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Effects of Hierarchical Roost Removal on Northern Long-Eared Bat (*Myotis septentrionalis*) Maternity Colonies

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Abstract

Forest roosting bats use a variety of ephemeral roosts such as snags and declining live trees. Although conservation of summer maternity habitat is considered critical for forest-roosting bats, bat response to roost loss still is poorly understood. To address this, we monitored 3 northern long-eared bat (*Myotis septentrionalis*) maternity colonies on Fort Knox Military Reservation, Kentucky, USA, before and after targeted roost removal during the dormant season when bats were hibernating in caves. We used 2 treatments: removal of a single highly used (primary) roost and removal of 24% of less used (secondary) roosts, and an un-manipulated control. Neither treatment altered the number of roosts used by individual bats, but secondary roost removal doubled the distances moved between sequentially used roosts. However, overall space use by and location of colonies was similar pre- and post-treatment. Patterns of roost use before and after removal treatments also were similar but bats maintained closer social connections after our treatments. Roost height, diameter at breast height, percent canopy openness, and roost species composition were similar pre- and post-treatment. We detected differences in the distribution of roosts among decay stages and crown classes pre- and post-roost removal, but this may have been a result of temperature differences between treatment years. Our results suggest that loss of a primary roost or ≤ 20% of secondary roosts in the dormant season may not cause northern long-eared bats to abandon roosting areas or substantially alter some roosting behaviors in the following active season when tree-roosts are used. Critically, tolerance limits to roost loss may be dependent upon local forest conditions, and continued research on this topic will be necessary for conservation of the northern long-eared bat across its range.

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Introduction

Roosts provide bats with sites for day-time sheltering as protection from weather and predators, mating, and social interaction. For species in temperate areas that form maternity groups in forested landscapes, roosts also provide thermal benefits for successful juvenile development [1–4]. Because of their importance in both survival and recruitment, roosts long have been considered a critical habitat feature for bats [5, 6]. Approximately half of all known bat species use plants as roosts [6]; in North America, roosts most commonly are found in snags or live trees with cavities or defects. Roosts such as snags in forests are ephemeral [7, 8]. Ephemerality of the roost resource strongly suggests that bats experience roost loss at some low constant background level, with periodic pulses of increased roost loss after intense disturbances from fire, wind throw, ice damage, insect outbreak, or certain types of forest management actions [9–12]. It seems likely, therefore, that bats are adaptive to roost loss. This plasticity often is ignored as many managers tasked with bat conservation often view roosts and roosting areas as fixed landscape elements that are decoupled from stochastic environmental processes [13, 14].

Bat conservation in forested landscapes often involves identification of roost sites with subsequent limitations on management activities (e.g., forestry) within these areas. Conservative approaches to roost habitat management may seem warranted, but this strategy may interrupt natural processes or anthropogenic management actions that are vital to create suitable roosts in the present or provide roosts in the future. Impacts of management actions that result in roost loss are unknown as few studies directly have assessed the effect of roost loss on bat roosting behavior in controlled, manipulative studies. Evidence from roost exclusion studies suggests that exclusion from permanent structures can decrease site fidelity, alter home range size, lower reproductive recruitment, and reduce colony size and the strength of association among individuals [15–18]. Conversely, several lines of evidence suggest that tree roosting bats may be tolerant of roost loss up to some threshold point. For example, bats have exhibited positive roosting responses to prescribed fire at short-term and long-term temporal scales [19–23]. Positive responses to prescribed fire may be due to rapid, increased snag recruitment that offsets the loss of existing snags [24–26]. Clearly, natural forest disturbance processes also can remove and create bat roosts. Natural forest disturbance processes contrast with many types of forest harvest that remove potential and available roosts without creating new roosts in the short-term. However, if applied on the landscape properly, it is possible that forest harvesting may mimic natural processes that also create suitable roosting areas or possibly enhance the quality of existing roosts, i.e., reduce canopy shading of remaining boles.

