Chapter

Case Study: Upland Ponds Provide On-Site Mitigation for Bat Habitat Along American Electric Power's 765-kV Powerline ROW in the Appalachian Mountains, USA

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Abstract

Initially, mitigation for protected species in the United States was project-specific, in-kind, and on-site, benefiting local populations of focal species. Recent mitigation policy uses *in-lieu* fees and mitigation banks, consolidating mitigation at large off-site locations, targeting regional population. This is true for the Indiana bat (*Myotis sodalis*), a species that roosts in trees and forages along many types of woodland edges. Drinking water is essential but considered ubiquitous and rarely factored into mitigation. In high-relief areas, runoff is rapid, precipitation is low, and evapotranspiration is high in late summer, limiting drinking pools for lactating females and juveniles. In Virginia's Ridge and Valley region, our on-site mitigation paired ponds, roost boxes, and edge foraging habitat along a new electric transmission line right-of-way (ROW). During mitigation, white-nose syndrome (a fungal disease) decimated populations of this and four additional species of bats, which we included in analyses. Mitigation metrics were abundance, presence of focal species, species richness, and species diversity. The Indiana bat was known regionally, and an adult male was captured pre-construction along the ROW but not at mitigation sites; the species was recoded acoustically at a mitigation site post-construction. For other focal species, abundance (total and reproductive females), was dramatically greater post-mitigation. Species richness and diversity increased severalfold post-mitigation.

Keywords: on-site mitigation, small-scale mitigation, mitigation success, Indiana bat, northern-long-eared bat, white-nose syndrome, created wetland, utility corridor

1. Introduction

When mitigation is a regulatory requirement, it must comply with laws and implementing regulations. According to the United States (U.S.) President's Council on Environmental Quality (40 CFR [Code of Federal Regulations] Part 1508.20) mitigation for the National Environmental Policy Act (NEPA) occurs when project impacts are offset by any combination of (a) avoidance, (b) minimization; (c) repair, rehabilitation, or restoration, (d) reduction or elimination via preservation and maintenance, and/or (e) compensation by replacing or providing substitute resources or environments. The U.S. Fish and Wildlife Service's (FWS) first mitigation policy (FR [Federal Register] Vol 46 No. 15 pp7644-7763, 23 January 1981) adopted this definition and provided guidance for timing, location, and type of compensatory mitigation. Mitigation was to last for the life of the project and afterwards for as long as the loss persisted (in-time). Mitigation banking was largely considered a matter of timing (i.e., mitigate now for future impacts). The preferred site for mitigation under the 1981 guidance was as close as feasible to the impact area (on-site), prioritized by plan area, proximity, and ecoregion, so that species associated with a habitat loss remained relatively stable over time in or near the impact area. In-kind mitigation was preferred, replacing lost habitat values (the suitability of an area to support a species), with no net loss of value. FWS's 1981 policy did not cover species listed under the Endangered Species Act (ESA). But under ESA section 7, actions of a Federal agency or applicant that could result in incidental take of listed species (without jeopardy to the species or adverse modification of critical habitat) must mitigate (avoid, minimize, and compensate) negative impacts of the project's development [1]. Practitioners are directed to species recovery plans to help identify opportunities for mitigation, largely on-site.

At its simplest, habitat values lost with development are mitigated by areal replacement of habitat of equal quality. However, such replacement is fraught with complications. Preserving existing habitat results in a net loss of habitat so replacement requires habitat creation, but creating a mature habitat may take decades, resulting in a time disparity between impact and replacement. Further, not all habitat, even if suitable, is of the same quality (e.g., pine versus hardwood forests), and the resource (food, water, or shelter) in shortest supply may limit its value. Alternatively, management, restoration, and enhancement may improve the quality of mitigation habitat, contributing to no net loss while lessening areal requirements.

In eastern North America, mitigation for the endangered Indiana (*Myotis sodalis*) and threatened northern long-eared (*M. septentrionalis*) bats, listed under the ESA, has focused on shelter in the form of natural woodland [2, 3], and occasionally artificial [4] roosts. Foraging habitat for these bats is broad-based [5], including areas near and within forests, such as edges and small openings, open woodlands, solitary trees, space above the canopy, and sometimes agricultural lands [6–12]. Nevertheless, foraging habitat may be as essential to maternity colonies as roosts [13]. Fidelity to foraging areas can determine roosts use [14] and limited roost availability may force bats to commute farther to forage [15], impacting reproductive success.

In the eastern U.S., water is typically considered readily available, even ubiquitous, to maternity colonies of the Indiana bat [5]. Its availability is rarely factored into mitigation, although the Indiana bat uses areas with water disproportionate to availability [13, 16], as do congeners [17]; small and ephemeral water bodies may be important habitat components [18]. Carter [19] stated that maternity colonies of the Indiana bat are associated with bottomland, riparian, wetland, or other hydric forest types in the midwestern U.S., whereas in the Appalachian Mountains, where such areas are limited, maternity colonies in uplands are small and ephemeral. The first successful mitigation employing habitat creation for the Indiana bat incorporated wetlands [20]. Congeners roost near water sources [21, 22] and ensuring water availability is standard conservation for many species of temperate bats [23].

