

Chapter 11

Impacts of White-nose Syndrome on Bats in the Delaware Water Gap National Recreation Area

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ABSTRACT

Since the emergence of White-nose Syndrome (WNS) in February 2006, populations of cave hibernating bats have experienced severe declines throughout eastern North America. We used mist-netting surveys to assess the potential impacts of WNS on the abundance, distribution, and demographic characteristics of bats in the Delaware Water Gap National Recreation Area by comparing capture data from 2013–14 with capture data from the park's last comprehensive bat survey in 1997–98. We captured 85 bats of 6 species in 38 nights of netting over 2013–14. A negative binomial regression model revealed that capture rates (bats/unit of net effort) of little brown myotis (*Myotis lucifugus*) and northern long-eared myotis (*M. septentrionalis*) declined significantly ($P \leq 0.001$) from 1997–98 to 2013–14. In contrast, capture rates of big brown bats (*Eptesicus fuscus*) increased significantly ($P \leq 0.001$) over this period. Our results are consistent with similar studies conducted elsewhere in the northeastern U.S. and suggest that populations of *Myotis* species and tri-colored bats (*Perimyotis subflavus*) are now rare with restricted distributions in the park. In contrast, big brown bats have increased and remain common and widely distributed in the park. We found evidence of decreased reproductive success in little brown myotis and northern long-eared myotis, but increased reproductive success for big brown bats.

KEY WORDS — bats, capture rates, Delaware Water Gap National Recreation Area, *Eptesicus fuscus*, mist netting, *Myotis lucifugus*, *Myotis septentrionalis*, *Perimyotis subflavus*, reproduction, White-nose Syndrome

Since 2006, large die-offs and subsequent population declines of cave hibernating bats have been reported due to the emergence of a new infectious disease in North America, White-nose Syndrome (WNS). WNS has been confirmed in 29 U.S. states as well as 5 Canadian provinces, and it is known to infect all 6 cave hibernating bat species found in Pennsylvania and New Jersey: little brown myotis (*Myotis lucifugus*), northern long-eared myotis (*M. septentrionalis*), eastern small-footed myotis (*M. leibii*), Indiana myotis (*M. sodalis*), tri-colored bat (*Perimyotis subflavus*), and big brown bat (*Eptesicus fuscus*) (U.S. Fish and Wildlife Service 2016).

Species within the genus *Myotis* and tri-colored bats have shown the greatest WNS-related mortality in the eastern United States (Dzal et al. 2011, Powers et al. 2015), and several studies have documented significant declines in the capture of these species during summer mist-netting surveys. For example, Francel et al. (2012) documented a 63–90% decline in mist-net capture rates of *Myotis* species and tri-colored bats in West Virginia following the onset of WNS. At Surry Mountain Lake, New Hampshire, Moosman et al. (2013) documented a 98% decline in summer capture rates of both little brown and northern long-eared myotis. Similarly, Reynolds et al. (2016) documented a 95.1% decline in summer captures of northern long-eared myotis in western Virginia. In contrast, big brown bat populations appear to be stable or increasing in WNS-infected areas, despite their vulnerability to the WNS fungus. For example, capture rates of big brown bats increased by 17% during post-WNS mist-netting surveys in West Virginia (Francel et al. 2012), and mist-netting surveys in New Hampshire revealed no change in summer captures of big brown bats between 2005–09 (prior to the detection of WNS, hereafter “pre-WNS”) and 2010–11 (after the detection of WNS, hereafter “post-WNS”) surveys (Moosman et al. 2013).

There is also evidence to suggest that WNS may negatively impact the timing of reproductive events (e.g., pregnancy and lactation) in bats that have survived WNS infection (Frick et al. 2010). While female bats emerge from hibernation in better body condition than males (Jonasson and Willis 2011), WNS-affected females may not have the fat reserves to meet the high energy demands required for normal fetal development, ultimately delaying parturition. Supporting this hypothesis, Francel et al. (2012) found delayed peaks in pregnancy for female little brown myotis and tri-colored bats in West Virginia in the years following the onset of WNS. They speculated that females in poor physical condition may be unable to care for their young upon giving birth, contributing to juvenile mortality. Also consistent with this hypothesis, Reynolds et al. (2016) reported a significant decline in the proportion of juvenile northern long-eared myotis captured after the appearance of WNS.

