly maximum counts averaged across the set of sites surveyed in a given year / all-time (1989–2014) maximum recorded counts for that set) and average count size by year (total bats counted / number of sites). The percentage is shown on the left axis; average count size by year is shown along the right axis. Error bars denote ± 1 standard error.

little brown myotis numbers. These declines would be even greater if we were able to obtain more accurate species counts and exclude big brown bats from the analysis.

Our data indicate that big brown bat colonies are doing better than little brown myotis colonies. Although species identification by volunteers can be problematic, of the 177 sites surveyed in 2014 with at least one previous year of count data, 111 colonies were identified as *Myotis* species (primarily little brown myotis) and 32 were big brown bats; the species was unknown at the remaining 34 sites. Counts of *Myotis* colonies have declined by 93% whereas big brown bat colonies appear more stable and have only declined by 23%.

DISCUSSION

The Appalachian Bat Count has been a valuable source of trend data for Pennsylvania's little brown myotis and big brown bats for 26 years. Emergence counts are distinctive in contrast to hibernacula surveys in that they can be conducted by volunteers and cooperators with little or no specialized training. This reliance on volunteers, or citizen science, enables the collection of large amounts of data at a reduced cost to natural resource agencies, and is a method that has been used with great success by the bird conservation community (e.g., eBird). However, a major limitation of the Appalachian Bat Count is the ability of surveyors to identify bats to species. While it is a fairly safe assumption that bats utilizing man-made structures for summer roosts in Pennsylvania are either little brown myotis or big brown bats, distinguishing between these 2 species in flight can be difficult. This is especially true for volunteers who may have little experience closely observing the 2 species in flight. This limitation has become of greater importance since the spread of