Insectivorous bats cannot survive without drinking water [24–27]. Lactating females drink more [28] and use water resources more, even when they are not readily available [29], such as in high relief mountainous habitat [30–34]. In high-relief areas, bats frequent small water pools (even road ruts) in the Appalachians [35] and Ozarks [36] of the U.S., and Slovakia, Europe [37]. Logging and other human land uses have eliminated may natural wetlands, including those in high-elevations [38, 39]. The greatest need for water by lactating females and newly volant young is in late summer, coincident with low precipitation, high evapotranspiration, and low surface water retention in areas of high relief and high altitude [40–42], all of which limit pools of drinking water. See Hoy [43] for a discussion of upland wetland types, hydrology, and seasonality. On narrow high-gradient streams, bank vegetation can further narrow the space over pools, making it difficult for bats to drink [44–46], despite frequent association of bats with larger streams [18].

Based on ESA section 7 consultation for an electric transmission line, we undertook voluntary conservation to improve on-site habitat quality. Along the right-of-way (ROW), we created small ponds to provide drinking water for bats through late summer, and we erected artificial roost boxes adjacent to the ponds. Woodlands edging the ROW provided foraging habitat. Initially, the focus of this mitigation was the Indiana bat, based on local occurrence [6, 47]. During mitigation monitoring, white-nose syndrome (WNS), a fungal disease that kills bats hibernating in caves, decimated population of many species in the eastern U.S. Monitoring analyses were expanded to species of bats that were both (a) considered rare by federal (FWS and Jefferson National Forest [JNF]) and state (Virginia and West Virginia) agencies, and (b) were demonstrably in the area (i.e., focal species): northern long-eared, little brown (*M. lucifugus*), eastern small-footed (*M. leibii*), and tricolored (*Perimyotis subflavus*) bats. Mitigation efficacy was assessed for focal species pre- versus post-project (i.e., pre-construction and post-mitigation) and pre- and post-WNS.

Use of ponds (and boxes) is a form of on-site, small-scale mitigation designed to aid local populations. We did not use in-lieu fee payments or mitigation banks that consolidate mitigation for multiple projects at large off-site locations and often target benefit to regional population. This trend has been increasingly encouraged by FWS in recent years [48]. We selected on-site, small-scale mitigation because (a) trading impacts at one location for mitigation at another is frequently inequitable [49], (b) small-scale mitigation can be very effective [50], (c) combining mitigation construction with project construction (on this and other projects) can be cost-effective, and (d) mitigation banks were not available as recent as a decade ago, long after project initiation [51] (in 2013 the Department of the Interior, Office of Policy Analysis listed 111 banks, but none for bats).

2. Methods

2.1 The project

American Electric Power Service Corporation (AEP) initiated a project in 1998 to construct a 765-kV, 145-km electric transmission line in Appalachian regions of southwest Virginia and West Virginia, U.S. (**Figure 1**). Studies were completed along 55 km of ROW, 17.7 km in JNF in Bland, Wythe, and Pulaski counties, Virginia (**Figure 1**), in the Ridge and Valley physiographic region where elevation is 610–1227 m, local relief

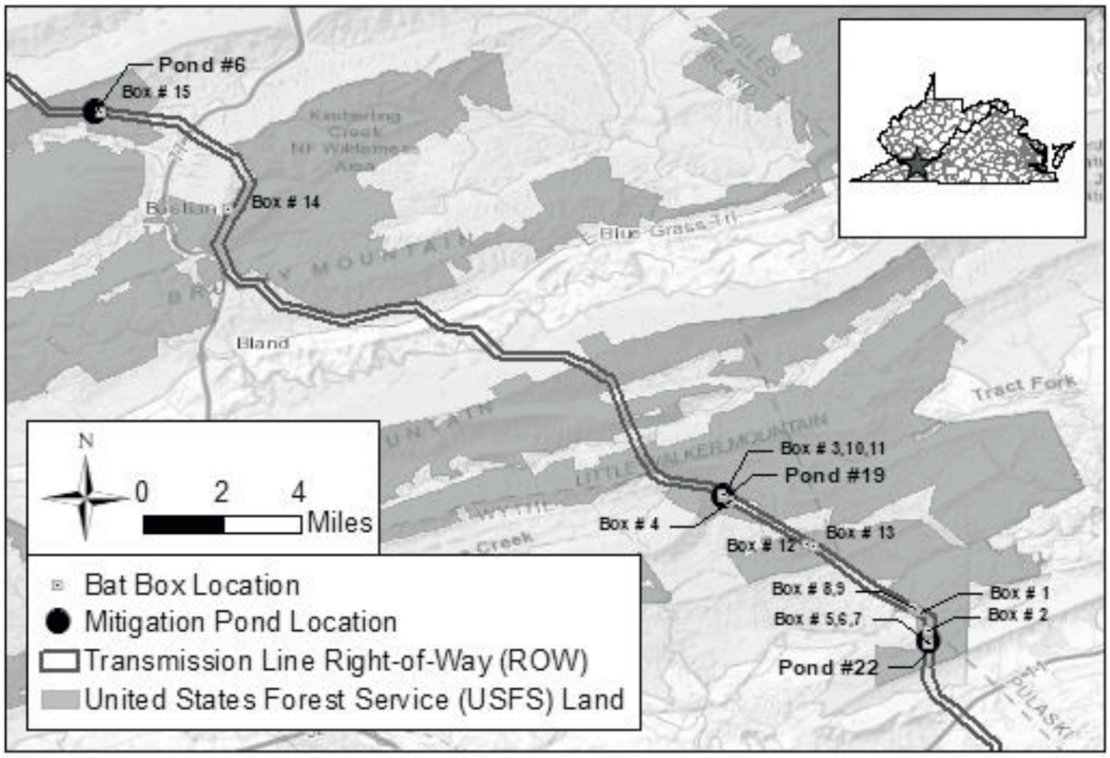

Figure 1.
AEP's 765 kV electric transmission line project in West Virginia and Virginia where mitigation consisting of ponds and boxes was employed.

is >300 m, and mean annual rainfall is 89–102 cm. Ridge tops are underlain by sandstones while mountain bases and valleys have cave-forming limestone and dolomites. It is within the Oak-Chestnut Forest described by Braun [52]. Winter hibernacula include natural caves and anthropogenic mines.