In 1997 and 1998 (pre-WNS), Dr. Karen A. Campbell of Albright College, Reading, PA, conducted an inventory of bats within the Delaware Water Gap National Recreation Area (DWGNRA) (K. A. Campbell, Albright College, unpublished report). She conducted mist-netting surveys at 19 sites within the park, 13 in Pennsylvania and 6 in New Jersey, to assess potential impacts of trail development on the foraging and roosting habitat of the federally-endangered Indiana myotis. Over the 2-year period, Campbell captured 156 bats representing 5 species: 52 little brown myotis, 51 northern long-eared myotis, 39 big brown bats, 12 tri-colored bats, and 2 eastern red bats.

More recently, studies were conducted within parts of the DWGNRA to evaluate these areas for the presence of Indiana myotis and the Pennsylvania state-threatened eastern

small-footed myotis. In July 2004, Bat Conservation and Management, Inc., (BCM) of Carlisle, PA, mist netted at 8 sites within the DWGNRA along the right-of-way for Columbia Gas Transmission Corporation's Line 1278 Pipeline (J. Chengler, Bat Conservation and Management, Inc., unpublished report). They captured 168 bats at these 8 sites, including 111 little brown myotis, 23 big brown bats, 12 northern long-eared myotis, 5 eastern red bats, 3 tri-colored bats, 2 hoary bats, and 2 eastern small-footed myotis. In the fall of 2005, BCM used mist nets and harp traps at Cold Air Cave, at the southern end of the DWGNRA, to assess the use of the cave and associated talus as a winter hibernaculum (J. Chengler, unpublished report). They captured 61 little brown myotis, 46 tri-colored bats, and 23 northern long-eared myotis. In 2009, Sanders Environmental, Inc., sampled 14 sites within the DWGNRA along the proposed right-of-way and access roads of PPL Electric Utilities' Susquehanna to Roseland 500 kV Transmission Line Project (C. Sanders, Sanders Environmental, Inc., unpublished report). They captured 113 bats at these 14 sites, the majority of which were little brown ($n = 39$) and northern long-eared myotis ($n = 30$). Taken together, these studies indicate that little brown myotis, northern long-eared myotis, and tri-colored bats were once common species within the DWGNRA.

White-nose Syndrome was first confirmed in the DWGNRA near Pahaquarry Creek (Warren County, NJ) in February 2009, making it the first national park unit in the United States to document WNS (L. Hilaire, National Park Service, personal communication). Prior to our study, little was known about the effects of WNS on summer bat populations in the DWGNRA, and it was unclear whether these populations were as impacted by WNS as populations in many other areas of the eastern United States (Turner et al. 2011, Francel et al. 2012, Moosman et al. 2013, Reynolds et al. 2016). To address these questions, we performed mist netting at the 19 sites surveyed by Campbell in 1997–98. We then compared our 2013–14 capture data (post-WNS) with Campbell's 1997–98 capture data (pre-WNS). We hypothesized that post-WNS capture rates of *Myotis* species and tri-colored bats would decline and that these species would now have more restricted distributions in the park. In addition, we hypothesized that capture rates of big brown bats, which appear to be less susceptible to WNS infection (Brooks 2011, Ford et al. 2011, Francel et al. 2012, Frank et al. 2014), would remain the same or increase between pre- and post-WNS surveys, and that this species would remain widely distributed in the park. Finally, we assessed possible demographic changes following the appearance of WNS in the park. We assessed impacts on reproduction by comparing captures of pregnant and lactating females, and the ratio of juveniles to adult females, between Campbell's 1997–98 surveys and our 2013–14 surveys. In addition, because WNS appears to exacerbate the rapid depletion of winter fat reserves in males more than females (Jonasson and Willis 2011, Johnson et al. 2014), we predicted that the ratio of adult males to adult females in our captures would be lower in 2013–14 than it had been in 1997–98.