Tolerance limits to roost loss are unclear and probably highly variable among bat species and the forest systems wherein they reside [15–18, 27, 28]. For colonial species, insight into the impacts of roost loss will require understanding both of individual and colony level factors [29]. Responses to roost loss may be apparent in demographics, survival, roost use, space use, and sociality. Unfortunately, demographic changes are exceedingly difficult to ascertain for bats that roost-switch frequently and exhibit fission-fusion behavior. Within the context of roost use, resilience to roost loss generally may be visible as either a shift in overall uses of individual roosts without a change in overall space use or social structure, or alternatively, as a shift in roosting area and roosts without a change in social structure. Conversely, if colonies are not robust to disturbance, the colony may either dissolve such that social structure at the site is not maintained, or dissolve to the point where no bats are present on the site [27]. Within the network of roosts used by colonies of bats, individual roosts frequently are used differentially, with some receiving intense use (primary roosts) and others limited use (secondary roosts) [29–31]. Roost switching studies have provided insight on why bats may switch roosts, but the underlying causes for differences in the relative level of roost use have not been investigated widely. Regardless, differential roost use suggests that individual roosts may either serve different functions for colonies and individual bats therein or vary in their value. If so, loss of heavily used or primary roosts may impact colonies more strongly than loss of less frequently used roosts [28, 29].

Our objective was to experimentally examine how hierarchical loss of roosts affects roosting social structure along with roost and space use by female northern long-eared bats (*Myotis septentrionalis*) during the maternity season at both the colony and individual level. Northern long-eared bats occur in forests throughout the eastern United States and southern Canada [32–38], but foraging activity consistently is greatest in closed-canopy forests [34, 39–44]. During the maternity season (May-July), female northern long-eared bats form non-random assorting colonies in upland forests under the exfoliating bark or within cavities of snags or declining live trees [10, 33, 36, 44]. This species is a proposed for listing as endangered and currently of high conservation concern in North America (*Federal Register* § 78:61045–61080) due to severe population declines following the onset and spread of White-nose Syndrome in eastern North America. An improved understanding of the effects of roost loss on this species will be important for development of future conservation efforts.

Accordingly, we evaluated the impacts of primary and multiple secondary roost loss specifically to reflect discussion in the literature by Rhodes et al. [29] and Silvis et al. [27] that suggests that loss of either a single primary of >20% of total roosts might result in colony fragmentation, a negative conservation outcome of substantial concern. We assessed changes in colony roost and space use, roost selection, and social structure, as well as changes in individual behaviors related to roost switching. We specified several *a priori* hypotheses related to the differing levels of roost site disturbance based on previous research on multiple species [15, 16, 18, 27, 29]. For primary roost tree removal, we proposed 2 hypotheses:

1. H_1: At the colony level, loss of the primary roost will result in an alternate tree receiving increased use, subsequently causing a previously less-used roost to become the primary roost [15, 16]; bats will not display evidence of roost seeking behavior. Bats will display an affinity for the same roosting area, but the core use area would re-center around the new primary roost, and roost selection would be consistent. At the individual level, loss of the primary roost will not impact roost switching behavior or distances moved between sequentially used roosts.
2. H_2: At the colony level, loss of the primary roost will result in dissolution of the colony [29]. Space use will either be random across the former roosting area or will be nonexistent. Bats will display characteristics of roost searching, and the characteristics of selected roosts will differ [18]. At the individual level, loss of the primary roost will increase roost switching frequency and the distances moved between sequentially used roosts.

For secondary roost loss, we proposed three hypotheses:

1. H_1: At the colony level, loss of multiple secondary roosts will not impact roosting behavior, social structure, space use, or roost selection by northern long-eared bat maternity colonies [27]. At the individual level, loss of multiple secondary roosts will not impact roost switching behavior or distances moved between sequentially used roosts. Roost characteristics will not differ.
2. H_2: At the colony level, loss of multiple secondary roosts will result in dissolution of the colony [27]. Space use will either be random across the former roosting area or will be nonexistent. Bats will display characteristics of roost searching and roost characteristics will differ [18]. At the individual level, loss of multiple secondary roosts will increase roost switching frequency and the distances moved between sequentially used roosts.
3. H_3: At the colony level, loss of multiple secondary roosts will result in increased social cohesion and increased use of the primary roost, and roosting area will decrease. Roost characteristics will not differ. At the individual level, loss of multiple secondary roosts will decrease the number of roosts used by individual bats and the distances moved between roosts.