Construction created an open ROW 60 m wide, new and widened, on a high-relief forested landscape. In addition to the ESA, AEP's compliance included numerous federal and state laws and regulatory agencies. One interagency outcome was voluntary conservation under the ESA to mitigate impacts to the Indiana bat. This included constructing upland ponds to provide drinking water (and aquatic insect prey), with adjacent roosting (roost boxes), and foraging (woodlands edging the ROW) habitats, along portions of the ROW crossing JNF (**Figure 1**).

For the 55 km of ROW (including 17.7 km in JNF) addressed by this mitigation, pre-construction bat surveys were completed in summer 2004. Project construction, including ROW clearing, tower and pond construction, and ROW reclamation included the period after netting 2004 through early 2007. Post-construction monitoring was initiated in summer 2007. Pond construction was contained within the ROW and did not constitute any additional impact, areal or temporal, greater than ROW construction impact.

2.2 Bat sampling

Bat surveys pre- and post-construction of the transmission line followed FWS protocol (current version at [53]) that specifies sampling effort, placement of sampling devices, and interpretation of results. Nets, and later acoustic bat detectors, were placed along edges because foraging and commuting bats frequent convex and concave woodland corridors, including utility ROWs, roads, and forest edges [16, 34, 54–59].

Suitable habitat may require the proximity of commuting corridors [18]. Per protocol [53], pre-project mist net capture of a listed bat denotes species presence and is sufficient to require ESA determination on whether development of a project will result in "take" and whether mitigation is required. We used this same presence or probable absence criteria to evaluate results of post-construction surveys, with addition of acoustic detection.

Pre- and post-construction sampling consisted of tending two nets per net site for 5 h/night for two nights (i.e., four net nights [NN]/site) during suitable weather during the summer maternity season (15 May–15 August). Pre-construction netting was completed 15 May–12 July 2004 at 53 sites along the proposed ROW in Virginia and West Virginia. This included the three sites (6, 19, and 22) where ponds were constructed on JNF lands. Post-construction monitoring surveys 2007, 2008, 2009, 2011, and 2013 consisted of netting and bat detector (acoustic) recordings at the three ponds sites.

Bat detectors were not an approved sampling technique during pre-construction sampling but were approved late during post-construction sampling. Bat echolocation calls were collected using AnaBat (Titley Enterprises, LLC) detectors. Per FWS protocol, the sample effort was two detector-nights (DN)/site (pond). Comparisons among sites and years were standardized by limiting data to nights when detectors recorded for 5 h and data after that time frame were excluded.

2.3 Data analyses

Metrics of mitigation success were abundance, presence of focal species, species richness, and species diversity [60]. Mist net effort was standardized per FWS protocol at 4 NN/site for each sample. Abundance was standardized as capture of bats/NN for all species, individual focal species, and reproductive females (pregnant, lactating, and post-lactating females). Project abundance was compared to five published local and regional (hereafter regional) studies (**Table 1**) completed using the FWS protocol. Comparisons among project samples and regional baseline populations (the median of five regional pre-WNS populations) were made as proportions (**Tables 2** and **3**). Detector results were expressed as calls/DN).

Richness was the number of species in any sample, and the diversity index [65] used was diversity = $1/\sum Pi^2$, where Pi is the proportion of bats belonging to species i, often stated as the number of equally represented species. Evenness of capture across space, time, and among species was compared using a Chi-square (χ^2) tests. Acoustic data were analyzed using Kaleidoscope Pro (Version 3.1.1), approved by FWS in 2016. When Kaleidoscope identified calls made by bats of the genus *Myotis* (except the small footed bat), they were also identified visually (vetted) by biologists approved by FWS.

2.4 Mitigation ponds

Pre-construction net sites were assessed for their ability to receive and sustain a small pond providing drinking water through the summer maternity season. Ponds were constructed at net sites 6, 19, and 22 (hereafter pond sites) in late-summer to early-autumn 2006 (**Figure 1**). Ponds were designed to US Forest Service standards, with a surface area of 140 m^2 sloped to a depth of 1–2 m [66] (**Figure 2**). A certified wetlands biologist visited ponds following construction and summers 2007–2010 and 2012 to assure they held water and were functional.