STUDY AREA

Our study was conducted in the Delaware Water Gap National Recreation Area, located along the middle stretch of the Delaware River, where it forms the border between Pennsylvania and New Jersey (Fig. 1). The DWGNRA encompasses 28,000 ha (70,000 acres), making it the largest National Park Service natural area between Maine and Virginia (National Park Service 2015). Forests of the DWGNRA were predominantly second

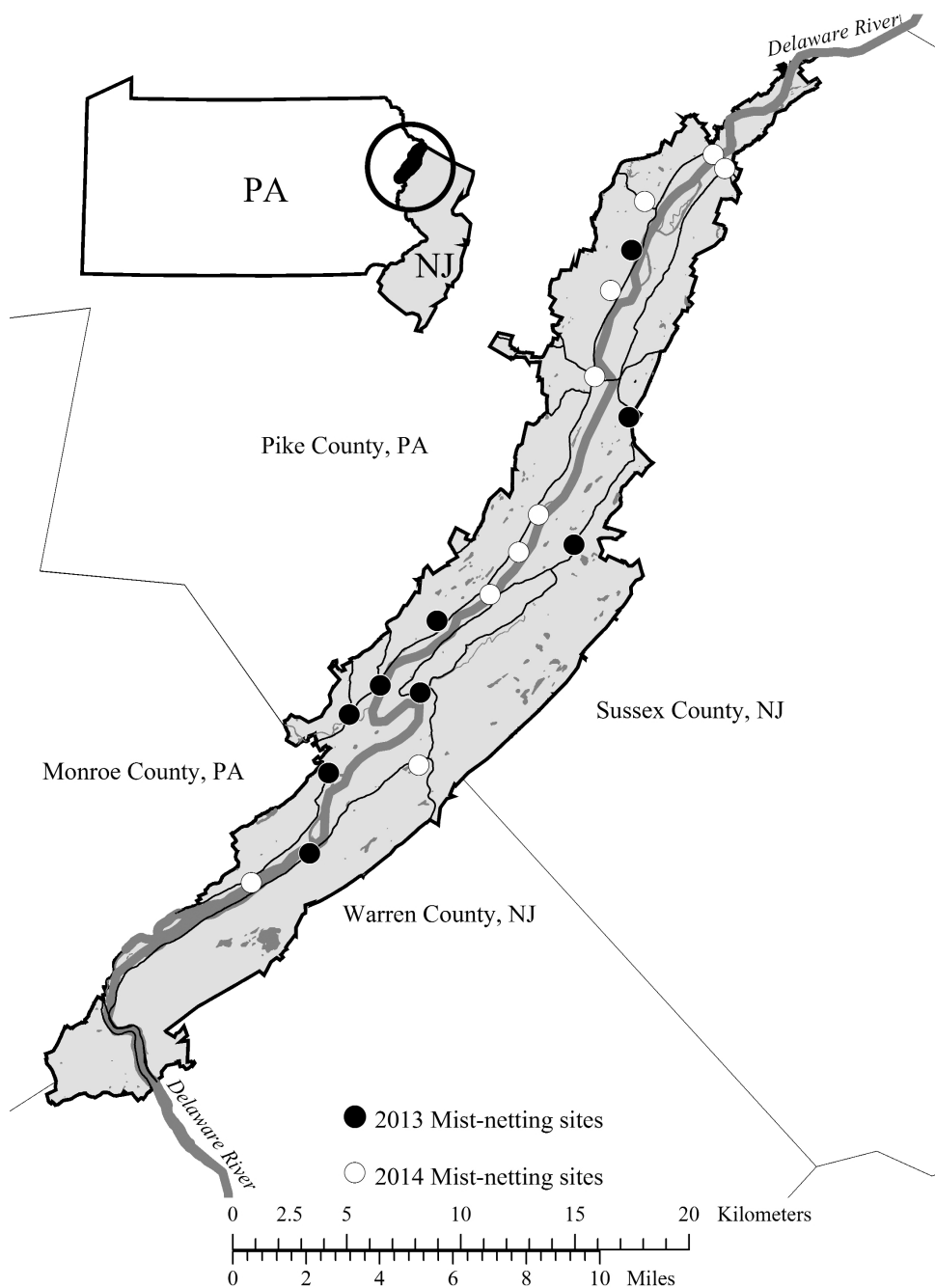


Figure 1. Locations of 2013–14 (post-WNS) mist-netting surveys conducted in the Delaware Water Gap National Recreation Area. These sites were also surveyed by Campbell in 1997–98.

growth, mixed hardwood communities (National Park Service 2015). Upland forests along the Pocono Plateau (PA) and Kittatinny Ridge (NJ) were dominated by chestnut oak (*Quercus montana*), white oak (*Q. alba*), and northern red oak (*Q. rubra*), with an understory of blueberry (*Vaccinium corymbosum*) and mountain laurel (*Kalmia latifolia*) (National Park Service 2015). Numerous small streams fed into the Delaware River and were lined with mature stands of eastern hemlock (*Tsuga canadensis*), eastern white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), yellow birch (*Betula lutea*), and American beech (*Fagus grandifolia*) (National Park Service 2015). Lowland forests within the floodplain of the Delaware River contained American sycamore (*Platanus occidentalis*), silver maple (*A. saccharinum*), and river birch (*B. nigra*), with black walnut (*Juglans nigra*) and hickories (*Carya spp.*) common in the valley lowlands (National Park Service 2015).