Methods

We conducted our study at 3 sites on the Fort Knox military reservation in Meade, Bullitt, and Hardin Counties, Kentucky, USA (37.9°N, −85.9°E, WGS84). Our sites lie in the Western Pennyroyal subregion of the Mississippian portion of the Interior Low Plateau physiographic province of the upper South and lower Midwest portion of the USA [45]. Forest cover is predominantly a western mixed-mesophytic association [46], with second- and third-growth forests dominated by white oak (*Quercus alba*), black oak (*Q. velutina*), chinkapin oak (*Q. muehlenbergii*), shagbark hickory (*Carya ovata*), yellow poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), and American beech *(Fagus grandifolia*) in the overstory, and sassafras (*Sassafras albidum*), redbud (*Cercis canadensis*), and sugar maple (*Acer saccharum*) in the understory [47].

We initially captured northern long-eared bats over small woodland pools from May through July 2011 (pre-roost removal) and 2012 (post-roost removal). We attached a radiotransmitter (LB-2, 0.31 g: Holohil Systems Ltd., Woodlawn, ON, Canada) between the scapulae of each female bat using Perma-Type surgical cement (Perma-Type Company Inc., Plainville, CT, USA). A uniquely numbered lipped band was attached to the forearm of all captured bats. After identifying a small number of roosts, we maximized number of bats captured by erecting mist nets around roosts located while radiotracking bats. Captured bats were released within 30 minutes of capture at the net site. Using TRX-1000S receivers and folding 3-element Yagi antennas (Wildlife Materials Inc., Carbondale, IL, USA), we attempted to locate radio-tagged bats daily for the life of the transmitter or until the unit dropped from the bat. For each located roost, we recorded tree species, diameter at breast height (dbh; cm), height (m), canopy openness (%), decay class ([48]; live [1], declining [2], recent dead [3], loose bark [4], no bark [4], broken top [6], broken bole [7]) and crown class ([49]; i.e., suppressed [S], intermediate [I], codominant [CO], dominant [D]). We estimated size of individual colonies by performing 5 exit counts per colony at day-roosts used by radiotracked bats.

We followed the methods of Silvis *et al.* [27] in defining a northern long-eared bat maternity colony as all female and juvenile bats connected by coincident roost use. We represented colonies graphically and analytically as two-mode networks that consisted of bats and roosts (hereafter “roost network”) [30, 31]. We used these roost network representations to describe patterns of roost use by colonies and to identify roosts for our removal treatments. To reduce bias resulting from uneven tracking periods and observing only a portion of each colony, we considered relationships to be binary (i.e., presence or absence of a connection) [50]. We assessed roost network structure using mean degree, network degree centralization, network density, and clustering. Within networks, degree is a count of the number of edges incident with a node [51]; high degree values indicate a large number of connections to a node. Network degree centralization, density, and clustering all have values between 0 and 1 (0 = low, 1 = high). Network degree centralization describes the extent that a network is structured around individual nodes, whereas network density and clustering describe the distribution of connections among nodes [52–56]. We calculated two-mode degree centralization and density using the methods of Borgatti and Everett [52] and clustering using the method of Opsahl [57] for our roost network. To determine whether our observed network values differed from those of random networks, we performed 999 Monte Carlo simulations and compared observed network metrics to random network metrics using two-tailed permutation tests [58, 59]; random networks [60] were generated with the same number of nodes as our observed networks and with a constant probability of link establishment. We then compared the relative difference from random networks pre-post treatment to assess whether colony social dynamics and roost use patterns were disrupted.

In February 2012 when bats were hibernating and not occupants of trees and snags, we implemented two roost removal treatments and one control following the identification and delineation of 3 colonies in 2011. For our primary roost removal treatment, we felled the single roost with the highest degree centralization value via chainsaw. For the secondary roost removal treatment, we similarly felled 5 randomly selected roosts (24% of colony total) with degree centralization values less than the colony maximum, but greater than the colony minimum in our secondary roost removal treatment group. This number was selected to specifically test the simulation-based predictions of Silvis *et al.* [27] that colonies may fragment with loss of >20% of roosts.