Bat species	Sample	No. NN	Bats/NN	Reproductive female bats/NN
All	2004 ROW	212	1.118	—
	2004 future ponds sites	12	0.083	—
	2007–2009 pond sites pre-WNS	36	4.167	—
	2011–2012 ponds sites post-WNS	24	0.417	—
	WV pre-WNS 1997–2008[1]	3577	3.416	—
	WV post-WNS 2010[1]	892	1.390	—
	WV pre-WNS 2002[2]	63	1.444	—
	WV pre-WNS 1998[3]	176	0.75	—
	VA pre-WNS 2000–2009[4]	804	1.959	—
	VA pre-WNS 1995–1996[5]	24	2.333	—
Indiana	2004 ROW		0.005	0
	2004 future ponds sites		0	0
	2007–2009 pond sites pre-WNS		0	0
	2011–2012 ponds sites post-WNS		0	0
	WV pre-WNS 1997–2008[1]	3577	0.010	0.001
	WV post-WNS 2010[1]	892	0.001	0.001
	VA pre-WNS 2000–2009[4]	804	0.001	0
	Pre-WNS: WV 2002[2]; 1998[3]; VA 1995–1996[5]	63; 176; 24	0	0
N. long-eared	2004 ROW		0.557	0.302
	2004 future ponds sites		0.083	0.083
	2007–2009 pond sites pre-WNS		0.889	0.278
	2011–2012 ponds sites post-WNS		0	0
	WV pre-WNS 1997–2008[1]	3577	1.438	0.583
	WV post-WNS 2010[1]	892	0.330	0.126
	WV pre-WNS 2002[2]	63	0.746	0.349
	WV pre-WNS 1998[3]	176	0.216	0.125
	VA pre-WNS 2000–2009[4]	804	0.412	0.170

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Bat species	Sample	No. NN	Bats/NN	Reproductive female bats/NN
	VA pre-WNS 1995–1996[5]	24	0	0
Little brown	2004 ROW		0.198	0.085
	2004 future ponds sites		0	0
	2007–2009 pond sites pre-WNS		0.472	0.083
	2011–2012 ponds sites post-WNS		0	0
	WV pre-WNS 1997–2008[1]	3577	0.836	0.247
	WV post-WNS 2010[1]	892	0.168	0.048
	WV pre-WNS 2002[2]	63	0.111	0.048
	WV pre-WNS 1998[3]	176	0.125	0.023
	VA pre-WNS 2000–2009[4]	804	0.313	0.113
	VA pre-WNS 1995–1996[5]	24	0	0
E. small-footed	2004 ROW		0.009	0.009
	2004 future ponds sites		0	0
	2007–2009 pond sites pre-WNS		0	0
	2011–2012 ponds sites post-WNS		0	0
	WV pre-WNS 1997–2008[1]	3577	0.042	0.016
	WV post-WNS 2010[1]	892	0.007	0.003
	WV pre-WNS 2002[2]	63	0.016	0
	VA pre-WNS 2000–2009[4]	804	0.095	0.034
	Pre-WNS: WV 1998[3]; VA 1995–1996[5]	176; 24	0	0
Tricolor	2004 ROW		0.042	0.005
	2004 future ponds sites		0	0
	2007–2009 pond sites pre-WNS		0.194	0
	2011–2012 ponds sites post-WNS		0	0
	WV pre-WNS 1997–2008[1]	3577	0.215	0.010
	WV post-WNS 2010[1]	892	0.049	0.008
	WV pre-WNS 2002[2]	63	0.048	0.016

Bat species	Sample	No. NN	Bats/NN	Reproductive female bats/NN
	WV pre-WNS 1998[3]	176	0.091	0.006
	VA pre-WNS 2000–2009[4]	804	0.246	0.040
	VA pre-WNS 1995–1996[5]	24	0.083	0.042

[1][61]: WV, 37 counties (31 pre-WNS; 8 post-WNS).
[2][47]: Preston County, WV.
[3][62]: Randolph County, WV
[4][63]: 11 counties, Cumberland Plateau and Ridge and Valley physiographic provinces, VA.
[5][64]: southeast VA.

Table 1.
Abundance, bats/per NN, including reproductive females for all bats and focal species during the 2004 preconstruction survey at all 53 net sites and at 3 pond sites (6, 19 and 22), post construction 2004–2009 (pre-WNS) and 2011–2013 (post-WNS), and for 5 regional studies pre- and one post-WNS.

Bat species	ROW pre-construction pre-WNS		Regional pre-WNS	Reproductive female pre-WNS:ROW pre-construction vs regional
	vs regional pre-WNS	vs regional post-WNS	vs regional post-WNS	
All	0.537	0.804	1.499	—
Indiana	1.000	5.000	5.000	0.000
N. long-eared	0.775	1.688	2.179	1.036
Little brown	0.474	1.179	2.488	0.689
E. small-footed	0.189	1.286	6.786	0.189
Tricolor	0.286	0.857	3.102	0.210

Table 2.
*Proportional abundance (bats/NN) at 53 ROW sites, pre-construction and pre-WNS, with median values of 5 regional studies (see **Table 1**), pre- and post-WNS, between regional pre- and post-WNS values, and between reproductive females (pregnant, lactating, and postlactating) pre-WNS—ROW and regional values.*

(a) (b)

Figure 2.
Pond site 22 construction (a) within and coincident with ROW development in August 2006, and (b) this same pond after first filling October 2006.

	Pond sites pre-construction		Pond sites post-construction		
Bat species	**vs ROW**	**vs regional pre-WNS**	**vs pond sites pre-construction**	**vs ROW**	**vs regional pre-WNS**
All	0.074	0.040	50.205	3.727	2.000
Indiana	0.000	0.000	0.000	0.000	0.000
N. long-eared	0.149	0.115	10.711	1.596	1.236
Little brown	0.000	0.000	Infinite	2.384	1.129
E. small-footed	0.000	0.000	0.000	0.000	0.000
Tricolor	0.000	0.000	Infinite	4.619	1.320

Table 3.
A comparison (proportion) of abundance (bats/NN) at 3 pond sites pre-construction, post-construction (pre-WNS), and post-construction and post-WNS, with the 53 sites on the ROW, and the median value of 5 local and regional projects pre-WNS (see **Table 1** *and foot-note) a single regional project post-WNS.*

2.5 Management adaptations: technology, science, and disease

Successful mitigation requires the ability to respond to unforeseen circumstances. Over the more than 2 decades of this project, adaptive management has increasingly become a requirement for ESA mitigation [67] but was rarely implemented when this project was initiated [68–71]. Over 20 years there were many changes in politics and regulatory policy, technology, scientific understanding, and disease that affected mitigation implementation and outcome, and also project finances. Many changes were made, and funds shifted to accommodate unforeseen challenges and opportunities.