METHODS

We conducted mist-netting surveys in the DWGNRA in 2013–14 in an attempt to replicate mist-netting surveys performed by Karen Campbell in 1997–98 (K. A. Campbell, unpublished report). Campbell surveyed 13 sites on the Pennsylvania side of the Delaware River (2 in Monroe County and 11 in Pike County) and 6 sites in New Jersey (4 in Sussex County and 2 in Warren County) over the 2-year period. Campbell's sites were selected based on habitat suitability for the Indiana myotis, and she put particular emphasis on locations along a proposed multi-use River Valley Trail (now known as the McDade Recreational Trail), which was being developed along the Pennsylvania side of the Delaware River. Campbell surveyed each site in late spring (27 May–5 June) and again in mid-summer (17–29 July), with the exception of 4 sites (Tom's Creek, Little Bushkill Creek, Raymondskill Creek, and Big Flatbrook Creek) where high water levels had precluded netting in late spring. At each site, Campbell deployed between 2 and 5 triple-high and double-high net sets, and she began her surveys at sunset and netted for approximately 6 hours or until the temperature dropped below 10° C (K. A. Campbell, personal communication).

In 2013–14, we revisited each of Campbell's 19 mist-netting sites to conduct follow-up surveys. We were unable to match the exact dates of Campbell's surveys, but we followed her approach of netting each site once in late spring or early summer (15 May–29 June) and again in mid- to late summer (1 July–15 August). We used a random sequence generator (www.random.org/sequence/) to determine the sampling sequence for the 19 sites, and we sampled 9 of Campbell's sites in 2013 and the remaining 10 in 2014 (Fig. 1). We also used Campbell's field notes to replicate her net placement and configuration as closely as possible, while ensuring that nets were placed perpendicular to potential flight corridors (e.g., farm roads, trails, creeks), and in locations where we expected the tree canopy and surrounding vegetation to funnel bats into the nets. At each site, we deployed 1 triple-high net set (Bat Conservation and Management, Inc., Carlisle, PA) consisting of 3 vertically stacked mist nets (Avinet, Inc., Dryden, NY, 38 mm mesh, 2.6 m high, 4 shelves) along with 1 or 2 single-high mist nets. The width of the mist nets used (6 m, 9 m, or 12 m) depended upon the width of the trail or stream being sampled. We followed the U.S. Fish and Wildlife Service 2013 Revised Range-wide Indiana Bat Summer Survey Guidelines (U.S. Fish and Wildlife Service 2013), which called for surveys beginning at sunset and

lasting for a minimum of 5 hours, or until the temperature dropped below 10° C. We checked each net at least every 10 minutes to ensure that captured bats did not become further entangled or chew their way out of the nets.

For each captured bat, we recorded species, sex, age (based upon epiphyseal ossification), and reproductive status (males: scrotal or non-reproductive and females: lactating, post-lactating, pregnant, or non-reproductive), following guidelines in Brunet-Rossinni and Wilkinson (2009) and Racey (2009). We also recorded body mass (g) and the length of the forearm (mm), hind foot (mm), ear pinna (mm), and tragus (mm). We took photographs of each bat to serve as documentation and for confirmation of species identifications. During instances in which multiple bats were captured simultaneously, we placed each bat in a separate cloth bag until it could be processed. At the end of each night, nets and other equipment were decontaminated following the U.S. Fish and Wildlife Service (2012) protocol established to prevent the spread of WNS. Disposable gloves were worn over leather gloves and discarded and replaced between individual bats. Nets and cloth holding bags were placed in a hot water bath (>50° C) for at least 20 minutes after each night of netting. All other equipment and non-porous surfaces (e.g., scales, rulers, processing table) were cleaned using Lysol disinfectant wipes after each bat.