We used conditional Wilcoxon 2-sample tests and conditional Chi-squared tests to compare continuous (height, dbh, and canopy openness) and categorical roost characteristics (species composition, decay stage, and crown class) pre- and post-treatment and among groups; we corrected for multiple comparisons using the Bonferroni method. Conditional tests were performed using Monte Carlo simulations with 999 permutations. We examined the roost switching behavior of individual bats by creating a Poisson regression model describing the number of roosts used by a bat relative to the total number of relocations, reproductive condition, and interaction of treatment identity and year. We used this Poisson model to conduct general linear hypothesis tests with Tukey’s adjustment for multiple comparisons to determine whether the number of roosts used by bats differed within or among treatment areas. We evaluated the fit of our Poisson model using maximum-adjusted D^2 [61]. We assessed the spatial component of roost switching behavior by individual bats by comparing the distances that bats within treatment areas moved between sequentially used roosts with general linear hypothesis tests, also with Tukey’s adjustment for multiple comparisons. We performed our general linear hypothesis tests for distances moved on a linear mixed model containing year, group, their interaction term, and reproductive condition as fixed effects, and bat identity as a random effect; we used a log transformation to normalize distance data. We assessed the fit of our linear mixed model using the conditional (R^{2c}) and marginal (R^{2m}) coefficients of determination [62].

We evaluated roost removal impacts on colony roosting area space use for each treatment group using Bhattacharya’s affinity (BA) [63] and the difference in roosting area centroids between years. The BA uses the joint distribution of 2 utilization distributions to quantify similarity between utilization distributions and is appropriate for comparisons of utilization distributions for the same individual or group [63]. These values range from 0 to 1, with values close to 1 indicating highly similar utilization distributions [63]. We calculated 95% utilization distributions from the pooled locations of all bats within a colony using bivariate normal fixed kernel methodology. To reflect the concentration of roost use, we weighted roost locations by the number of times a roost was used by radio-tagged bats [64]. We used the reference method for smoothing parameter estimation as appropriate for weighted locations [65]; that also allowed us to consider our estimates of colony space use as liberal. In cases where roosting areas of separate colonies overlapped to an appreciable extent, we calculated the utilization distribution overlap index (UDOI) to determine if space use was independent; UDOI values range from 0 to infinity, with values <1 indicating independent space use, and values >1 indicating non-independence [63].

We assessed overall changes in colony roost use patterns by comparing pre- and post-roost removal network degree centralization, density, and clustering for the roost networks. We used this same comparative network approach to assess changes in colony roosting social structure for the single mode projections of our 2-mode roost networks [66]. This projection allowed us to focus on existing direct and indirect connections among bats in a colony. Because comparing values from networks of differing size may yield inappropriate inferences [67], we used indirect comparisons of network characteristics. In these, we compared the relative difference between a roost or social network and its equivalent random network pre- and post-treatment. All analyses were performed in the R statistical program version 3.0.2 [68]. We calculated conditional tests using the *coin* package [69], linear mixed models using *lme4* [70], and utilization distributions, BA, and UDOI values using the *adehabitatHR* package [71]. We used the *igraph* [72] and *tnet* libraries [57] to visualize networks and calculate metrics. Lastly, network Monte Carlo simulations were performed using a custom script with dependencies on the *igraph* and *tnet* libraries. We used an α = 0.05 for all tests of statistical significance.

Ethics statement

Our study was carried out in accordance with state requirements for capture and handling of wildlife (Kentucky Department of Fish and Wildlife Resources permit numbers SC1111108 and SC1311170) and did not involve any endangered species at the time of the study. Capture and handling protocol followed the guidelines of the American Society of Mammalogists [73] and was approved by the Virginia Polytechnic Institute and State University Institutional Animal Care and Use Committee (protocol number 11–040-FIW). We received explicit permission to conduct work on the Fort Knox military reservation from the reservation staff biologists and Fort Knox Range Control. Data used in this study are archived in the Virginia Polytechnic Institute and State University VTechWorks institutional repository (DOI: 10.7294/W4H41PBH).