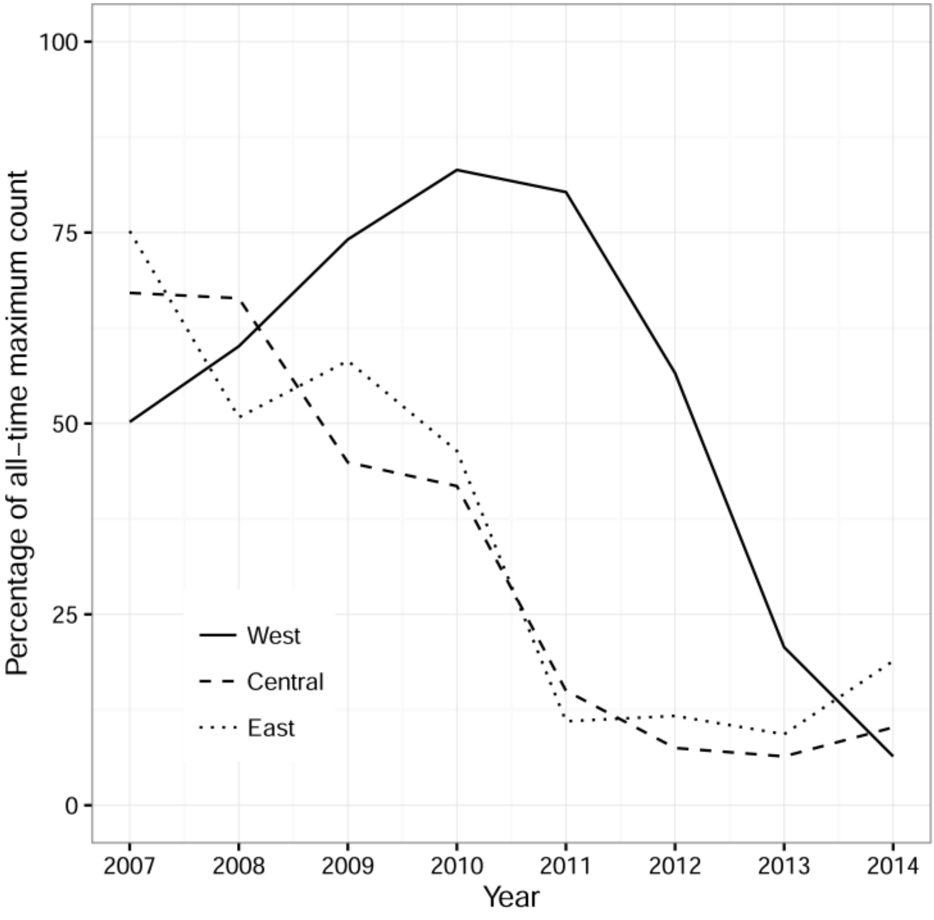

Figure 5. Percentage of yearly maximum counts in relation to all-time (1989–2014) maximum counts (yearly maximum counts averaged across the set of sites surveyed in a given year / all-time (1989–2014) maximum recorded counts for that set) by Pennsylvania region (West, Central, East). Sample sizes, listed in order by year (2007–2014), are 6, 8, 14, 27, 34, 45, 52, 64 (West); 25, 27, 32, 43, 55, 55, 58, 57 (Central); 5, 13, 8, 19, 25, 31, 30, 46 (East).

Table 1. Pre-volant and volant summer roost emergence counts (2009–2014) for 9 little brown myotis roosts located by radio tagging and tracking as they exited Seawra Cave, a Mifflin County hibernaculum documented with WNS in April 2009 (first known to be affected in winter of 2008–2009).

					Pre-volant			Volant			% Increase
Roost code	Dist. (km)[a]	County	Structure	Year	Date	Count	Change from 2009	Date	Count	Change from 2009	pre-volant volant
0944C1	3.9	Mifflin	House	2009	10-Jun	937		16-Jul	1,305		39%
				2010	25-Jun	350	-63%	15-Jul	482	-63%	38%
				2011	24-May	71	-92%	15-Jul	169	-87%	138%
				2012	07-Jun	66	-93%	18-Jul	124	-90%	88%
				2013	05-Jun	88	-91%	12-Jul	116[b]	-91%	32%
				2014	10-Jun	108	-88%	15-Jul	172[c]	-87%	59%
0955C1	21.1	Snyder	House	2009	09-Jun	931		15-Jul	1,728		86%
				2010	11-Jun	268	-71%	06-Jul	462	-73%	72%
				2011	14-Jun	64	-93%	22-Jul	131	-92%	105%
				2012	07-Jun	66	-93%	12-Jul	48	-97%	-27%
				2013	11-Jun	40	-96%	15-Jul	58	-97%	45%
				2014	28-May	0	-100%	16-Jul	10	-99%	NA
0955C2	21.9	Snyder	House	2009	02-Jun	1,514		12-Jul	2,500		65%
				2010	02-Jun	125	-92%	15-Jul	146	-94%	17%
				2011	*Roost lost,-house remodeled and bats evicted-Close (<1mi) to 0955C1*[d]						
0944C2	22.4	Mifflin	House and garage	2009	31-May	261		29-Jul	457		75%
				2010	17-Jun	76	-71%	14-Jul	136	-70%	79%
				2011	13-Jun	34	-87%	10-Jul	61	-87%	79%
				2012	26-Jun	15	-94%	16-Jul	5	-99%	-67%
				2013	05-Jun	2[e]	-99%	*No volant count conducted*			NA
				2014	*No count conducted in 2014*						
0944C3	13.3	Mifflin	House	2009	04-Jun	962		21-Jul	561[f]		-42%
				2010	24-May	138	-86%	13-Jul	186	-67%	35%
				2011	15-Jun	19	-98%	12-Jul	2	-100%	-89%
				2012	13-Jun	4	-100%	09-Aug	1	-100%	-75%
				2013	*No count conducted in 2013*						
				2014	*No pre-volant count conducted*			17-Jul	0	-100%	NA
0960C1	29.2	Union	House	2009	22-May	386		28-Jul	389[f]		1%