To account for variation in the number and size of nets used, and variation in the length of nightly sampling, we standardized sampling effort as units of effort where 1 unit of effort = 1 m² of net in place for 1 hour (Pennsylvania Game Commission 2016). Statistical analyses were performed with SPSS version 21.0 (IBM Corp., Armonk, NY), using $\alpha = 0.05$. We compared pre-WNS and post-WNS capture rates relative to netting effort using generalized linear model procedures. Given the nature of the mist-netting capture data (counts), we developed Poisson and negative binomial models using the numbers of captures for each bat species as the response variable, with survey date as the sampling unit and survey period (pre- or post-WNS) as the predictor variable. To account for differences in sampling effort across nights and survey periods, netting effort each night ($\log_{10}$ net area $\times$ hours) was included as an offset variable (Field 2009). We then compared Poisson and negative binomial models for each bat species using Akaike's Information Criterion (AIC). Campbell's field notes were not available for 5 nights in 1997–98, so we estimated the length of the survey period on these nights using historic hourly temperature records from the Avoca Airport in Wilkes-Barre, PA (<http://www.wunderground.com/history/airport/KAVP/2014/2/10/DailyHistory.html>), assuming that netting was halted when temperatures dropped below 10° C.

Because our sample sizes were small and violated the assumptions of a traditional chi-square test, we used a Fisher's exact test (Field 2009) to compare pre- and post-WNS bat captures by sex (adult male vs. adult female) and also to compare pre- and post-WNS ratios of the numbers of juveniles to adult females captured during the mid- to late summer netting period (1 July–15 August), when young were volant.

RESULTS

In 2013–14, we conducted mist-netting surveys on 38 nights (182.49 hours) at 19 sites, with 98 mist nets deployed and a total of 21,363.6 units of effort (m² net $\times$ hours). We captured 85 bats and 6 species: big brown bat ($n = 71$, 83.5% of captures), eastern red bat (6, 7.1%), little brown myotis (4, 4.7%), eastern small-footed myotis (2, 2.4%), northern

long-eared myotis (1, 1.2%), and tri-colored bat (1, 1.2%). Of the 85 bats captured, 9 escaped from our nets before all data could be collected. We were able to determine sex and species for 6 of the 9 individuals (5 big brown bats and 1 eastern red bat) before they escaped and these were included in the calculations of capture rates and in the totals of males and females; the other 3 escaped bats (2 big brown bats and 1 eastern red bat) were included in the species totals but not in the totals of males and females. Species richness was highest at Big Flatbrook Creek (NJ) and Raymondskill Creek (PA), with 3 species captured at each site (Table 1). Campbell conducted mist-netting surveys on 43 survey nights (249 hours) at the 19 sites, with 160 mist nets deployed for a total of 48,993 units of effort ($\text{m}^2 \text{ net} \times \text{hours}$). She captured 156 bats and 5 species: little brown myotis ($n = 52$, 33.3% of captures), northern long-eared myotis (51, 32.7%), big brown bat (39, 25.0%), tri-colored bat (12, 7.7%), and eastern red bat (2, 1.3%). Species richness in 1997–98 was highest at Little Bushkill Creek (PA), with 5 species captured (Table 1).

For all species, the negative binomial model generated a lower AIC value than the Poisson model. Therefore, we examined the effect of survey period (pre- and post-WNS) on capture rates using separate negative binomial regression models for each species. There was a decline in capture rates of little brown myotis ($\chi^2 = 14.38$, $P \leq 0.001$) and northern long-eared myotis ($\chi^2 = 11.52$, $P \leq 0.001$) from 1997–98 to 2013–14, whereas there was an increase in capture rates of big brown bats ($\chi^2 = 10.51$, $P \leq 0.001$) between WNS periods (Fig. 2). Capture rates of tri-colored bats ($\chi^2 = 0.53$, $P = 0.053$) and eastern red bats ($\chi^2 = 3.20$, $P = 0.074$) did not differ between WNS periods (Fig. 2). Because eastern small-footed myotis were only captured during post-WNS surveys, and only on a single night, changes in their capture rate between survey periods could not be assessed. No Indiana myotis, hoary bats, or silver-haired bats were captured during either 1997–98 or 2013–14 netting surveys.