Results

We captured 58 female northern long-eared bats pre-treatment in 2011. Based on patterns of coincident roost use, we assigned 36 of these bats (11 gestating, 20 lactating, 1 post-lactation, and 4 non-reproductive) to 3 colonies. Exit counts for these 3 colonies generated minimum estimated colony sizes of 13, 18, and 14 bats, respectively. We captured 67 bats post-treatment in 2012, 62 of which (4 gestating, 45 lactating, 10 post-lactation, and 3 non-reproductive) we were able to assign to the 3 colonies identified in 2011. We recaptured only 3 individuals banded in 2011 during 2012. Exit counts indicated that the 2012 colonies contained a minimum of 24, 20 and 25 bats, respectively. We located 58 roosts over 204 relocation events for the 3 colonies identified in 2011 and 100 roosts (7 of which were used in 2011) over 324 relocation events in 2012. We recorded a mean (± SD) of 5.7 (± 1.5) locations per bat in 2011 and 5.2 (± 2.9) in 2012.

We identified between 4 and 33 roosts per colony pre-roost removal, and between 23 and 42 roosts per colony post-removal (Table 1). When controlling for the total number of relocations of an individual bat and reproductive condition, the number of roosts used by individual bats was similar between pre- and post-treatment and among colonies, with the exception of the control colony, pre-removal, that differed from all other groups (model $D^2 = 0.74$; Tables 1, 2).

	Control		Primary Roost Removal		Secondary Roost Removal	
	Pre	Post	Pre	Post	Pre	Post
Total Roosts Used	4	23	33	42	21	35
Total Relocations	88	86	75	130	41	108
Mean Roosts Used Per Bat	1.2 (± 0.6) ^{a,b,c,d,e}	4.4 (± 1.9) ^{a}	4.8 (± 1.9) ^{b}	3.6 (± 2.0) ^{c}	4.1 (± 1.6) ^{d}	3.2 (± 1.8) ^{e}
Median Non-Zero Roost Switching Distance	111.1 (± 157.6)	147.6 (± 180.1)	156.2 (± 103.2)	161.9 (± 114.4)	100.4 (± 146.7) ^{a}	219.4 (± 173.8) ^{a}
Kernel Density 95% Roosting Area (ha)	1.3	58.3	50.0	32.3	45.3	41.1
Bhattacharya's Affinity	NA	0.12	NA	0.75	NA	0.77
Difference in Roosting Area Centroid (m)	NA	258.7	NA	71.2	NA	128.7
Network Degree Centralization	0.99 (>)	0.43 (>)	0.44 (>)	0.72 (>)	0.3	0.28 (>)
Network Clustering Coefficient	0.00	0.69	0.57	0.80 (>)	0.57	0.70 (>)
Network Density	0.30	0.19	0.14	0.08	0.19	0.09

Roosting movement and space use summary metrics for 3 northern long-eared bat (*Myotis septentrionalis*) maternity colonies subjected to different levels of roost removal on the Fort Knox military reservation, Kentucky, USA, pre- and post-roost removal (2011 and 2012) treatment. Where applicable, values are presented with standard deviation (± SD) and significant differences ($P < 0.05$) between groups are indicated by superscripts a–e. Network metrics were calculated directly from the two-mode network consisting of bats and roosts; arrows indicate the direction of difference when metrics differ from random networks.

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Table 1. Summary of female northern long-eared bat roost use patterns.
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Predictor	Parameter Estimate	SE	z value	P-value
Intercept	-0.65	0.28	-2.348	0.02
Locations	0.15	0.02	6.442	< 0.001
Post-removal	1.13	0.28	4.018	< 0.001
Treatment: Primary	1.33	0.32	4.486	< 0.001
Treatment: Secondary	1.44	0.28	4.816	< 0.001
Repro: Non-reproductive	-0.26	0.31	-0.843	0.40
Repro: Post-lactation	0.05	0.19	0.255	0.80
Repro: Gestating	-0.14	0.20	-0.711	0.18
Post-removal x Primary	-1.54	0.36	-4.241	< 0.001
Post-removal x Secondary	-1.38	0.33	-4.223	< 0.001

Parameter summary of the Poisson model describing the number of roosts used by female *Myotis septentrionalis* from 3 maternity colonies subjected to different levels of roost removal (2011 and 2012) on the Fort Knox military reservation, Kentucky, USA, pre- and post- roost removal treatment. Locations = number of days bat was located; Repro = bat reproductive condition.