				2010	26-May	95	-75%	11-Jul	155	-60%	63%
				2011	14-Jun	15	-96%	12-Jul	9	-98%	-40%
				2012	12-Jun	20	-95%	17-Jul	29	-93%	45%
				2013	03-Jun	3	-99%	29-Jul	1	-100%	-67%
				2014	20-Jun	8	-98%	11-Jul	1	-100%	-88%
0934C1	15.6	Juniata	House	2009	05-Jun	3,185		20-Jul	5,110		60%
				2010	16-Jun	1,606	-50%	16-Jul	2,223	-56%	38%
				2011	02-Jun	112	-96%	13-Jul	449	-91%	301%
				2012	06-Jun	107	-97%	09-Jul	278	-95%	160%
				2013	17-Jun	143	-96%	17-Jul	208	-96%	45%
				2014	05-Jun	118	-96%	08-Jul	319	-94%	170%
0944C5	47.8	Mifflin	House	2009	29-May	462		22-Jul	694		50%
				2010	17-Jun	112	-76%	20-Jul	180	-74%	61%
				2011	09-Jun	91	-80%	18-Jul	144	-79%	58%
				2012	04-Jun	45	-90%	18-Jul	56	-92%	24%
				2013	12-Jun	32	-93%	16-Jul	71	-90%	122%
				2014	13-Jun	72	-84%	09-Jul	121	-83%	68%
0944C6	48.5	Mifflin	House and outbuildings	2009	01-Jun	1,854		14-Jul	3,104		67%
				2010	10-Jun	1,030	-44%	19-Jul	1,390	-55%	35%
				2011	09-Jun	138	-93%	12-Jul	232	-93%	68%
				2012	11-Jun	69	-96%	10-Jul	122	-96%	77%
				2013	12-Jun	85	-95%	16-Jul	73[b]	-98%	-14%
				2014	04-Jun	33	-98%	09-Jul	132[b]	-96%	300%
Totals				2009		10,492			15,848		51%
				2010		3,800	-64%		5,360	-66%	41%
				2011		544	-95%		1,197	-92%	120%
				2012		392	-96%		663	-96%	69%
				2013		393	-96%		527	-97%	34%
				2014		331	-97%		755	-95%	128%

[a] Distance from hibernaculum (Seawra Cave).
[b] Site now a mix of little brown myotis and big brown bats.
[c] Site now contains mostly big brown bats.
[d] Roost lost, house remodeled and bats evicted. Site is 0.8 km from 0955C1. It is likely that some of the colony moved to 0955C1. Excluding this roost from the analysis still documents 96 and 94% declines in pre-volant and volant counts, respectively.
[e] Two big brown bats.
[f] Colony may have begun to disperse.

WNS, as little brown myotis have suffered greater declines from the disease than big brown bats, as noted in summer netting capture trends (C. Butchkoski, unpublished report), and the latter species now comprises a larger portion of the total bat count.

White-nose Syndrome has caused declines in little brown myotis and big brown bats associated with winter hibernacula in Pennsylvania (Turner et al. 2011). The results of the Appalachian Bat Count corroborate these declines, and demonstrate that winter mortality has affected summer population levels. This finding is true whether examining 9 sites linked to a known WNS-affected hibernaculum or by looking at bats from 43 summer roosts whose winter hibernacula are unknown. The 9 summer roost sites linked to Seawra Cave reveal a pattern of major (~90%) declines within 2 years of the appearance of the disease at the associated hibernaculum. Regional differences in population declines show the