Only one pregnant female was captured during each survey period (pre- and post-WNS). Also, there were only 11 lactating females (10 big brown bats and 1 little brown myotis) captured during 1997–98 surveys, and 12 lactating females (11 big brown bats and 1 tri-colored bat) captured during 2013–14 surveys. The ratio of juveniles to adult females in the late-season netting period was greater in 2013–14 than 1997–98 for big brown bats ($P = 0.006$) (Table 2). There was no difference in the number of adult males and adult females captured between 1997–98 and 2013–14 surveys for big brown bats ($P = 1.000$) (Table 3). The small post-WNS sample sizes for all species except big brown bats prevented statistical comparisons for juvenile recruitment and adult sex ratios (Table 3).

DISCUSSION

In 2013–14, we captured 6 of the 9 bat species expected to be found within the Delaware Water Gap National Recreation Area; we did not capture Indiana myotis, hoary bats, or silver-haired bats, although contemporaneous acoustic monitoring did detect hoary bats and silver-haired bats.

Capture rates and species composition changed dramatically between pre-WNS and post-WNS periods. While little brown myotis ($n = 52$, 33.3% of total captures) and northern long-eared myotis ($n = 51$, 32.7%) comprised the majority of Campbell's captures in 1997–98 (pre-WNS), capture rates (bats/1,000 units of effort) of these 2 species declined from 1.061 to 0.187 for little brown myotis and from 1.041 to 0.047 for northern long-

Table 1. Number of bats captured during mist netting at 19 sites in the Delaware Water Gap National Recreation Area in 1997–98 (pre-WNS) and 2013–14 (post-WNS), by site and species.

Site	Years	Big brown bat	Eastern red bat	Little brown myotis	Northern long- eared myotis	Eastern small- footed myotis	Tri- colored bat
Big Flatbrook Creek, NJ	1997–98	2	0	2	0	0	0
	2013–14	0	0	1	1	0	1
Birchenough, NJ	1997–98	2	0	2	1	0	3
	2013–14	0	0	0	0	0	0
Flatbrook, NJ	1997–98	0	0	3	0	0	0
	2013–14	2	0	0	0	0	0
Pahaquarry Creek, NJ	1997–98	0	0	0	0	0	1
	2013–14	0	0	0	0	0	0
Watergate, NJ	1997–98	0	0	2	1	0	0
	2013–14	7	0	0	0	0	0
White Brook, NJ	1997–98	0	0	1	0	0	0
	2013–14	0	0	0	0	0	0
Conashaugh Creek, PA	1997–98	7	0	6	9	0	2
	2013–14	15	0	0	0	0	0
Dingman's Creek, PA	1997–98	0	0	0	0	0	0
	2013–14	1	0	0	0	0	0
Dry Brook, PA	1997–98	10	0	3	5	0	0
	2013–14	6	0	0	0	0	0
Eshback Access, PA	1997–98	0	0	1	0	0	0
	2013–14	3	0	0	0	0	0
Little Bushkill Creek, PA	1997–98	9	1	2	9	0	3
	2013–14	0	0	0	0	0	0
Park Headquarters, PA	1997–98	1	0	6	0	0	0
	2013–14	3	0	0	0	0	0
Randall Creek, PA	1997–98	0	1	3	0	0	0
	2013–14	0	1	0	0	0	0
Raymondskill Creek, PA	1997–98	0	0	3	2	0	3
	2013–14	5	1	2	0	0	0
Spackman's Creek, PA	1997–98	0	0	5	0	0	0
	2013–14	0	3	0	0	0	0
Smithfield Beach, PA	1997–98	0	0	0	0	0	0
	2013–14	13	0	0	0	2	0
Tom's Creek, PA	1997–98	2	0	13	24	0	0
	2013–14	2	0	0	0	0	0
Travis House, PA	1997–98	0	0	0	0	0	0
	2013–14	2	0	1	0	0	0
Tumbling Waters, PA	1997–98	6	0	0	0	0	0
	2013–14	12	1	0	0	0	0
Total	1997–98	39	2	52	51	0	12
	2013–14	71	6	4	1	2	1

eared myotis. We captured little brown myotis at 3 sites and northern long-eared myotis at just 1 of 19 sites during our surveys, whereas Campbell captured these species at 13 and 7 sites, respectively (Table 1). Although there was not a statistically significant difference in capture rates of tri-colored bats between WNS periods, captures rates of this species