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Table 2. Factors influencing the number of roosts used by individual female northern long-eared bats.
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Neither roost dbh nor height differed between treatments or among colonies (Table 3). Canopy openness was similar between pre- and post-treatment, but some individual colonies differed from one another (Table 3). Distribution of roosts among decay stages differed pre- and post-treatment within the primary removal colony but not in the control colony or the secondary removal colony (Table 3). Distribution of roosts among crown classes differed pre- and post-treatment for the primary removal colony but not in the control or secondary removal colony (Table 3). Distribution of roosts among decay stage and crown classes did differ among colonies in some cases (Table 3). We found no difference in roost species composition between pre- and post-treatment or among any of our groups (Table 3). Sassafras (*Sassafras albidum*) trees or snags were the most commonly used roost species, accounting for between 43 and 57% of roosts used in each group.

	Control		Primary Roost Removal		Secondary Roost Removal	
	Pre	Post	Pre	Post	Pre	Post
dbh (cm)	31.6 (± 4.6)	32.2 (± 15.0)	34.6 (± 22.2)	34.5 (± 14.5)	30.5 (± 24.5)	30.8 (± 16.4)
Height (m)	13.4 (± 9.5)	18.0 (± 8.3)	15.4 (± 8.3)	17.7 (± 9.1)	14.7 (± 7.1)	15.4 (± 8.0)
Canopy Openness (%)	5.7 (± 4.1)	4.1 (± 2.9) [illegible]	4.7 (± 4.6) [illegible]	5.4 (± 3.4) [illegible]	4.1 (± 8.2) [illegible]	2.0 (± 3.2) [illegible]
Decay Stage (% in stage)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Stage 1	0.0	17.4	15.2	35.7	9.5	17.1
Stage 2	50.0	21.7	12.1	23.8	28.6	14.3
Stage 3	0.0	21.7	12.1	14.3	19.0	17.1
Stage 4	0.0	13.0	18.2	19.0	9.5	37.1
Stage 5	25.0	17.4	18.2	4.8	28.6	11.4
Stage 6	25.0	8.7	24.2	2.4	4.8	2.9
Crown Class (% in class)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Suppressed	75.0	17.4	69.7	7.1	66.7	34.3
Intermediate	25.0	47.8	15.2	57.1	9.5	40.0
Co-dominant	0.0	21.7	6.1	26.2	9.5	14.3
Dominant	0.0	13.0	9.1	9.5	14.3	11.4

Summary of roost characteristics (mean ± SD) for 3 northern long-eared bat (*Myotis septentrionalis*) maternity colonies subjected to different levels of roost removal on the Fort Knox military reservation, Kentucky, USA, pre- and post- roost removal (2011 and 2012) treatment. Significant differences ($P < 0.05$) between groups are indicated by superscripts a–e.

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Table 3. Summary of female northern long-eared bat roost characteristics.
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Distances moved between sequentially used roosts were non-normally distributed with right skew; median distances were between 111.1 and 219.4 m (Table 1). Distances between sequentially used roosts differed only pre- and post-roost removal in our secondary roost removal treatment group (model R^{2c} = 0.18, R^{2m} = 0.08; Tables 1, 4). Overall colony roosting areas were between 1.3 and 58.5 ha (Table 1). Patterns of roosting area space use largely were consistent between pre- and post-treatment in our primary and secondary roost removal treatment groups, particularly evident in the distances between weighted colony roosting area centroids (Table 1, Fig. 1). However, space use by and roosting area centroids of our control colony differed substantially between years (Table 1).

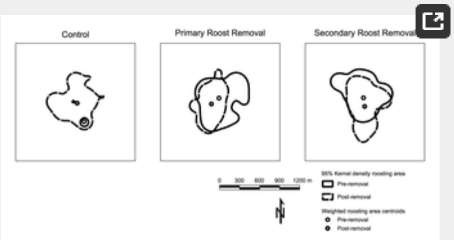

Figure 1. Northern long-eared bat maternity colony roosting areas.
Roosting areas (95% utilization distribution) of 3 northern long-eared bat (*Myotis septentrionalis*) maternity colonies subjected to different levels of roost removal on the Fort Knox military reservation, Kentucky, USA, pre- and post- roost removal (2011 and 2012)
https://doi.org/10.1371/journal.pone.0116356.g001