At project initiation, pre-construction sampling, and mitigation design bat detectors were not part of FWS sampling protocol. However, technology and regulatory acceptance evolved rapidly so we incorporated this technology in mitigation monitoring. This adds complexity because acoustic detection was not available to assess impacts but was available to assess mitigation success. FWS's protocol for acoustics use included guidance for field use (detector placement, level of effort, and acceptable environmental conditions), interpretation of recordings (computer-assisted and human vetting), and interpretation of an acoustic "capture" (like a mist-net capture). This protocol changed over time. After monitoring was complete, we reassessed data using the approach outlined in the current (2022) sampling protocol to ensure consistency.

The original mitigation design included installation and monitoring of 30 metal-clad boxes at 15 locations with solar exposure along the ROW in JNF. This included one location near pond site 6, two near pond site 19, and three near pond site 22 (**Figure 1**). Boxes had 7 (58 × 68.5 × 18 cm) or 14 (58 × 68.5 × 38 cm) chambers; 10 locations had two 7-chamber boxes and 5 locations had one 7-chamber and one 14-chamber box. Two boxes were mounted back-to-back 3 m high on metal poles (**Figure 3**) facing roughly southeast and northwest to provide a diversity of temperatures inside boxes over a range of environmental conditions. This design allowed assessment of box use in relation to temperatures inside and out, elevation, orientation, and potentially pond use. Boxes were equipped with Thermocron iButton data loggers (Maxim Integrated Products, Sunnyvale, California). These were removed

Figure 3.
Small and large (7 and 24 chamber) metal-clad bat boxes erected on metal poles within the transmission line ROW.

after one season when we learned they emit high frequency sounds that may disturb bats [72]. Boxes were monitored for bats annually, and nests of stinging insects were removed during winters.

In 2011 wooden boxes on wooden poles were added near pond sites 6 and 19 (two each) because of concerns that bats might receive a nuisance static-electrical shock when landing on the metal-clad boxes that go to ground and so deter use. During initial monitoring, no bats were observed in boxes, but guano was collected at metal clad boxes at sites 7 (April 2010) and 8 (June 2013) and in 2010 under a wooden box (site 11.1). In 2021, 1 big brown bat (*Eptesicus fuscus*) was in a box at site 5, and guano was under six metal-clad boxes (sites 1, 2, 5, 6, 7, 15) and one wooden box (15.1.). These limited data do not support the hypothesis that metal-clad boxes on metal poles deterred bat use. At mitigation design, use of environmental DNA, including feces to identify species was in its infancy. In 2012, having lost roost box thermal data and with the advent of WNS in the project region [61], we added guano screens below boxes to collect feces for DNA testing to improve detection of use. However, DNA in feces degrades rapidly and we were unable to identify species.

Vernal pools and small wetlands are important for many species [73]. We designed ponds as functioning wetlands although they were not used for wetland mitigation credits. We expected to gain a natural complement of obligate and facultative wetland plants and animals through natural processes and species complements were monitored. Control of non-native invasive plants was not planned but they and aggressive native cattails (*Typha* sp.) were removed by hand as time allowed. Although fenced, cattle were allowed into one pond on two occasions; they were removed, and the fence repaired.

The biggest impact to the original mitigation plan and assessing success, was the arrival of WNS. We expanded 5 years of annual monitoring to bi-annually for the last two surveys because WNS demonstrably affected summer bat populations [61] and expanded analyses of mitigation success to include pre- and post-WNS effects.

3. Results

3.1 Pre-construction

In total, 237 bats representing nine species were captured during the 2004 pre-construction survey at 53 sites. The capture rate was 1.118 bats/NN (**Table 1**) and mean richness was 1.7 species/site. Capture included an adult male Indiana bat, 118 northern long-eared bats (64 reproductive females) at 33 sites, 42 little brown bats (18 reproductive females) at 14 sites, 2 reproductive female eastern small-footed bats at 2 sites, 9 tricolored bats (1 reproductive female) at 7 sites, 43 big brown bats, 13 eastern red bats (*Lasiurus borealis*), 7 silver-haired bats (*Lasionycteris noctivagans*), and 2 hoary bats (*Lasiurus cinereus*). Catch was not evenly distributed across species (χ^2 = 440.6582, P < 0.001) and collective species diversity was 3.5.

Abundance of all species combined from the ROW was 53.7% of the median regional value (**Table 2**). Similarly, abundance of focal species was typically less than median regional values, ranging from 18.9% for the eastern small-footed bat to 100% for the Indiana bat (**Table 2**). Abundance of reproductive female northern long-eared bats from the ROW was 103.6% of regional, but for other focal species it was 0–68.9% of regional values (**Table 2**).

At the three sites where ponds were later constructed, only one bat, a pregnant northern long-eared bat, was captured during the pre-construction survey. The catch was 0.083 bats/NN, species richness was 1.0, and diversity was 1.0. Abundance of species collectively and individual focal species was less than along the ROW (0–14.9%) and median regional values (0–11.5%) (**Table 3**).