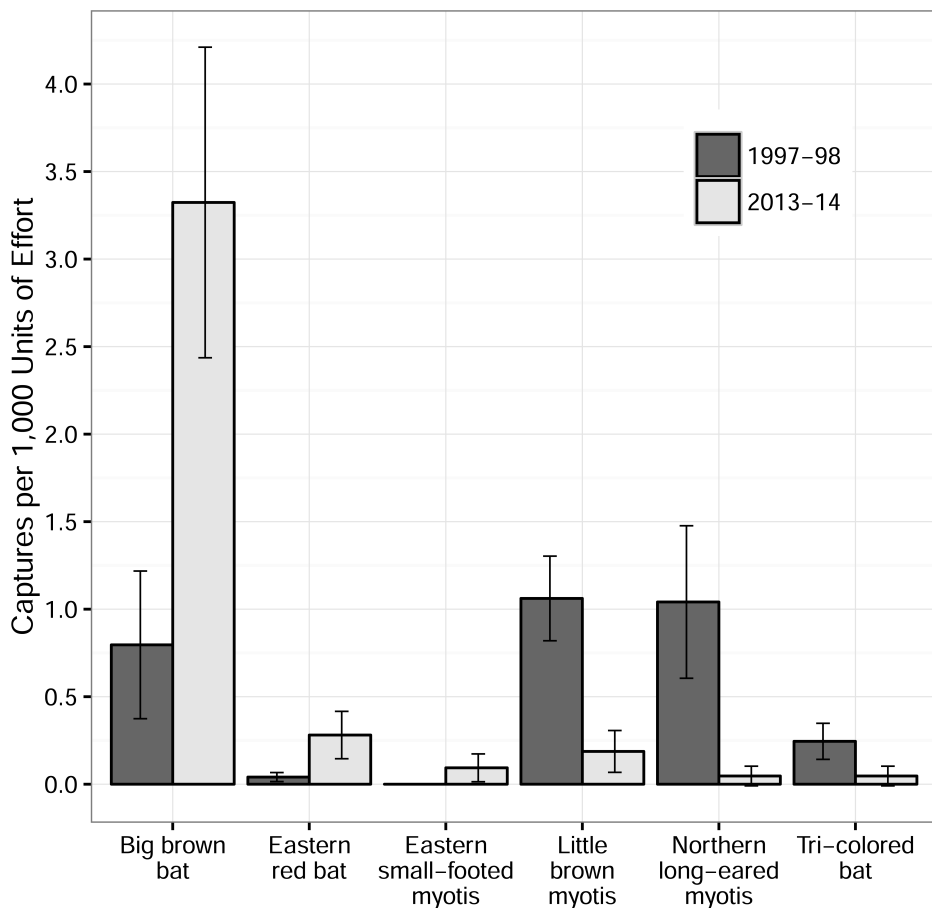


Figure 2. Capture rate (number of individuals captured/m² net hour $\times$ 1000) for each bat species in 1997-98 (pre-WNS) and 2013-14 (post-WNS). Error bars indicate mean values $\pm$ 1 SE.

declined from 0.245 to 0.047 captures per 1,000 units of effort, suggesting that this species has declined drastically in the park as well.

The Pennsylvania Game Commission has documented a statewide decline in little brown myotis, northern long-eared myotis, and tri-colored bats since 2004 (Butchkoski and Bearer, current volume). Statewide capture rates of affected species in Pennsylvania have fallen from 3.50 to 0.52 captures per 1,000 units of effort for little brown myotis, from 2.80 to 0.85 for northern long-eared myotis, and from 0.12 to 0.02 for tri-colored bats (Butchkoski and Bearer, current volume). Similar findings have been reported throughout the mid-Atlantic and northeastern United States (e.g., Franci et al. 2012, Moosman et al. 2013, Reynolds et al. 2016).

Capture rates of big brown bats increased significantly ($P \leq 0.001$) between pre- and post-WNS surveys, from 0.796 to 3.323 captures per 1,000 units of net effort, and this

Table 2. Numbers of adult females and juveniles captured during the mid- to late-summer netting period (1 July–15 August), and the proportion of juveniles relative to adult females, pre- and post-WNS, by species.