Predictor	Parameter Estimate	SE	t value	P-value
Intercept	4.50	0.50	0.503	< 0.001
Post-removal	0.47	0.52	0.520	0.37
Treatment: Primary	0.41	0.52	0.519	0.43
Treatment: Secondary	-0.23	0.55	0.547	0.68
Repro: Non-reproductive	0.79	0.43	0.433	0.07
Repro: Post-lactation	-0.17	0.22	0.217	0.44
Repro: Gestating	0.53	0.23	0.227	0.02
Post-removal x Primary	-0.36	0.55	0.549	0.52
Post-removal x Secondary	0.46	0.58	0.580	0.43

Parameter summary of the linear mixed model describing the log transformed non-zero distances moved between sequentially used roosts by female *Myotis septentrionalis* in 3 maternity colonies subjected to different levels of roost removal on the Fort Knox military reservation, Kentucky, USA, pre- and post- roost removal (2011 and 2012) treatment. Repro = bat reproductive condition.

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Table 4. Factors influencing distances moved between roosts by female northern long-eared bats.
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Roost network degree centralization significantly was greater than random for primary removal and control colonies, but not the secondary roost removal colony pre-treatment (Table 1). Roost network clustering differed from random networks in both the primary and secondary roost removal colonies post-treatment, but, for all other colonies, there was no difference from random networks (Table 1). Roost network density did not significantly differ from random networks for any group (Table 1). As represented in the social networks, bats shared between 3.5 and 15.9 social connections with other bats within colonies (Table 5). Social network degree centralization differed from random networks only for the control colony pre-treatment and the primary roost removal treatment post-treatment; the former was significantly less than and the latter significantly greater than equivalent random networks (Table 5). Social network clustering significantly was greater than that of random networks for colonies except the secondary roost removal treatment colony pre-treatment (Table 5). Social network density did not differ from random networks pre-treatment, but was greater in all other cases (Table 5).

	Control		Primary Roost Removal		Secondary Roost Removal	
	Pre	Post	Pre	Post	Pre	Post
Minimum Colony Size	18	20	14	25	13	24
Number of Bats Tracked	15	14	13	25	8	23
Mean Bat Degree	14.0 (± 0.0)	6.7 (± 2.7)	4.6 (± 2.6)	15.9 (± 5.3)	3.5 (± 1.9)	6.1 (± 2.1)
Network Degree Centralization	0 (<)	0.38	0.33	0.37 (>)	0.48	0.14
Network Clustering Coefficient	1 (>)	0.76 (>)	0.74 (>)	0.93 (>)	0.64	0.77 (>)
Network Density	1	0.51	0.38	0.66	0.5	0.28

Pre- and post- roost removal (2011 and 2012) treatment social network metrics for 3 northern long-eared bat (*Myotis septentrionalis*) maternity colonies subjected to different levels of roost removal on the Fort Knox military reservation, Kentucky, USA. Where appropriate, when network metrics differed from random networks, the arrow indicates the direction of difference.

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Table 5. Northern long-eared bat maternity colony social network metrics.
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Visual inspection of the roost network maps indicated that the secondary roost removal colony was split into 2 groups connected only by a single roost post-treatment (Fig. 2). Because these 2 halves possibly represented 2 separate colonies connected by a single ‘chance’ roost use, we conducted a *post-hoc* analysis wherein we removed the roost connecting the 2 network sections (subcolony 1 and subcolony 2) and re-calculated spatial metrics. Roosting area was 46.37 ha for subcolony 1 and 27.43 ha for subcolony 2. Roosting areas of these 2 sections overlapped substantially (UDOI = 1.26).

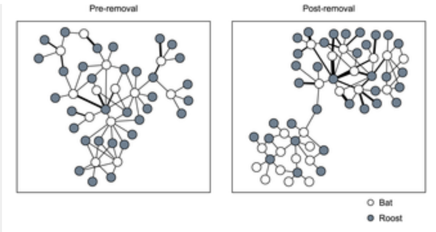

Figure 2. Northern long-eared bat maternity colony roost network map.