3.2 Post-construction

Sampling at ponds produced 160 bats representing 7 species over 5 monitoring seasons, 2007–2013: 49 (31%) big brown, 53 (33%) eastern red, 32 (20%) northern long-eared, 16 (10%) little brown, 7 (4%) tricolored, 2 hoary, and 1 silver-haired bats. All bats of focal species were caught pre-WNS. At pond sites 6, 19, and 22 respectively, 32, 48, and 80 bats were caught. Captures differed among ponds (χ^2 = 22.4; P < 0.001), years (χ^2 = 110.1; P < 0.001), and species (χ^2 = 126.3; P < 0.001). More bats were typically caught at pond sites 22 than 19 and 6. Ninety-four percent of captures (150 of 160) were pre-WNS. Post-mitigation abundance, richness, and diversity increased pre-WNS and decreased post-WNS at each pond site (**Figure 4**) and collectively (**Table 1**).

Abundance at pond sites of combined species post-construction and pre-WNS was >5000% of pre-construction pond sites, 373% of pre-construction ROW, and 200% of regional values (**Table 3**). Similarly, abundance of focal species (Indiana, northern long-eared, little brown, eastern small-footed, and tricolored bats) at pond sites post-construction and pre-WNS was 112.9–1071% compared to pre-construction of ponds, ROW, and regional values (**Table 3**). Abundance of reproductive females followed a similar pattern (**Table 1**). Abundance of all species at pond sites post-construction and post-WNS was 502% of preconstruction, 10%, of post-construction and pre-WNS, 20% of regional values pre-WNS, and 30% of regional values post-WNS.

Abundance based on calls/DN at pond sites post-construction, was greater pre- than post-WNS for all species combined (189.4 versus 51.9 calls/DN), and for Indiana (1.5 versus 0.3), northern long-eared (1.9 versus 0.1), little brown (20.1 versus 0.6), and tricolor (80.4 versus 4.8) bats. Calls for the eastern small footed bat were not vetted.

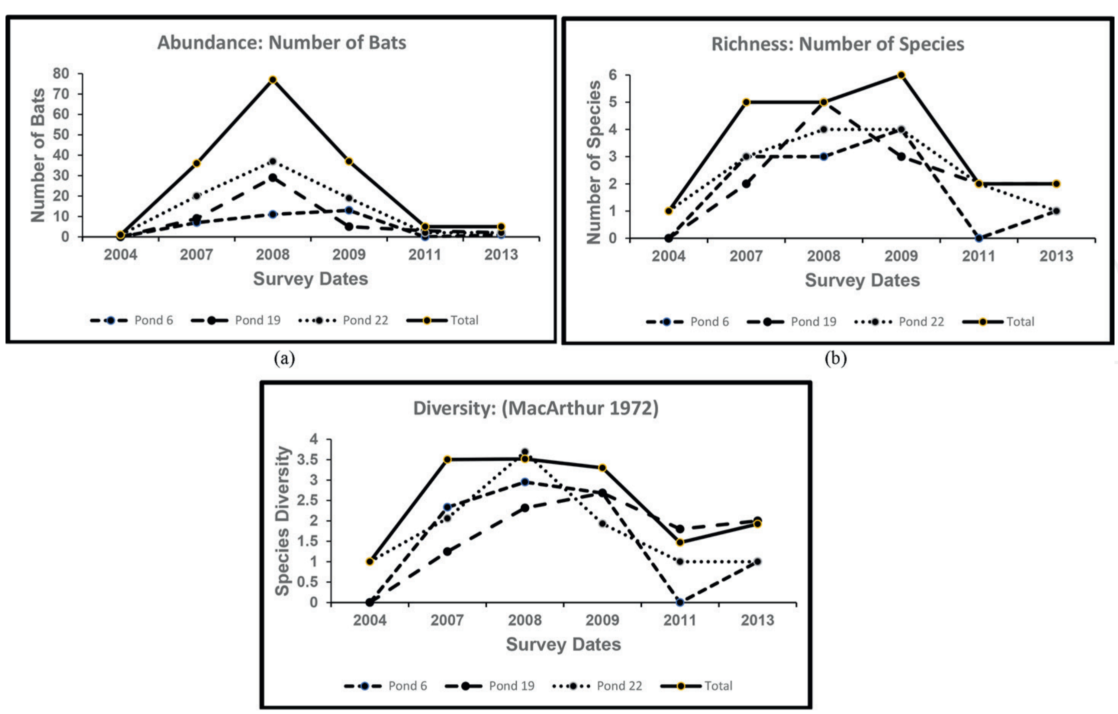

Figure 4.
Abundance (a), richness (b), and diversity (c) of bat captures at each of 3 pond sites including the pre-construction survey (2004) and 5 post-construction monitoring surveys pre-WNS (2007–2009) and post-WNS (2011 and 20013).

4. Discussion and conclusions

Low bat abundance, especially reproduction females, at high altitudes [30, 34, 74–76] is often attributed to cool variable temperatures, but drinking water is also less common in areas of high-relief, frequent at high altitudes [77]. If water is limited in late summer when need is greatest, lactating females and young bats travel farther to drink, potentially limiting juvenile recruitment [78]. In late summer on mountainous landscapes, drinking water can be more limiting than prey [33]. Providing drinking water, in conjunction with corridors used for commuting and foraging [8, 11, 56], may benefit bats more than replacing tree roosts on a heavily wooded landscape. At a minimum, bats use and benefit from natural and created pools across a broad geography and habitat type [79–84].