Species	1997–98			2013–14		
	Juveniles	Adult females	Ratio	Juveniles	Adult females	Ratio
Big brown bat	0	22	0.00	12	31	0.39
Eastern red bat	0	1	0.00	2	2	1.00
Little brown myotis	12	16	0.75	0	1	0.00
Northern long-eared myotis	5	27	0.19	0	0	0.00
Eastern small-footed myotis	0	0	0.00	0	0	0.00
Tri-colored bat	4	4	1.00	0	1	0.00
Total	21	70	0.30	14	35	0.40

species was captured at 12 of 19 sites and comprised 83.5% of captures in 2013–14, compared to only 8 of 19 sites and 25% of captures in 1997–98. While big brown bats are susceptible to WNS infection, this species does not exhibit the mass mortality that is observed in other hibernating bats, most notably *Myotis* species and tri-colored bats (Ford et al. 2011, Turner et al. 2011). Given their larger body size, big brown bats have greater fat reserves (up to 30% of their total body weight) and WNS-infected big brown bats may therefore be less likely to deplete their fat reserves by the end of hibernation (Frank et al. 2014). The roosting behavior of big brown bats may also contribute to their limited susceptibility to infection. During hibernation, big brown bats generally roost individually or in small, isolated clusters (Merritt 1987, Raesly and Gates 1987), which may help to reduce the transfer of *P. destructans* from infected to uninfected individuals (Francel et al. 2012). Big brown bats have also been noted to roost in dry, less humid areas near the entrances of hibernacula (Raesly and Gates 1987), which may not provide ideal environmental conditions for the growth of *P. destructans* (Raudabaugh and Miller 2013). While *Myotis* and tri-colored bats give birth to 1 young (Whitaker and Hamilton 1998), female big brown bats typically give birth to 2 young per litter (Kurta and Baker 1990), which may allow populations of this species to rebound from WNS more rapidly.

Capture rates of eastern red bats increased from 0.041 to 0.281 captures per 1,000 units of net effort between the 1997–98 and 2013–14 surveys, although the difference was not

Table 3. Comparison of adult females and adult males, pre- and post-WNS, by species.

Species	1997–98		2013–14	
	Adult males	Adult females	Adult males	Adult females
Big brown bat	15	24	23	34
Eastern red bat	1	1	1	2
Little brown myotis	19	21	2	2
Northern long-eared myotis	17	29	0	1
Eastern small-footed myotis	0	0	0	2
Tri-colored bat	4	4	0	1
Total	56	79	26	42

statistically significant. In addition, eastern red bats were documented at 4 sites during the present study, but only 2 sites in 1997–98 (Table 2). Our captures of eastern red bats occurred between 6 and 31 July, suggesting that these were summer resident bats and not migrants. As a migratory species that doesn't hibernate, eastern red bats are apparently not affected by White-nose Syndrome (Ford et al. 2011), and our data suggest that this species is now more common and widely distributed in the DWGNRA.

We could not assess changes in capture rates for eastern small-footed myotis because we only captured 2 individuals in 2014, and this species was not captured during Campbell's pre-WNS netting surveys. The eastern small-footed myotis is listed as a Pennsylvania state threatened species (Pennsylvania Natural Heritage Program 2016), largely because there are few records of this species within the state and relatively little is known about its foraging and roosting ecology (Best and Jennings 1997). Records indicate that eastern small-footed myotis roost in rock crevices (Johnson et al. 2011), rocky outcrops (Johnson and Gates 2008), talus slopes (Moosman et al. 2015), and other suitable rock structures (Best and Jennings 1997). A large talus slope above Cold Air Cave at the southern end of the park may serve as suitable summer roosting habitat for this species, although there are no records to confirm this.

Big brown bats and eastern red bats now appear to be the most common and widely distributed bat species within the DWGNRA. In contrast, tri-colored bats and members of the genus *Myotis* appear to have declined drastically since 1997–98 and are now rare and restricted in distribution, presumably due to mortality associated with White-nose Syndrome. Significant declines in capture rates of *Myotis* species following the emergence of White-nose Syndrome are consistent with the findings of previous studies conducted in the northeastern United States. The potential shift to a bat community dominated by big brown and eastern red bats may therefore represent an ecological release as the result of reduced foraging competition following the decline of *Myotis* species and tri-colored bats (Ford et al. 2011).

Our data allow only limited conclusions about post-WNS demographic changes. The numbers of lactating and pregnant females are very low for both pre- and post-WNS data. Given significant declines in summer captures, however, it is clear that there has been a drastic reduction in reproduction for little brown myotis and northern long-eared myotis, and probably also for tri-colored bats. In contrast, our post-WNS data provide evidence of increased reproductive success in big brown bats, which is consistent with the significantly greater capture rates for this species. We found no evidence for decreased survival of male bats for species affected by WNS.

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