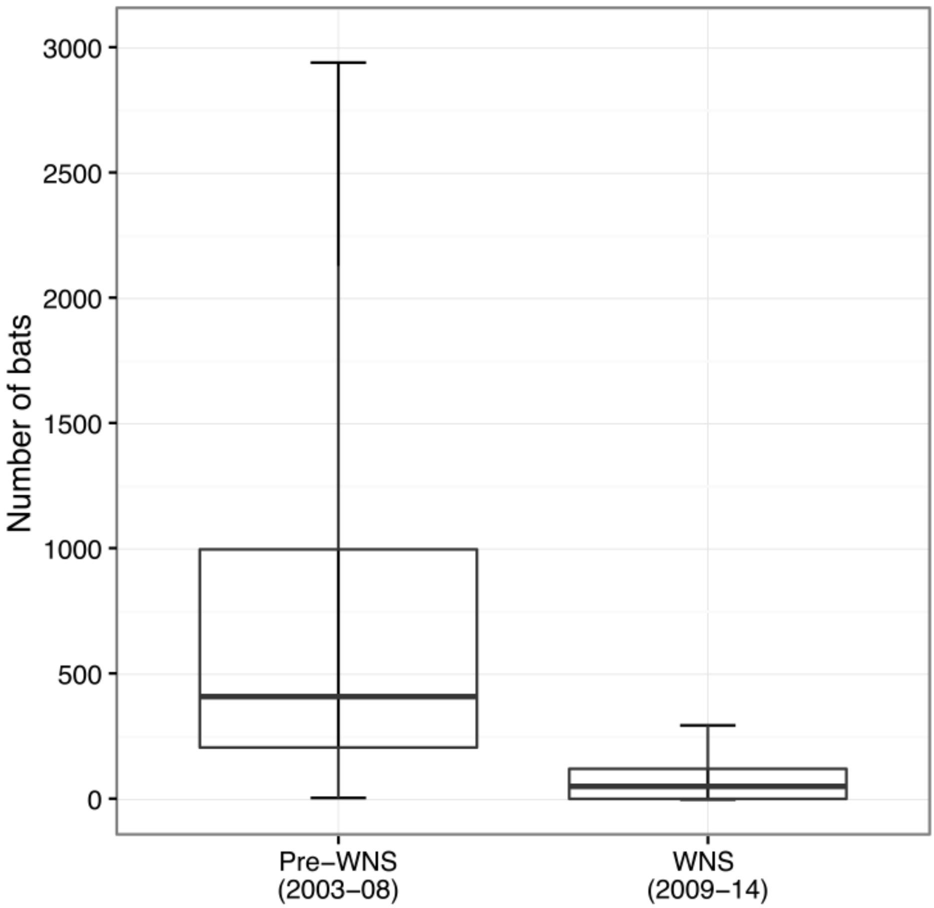

Figure 6. Average number of bats counted over the most recent 2 surveys in each study period for 43 sites (see methods). Boxes represent the median with one quartile of the distribution below and above the mean. Whiskers extend to the 10th and 90th percentiles. The full ranges of data (7–13,700 for pre-WNS and 0–743 for WNS) are not shown to allow for clear presentation of the 10th to 90th percentiles.

same pattern. Whereas WNS was first confirmed in most central and eastern Pennsylvania counties during the winters of 2008–2009 and 2009–2010, most western Pennsylvania counties were not confirmed until the winters of 2010–2011 or 2011–2012. The timing of major declines at summer bat roosts corresponds closely with the timing of the disease spread (Fig. 5).

Despite the overall declines of little brown myotis since 2009, we have noted colonies that have stabilized or increased over the past 2–3 years. In 2015, for example, 845 little brown myotis were counted emerging from 7 bat boxes mounted side by side at a Huntingdon County site. Although down from a high of 2,787 bats in 2010, counts there have increased each year since 2012, when the lowest yearly count of 478 bats was recorded. Similarly, 632 little brown myotis were counted emerging from a building in Pike County in 2015. This count was close to the 657 counted in 2014, and up from 335 in 2012. Sites like these run counter to the overall trend. Additional studies could help in understanding where these bats are hibernating, and whether the colony size is maintained through greater survival and reproduction or through consolidation of bats from other colonies. Careful monitoring and management of these sites is also needed to ensure that they remain viable roosting locations (Fenton 1997).

Both little brown myotis and big brown bats roost in groups which are usually maternity colonies comprised of females with newborn pups (Merritt 1987). These roosts are often in buildings making it relatively easy for volunteer participation in these essential surveys. However, the behavior of using man-made structures is not without conflict. Bats can get into living spaces where they are not welcome. This increases the risk of humans and pets coming into contact with sick bats (Constantine 1979), and bats may need to be evicted when such conflicts arise.

For the do-it-yourselfer, there are resources available. The Pennsylvania State University Cooperative Extension's publication "*A Homeowner's Guide to Northeastern Bats and Bat Problems*" (Williams and Brittingham 2006) is available as a free download (Penn State Extension 2016). It provides basic information and timing on how to evict bats from a structure as well as artificial roost (bat box) plans to assist in keeping the colony in the area for insect control. The PGC also has updated bat box designs on its website (www.pgc.pa.gov). For participants in the Appalachian Bat Count, bat houses may be provided as supplies are available. Conducting counts of the colony is the first step in working with bat boxes to identify the size (bat capacity) of artificial roost needed. Persons interested in participating in Pennsylvania's Appalachian Bat Count should visit the PGC website for protocols and data forms, or email the PGC at pgccomments@pa.gov.

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