4.1 Mitigation success pre-WNS

Rare populations are hard to sample [60, 85–87]. For regulatory compliance under ESA, capture of just one bat, via mist net or acoustic detection, is demonstrable proof of presence. In this project area of steep relief and high altitude, for the initial focal species, the Indiana bat, success was limited. Although not netted at pond mitigation sites before or after mitigation, a single individual was captured along the project ROW pre-project, which represented a higher level of abundance than regional studies. This species was also documented acoustically at a pond during mitigation, and per FWS protocol, documents presence and thus limited success. This scenario also played out for the eastern small-footed bat, although acoustic recordings were not considered. For the three remaining focal species and for all species combined, abundance (measured by netting and acoustics) was dramatically greater after mitigation than pre-project at (1) the mitigation site, (2) the project ROW, and (3) regionally, whereas pre-project abundance at mitigation sites was lower than regional values. Abundance of reproductive females of focal species was also greater after mitigation. Richness and diversity increased severalfold with pond mitigation.

While improved abundance (notably of reproductive females), richness, and diversity support success of pond mitigation, these are not the only criteria of success. From a regulatory perspective, rare or unique species may be valued more than abundance, but for this project abundance of all species and focal species improved with mitigation. Similarly, diversity is not a stand-alone assessment criterion. For example, abundance may be low, and desirable species may be absent or fail to reproduce despite high diversity. But that did not happen with this mitigation. Similarly, species richness may be devalued if desired species are absent or invasive species abound, but that also was not true. In addition, maintaining or enhancing species richness and diversity may be important when combating threats like disease, e.g., WNS [88], and development, e.g., wind energy [89]. Richness and diversity on a broad scale may provide resilience against local stochastic events that jeopardize small and isolated populations.

4.2 Mitigation success post-WNS

WNS threatens extinction or regional extirpation of many bats, including focal species of this study [88]. Despite abundant documentation within hibernacula [90], this was one of the first documented effects of WNS on summer populations [82, 91–95]. Based on netting and acoustic sampling, presence of listed and focal species, abundance at multiple levels, species richness, and diversity decreased dramatically with onset of WNS. Post-WNS captures were limited to eastern red and hoary bats, species for which WNS mortality is not documented, and the big brown bat, a species that suffers limited effects from WNS [96]. Nevertheless, post-WNS, mitigation exhibited limited success based on collective abundance of all species, richness, and diversity.

4.3 On-site mitigation

Mitigation can be implemented locally on-site where impacts occur, or at a distant off-site location, often at a large scale [48] (typically a bank) and in recent years funded by *in-lieu* fee payments. Both on-site, often small-scale, and offsite large-scale mitigation have advantages and disadvantages. Large scale mitigation is a recent trend [48], particularly for bats. Frequently-cited benefits are consolidating mitigation for many small, isolated impacts, especially in areas with high development pressure, while lessening collective administrative burdens and potentially costs [97, 98]. However, evidence of claimed benefits of large-scale mitigation is generally lacking [99], and few studies determine overall effect on individuals or populations [100]. Small-scale mitigation is just sometimes better [50].

Replacing lost habitat is often the first mitigation choice. Replacing lost woodlands at a distant location arguably does not benefit individuals directly affected, a goal of ESA mitigation, and preserving existing habitat at a distant site does not support a no-loss or net gain objective (FR Vol. 81, No. 248, pp. 95316-95349). Wild populations are strongly stochastic [101, 102] so maintaining or improving a broad local population [50] provides resiliency against stochastic events [103–105]. This is especially important for long-lived species [106] such as bats. Long-term conservation of many species of bats may depend on maintaining local viable populations across a wide geographic area. Replacing lost habitat locally is not always possible because of competing land uses. A heavily wooded landscape (such as Appalachia) may offer limited opportunities and diminishing returns for reforestation. The timeline for creating a forest, 50–80 years [107, 108], is inconsistent with timing of the impact [109]. Appalachia mine lands may provide a mitigation opportunity, but mining typically impacts woodlands so reforestation of mined lands where forest habitat was lost does before provide no net loss, mitigation timelines may be even longer [110], and mining and has its own mitigation requirements (Surface Mining Control and Reclamation Act or SMCRA) that may favor competing uses that conflict with bat mitigation [111].

Alternatives to habitat creation, on- or off-site, are habitat restoration or enhancement. Standing water is a resource required and frequently used by bats [79–84, 112]. Standing water is uncommon because in late summer in areas of high relief and altitude wetlands dry seasonally and during drought [113, 114], and many wetlands have been lost because of past land uses [38, 39]. Wetland enhancement and restoration improve habitat and benefit bats by providing drinking water, which is the goal of mitigation.

Effective mitigation is in-time, off-setting impacts at the time they occur. Constructing mitigation ponds during project construction does this; bats begin to use ponds as soon as they are available [84]. Further, regulatory compliance forces construction to be completed off-season (non-reproductive season) when bats are at hibernacula, making ponds available for filling with spring rains before bats return for the summer reproductive season. Combining project and mitigation construction saves money and it increases the probability mitigation is completed. Mitigation that is complex and time consuming for project proponents and regulatory agencies is often ineffective or is not completed [115, 116]. Combining mitigation and project construction spatially and temporally creates no additional adverse impacts and reduces costs. This mitigation is also a cost savings over the long-term capital investment to grow large trees on an additional mitigation site. In short, providing drinking water is not just ecologically sound, but can be cost-effective, a stated goal of endangered species conservation [117].

Simple, cost-effective, successful mitigation should be given priority. Regulatory compliance policy streamlining or providing approval, *a priori*, for situations where ponds (and boxes) can be used for mitigation, would benefit applicants and agencies while producing good outcomes. Prime candidates for such approval are utility ROWs crossing forested landscapes. Although typically considered an impact rather than an asset, ROWs are a conservation resource for many species. This sometimes includes rare species [118], and many species of bats uses these concave corridors [18, 56, 119]. Mitigation based on banking and related *in-lieu* fee programs are limited by the geographic availability of operational banks because of land availability, direct and administrative costs, and the time to create functional banks. Ponds (and boxes) placed near foraging habitat provide functional, small-scale, on-site, cost effective mitigation.

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Abbreviations

AEP	American Electric Power Service Corporation—one of the largest generators of electricity in the U.S., with more than 5.5 million customers in 11 states, and with 40,000 miles of lines has the largest transportation network in the U.S.
CFR	Code of Federal Regulations—official legal publication used by departments and agencies of the U.S. Federal Government to codify rule making
ESA	Endangered Species Act—enacted 28 December 1973, it establishes protections for fish, wildlife, and plants listed as threatened or endangered and provides for interagency cooperation to avoid take of listed species
FR	Federal Register—official daily publication of the U.S. Federal Government for rules, proposed rules, and notices of Federal agencies and organizations, and executive orders and other presidential documents
FWS	U.S. Fish and Wildlife Service—a bureau in the U.S. Department of the Interior, with primary responsibility for conservation and management of fish, wildlife, plants, and their habitats

JNF	Jefferson National Forest—a U.S. National Forest in southwest Virginia, administered with George Washington National Forest, collectively one of the largest blocks of public land in the eastern U.S.
NEPA	National Environmental Policy Act—U.S. law signed 1 January 1970, which requires federal agencies to assess and disclose environmental effects of proposed actions prior to decision-making
NOAA	National Oceanic and Atmospheric Administration—a regulatory agency in the U.S. Department of Commerce that monitors oceanic and atmospheric conditions and forecasts weather
ROW	right-of-way—the easement corridor on which a utility, road, or railroad line is built and operated.
SMCRA	Surface Mining Control and Reclamation Act - passed 20 May 1977, is the primary U.S. federal law regulating environmental effects of coal mining
U.S.	United States of America
WNS	white-nose syndrome - a fungal disease that kills hibernating bats, which has decimated population of many species in the eastern U.S.

A. Appendix

If water is limiting, bats likely use ponds more during drought, influencing interpretation of post-construction sampling. However, as long-term practitioners in the project area's high elevation, high-relive topography, we know that net sites spaced by 1 km, as defined by FWS sampling protocol, often e (**Table A1**)

Year	Pond	July	August
2007	6	75–110	10–75
	19	75–150	25–50
	22	50–90	50–100
2008	6	75–110	50–90
	19	90–150	100–150
	22	90–110	110–150
2009	6	50–100	75–110
	19	50–90	75–110
	22	75–125	75–100
2011	6	25–75	25–75
	19	25–90	25–75
	22	50–150	25–90
2013	6	90–125	50–110
	19	150–300	90–125
	22	200–300	25–90

Table A1.
Range of percent of normal precipitations in July and August within 4 km of the three pond sites (6, 19, and 22) in JNF during each of the 5 post-construction sample years.

xperience very different precipitation on any night, as dramatically as no rainfall to torrential downpours. Thus, localized precipitation can produce a spotty distribution of available drinking water, and effects of drought, across the landscape.

FWS protocol defines an active (foraging) area for the Indiana bat as a circle with a 4 km radius (2.5 mi), or 5,082.6 ha (50.8 km^2), so we used this to define the area within which drought might determine the availability of drinking water.

The National Oceanic and Atmospheric Administration (NOAA) [120] provides precipitation on a 4 by 4 km (16 km^2) grid. We examined late summer monthly precipitation, July and August, as a percent of normal at the three pond locations in JNF during each of the five post-construction sample years. We examined range of percent of normal precipitation for 4 by 4 km grids within 4 km of pond sites (**Table A1**).

If we define a local drought, within 4 km of a pond, as <90% of expected precipitation throughout, then pond 6 experienced droughts in July and August in 2011 whereas ponds 6 and 19 experienced August droughts in 2007 and 2011. If we define a drought as <75% of expected precipitation throughout, then only pond 19 in August 2007 experienced drought. In contrast. Precipitation was >150% only in 2013 at ponds 19 and 22.

Post-construction, bat capture differed among ponds (χ^2 = 22.4; P < 0.001) and years (χ^2 = 110.1; P < 0.001). Clearly, WNS was the largest contributor to a difference among years and we cannot ascertain impacts of drought; 94% of captures were pre-WNS (2007–2009). More bats were typically caught at pond 22 than 19 and 6, which again provides no clear effect of drought, particularly pre-WNS.

Regardless of local weather conditions, every pond held water at every visit post-construction, including summer 2020, 15 years after construction. As such, even during local drought conditions, these ponds provided bats drinking water (and potentially an aquatic-insect food-base). While these observations do not help provide a graded metric of the value the ponds provide, they do help demonstrate that the mitigation goal of providing drinking water to focal species of bats during late summer was met.

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