Pre- and post- roost removal treatment (2011 and 2012) 2-mode roost network map of a northern long-eared bat (*Myotis septentrionalis*) maternity colony subjected to removal of 5 secondary roosts on the Fort Knox military reservation, Kentucky, USA. Edge width is scaled by the number of connections between a bat and an individual roost.
https://doi.org/10.1371/journal.pone.0116356.g002

Discussion

In our manipulative roost removal experiment, treatments did not result in abandonment of roosting areas by northern long-eared bats. Persistence after exclusion from a roost also has been observed in big brown bats (*Eptesicus fuscus*) in northern forest-prairie transitions zones in Canada [15] and disc-winged bats (*Thyroptera tricolor*) in Costa Rican tropical forests [18], species that both exhibit relatively frequent roost switching. In contrast, syntopic little brown bats (*Myotis lucifugus*), that form larger colonies and roost-switch less than northern long-eared bats, appear to abandon roosting areas after exclusion [16]. Persistence after roost loss may be related to the greater number of roosts used by colonies and to roost ephemerality. Roost fidelity is less in species with more ephemeral roosts [74], therefore, having a variety of alternate roosts or some degree of flexibility in what roosts may be selected may be an adaptation for tolerating roost loss for the northern long-eared bat.

Northern long-eared bat maternity colony roosting areas did not appear to change as a result of either of our roost removal treatments. In contrast, Chaverri and Kunz [18] found that exclusion resulted in larger individual roosting home ranges in disc-winged bats [18] and Borkin et al. [17] found that roost loss resulted in smaller home ranges in New Zealand long-tailed bats (*Chalinolobus tuberculatus*) [17]. Increased home range size in disc-winged bats was related to the need to locate a limiting resource—suitable roosts [18]. However, northern long-eared bats are not extreme roost specialists [32, 75, 76] and potential roosts are not limited on our sites [77]. On the other hand, decreased home range size in New Zealand long-tailed bats as a result of roost loss following clear-cutting, reflected the lack of available roosts and alternative roosting areas in the harvested areas [17]. Locally, large numbers of available roosts may explain why so few roosts were used in both years of our study and why colony locations did not change.

It was surprising that so few roosts were used both pre- and post-treatment, but could be the result of tracking different bats in each year. We captured a substantial proportion of the bats within individual colonies (range 0.62–1.0, $\bar{x} = 0.84$). As such, it is unlikely that our low recapture rate was due to sampling effort. Regardless, roost removal treatments did not impact the number of roosts used by individual bats within treatment areas when controlling for the number of total locations and reproductive condition. The lack of difference in the number of roosts used differs from Borkin *et al.* [17], who found that bats used fewer roosts post-roost loss. The number of roosts used per bat was fewer in 2011 than in 2012 in our control colony, but this is likely due to the fact that the colony was captured and tracked during parturition in 2011 [78]; the number of roosts used per bat in the control colony in 2012 was consistent with that of all other groups. Given the positive relationship between the number of roosts located and the number of days a bat was tracked, differences in the total number of roosts located per colony were not unexpected.

Northern long-eared bats are known to exhibit inter-annual site fidelity of at least 5 years in a mixed pine-deciduous system in Arkansas [79], but our low recapture rates relative to our sampling effort suggest that bats marked during the first year of our study largely were not present in the second. Whether this is due to high annual adult mortality or some other socio-spatial assortment dynamic is unknown, but Perry [79] also recaptured few banded individuals. Consistent patterns of space use between years suggest that, although colony composition changed, colony identity did not. Northern long-eared bat maternity colonies [80] as well as those of some other species [81] contain maternally-related individuals, and it is possible that primarily juveniles from the first year returned in the second. In the context of having tracked different bats within colonies, our data may be interpreted best not as changes in behavior of individual bats resulting from removal treatments, but as differences in patterns of colony behavior at our treatment sites.

In contrast to Chaverri and Kunz [18], we observed no change in roost species selection post-roost removal. This is consistent with the high roost availability at our sites [27]. Roost decay stage and crown class in the primary removal colony were the only roost characteristics to differ between pre- and post-treatment. Selection for more advanced stages of decay in 2011 appears to be correlated with crown class, as trees in advanced stages of decay at our sites are primarily in suppressed crown classes. Although the difference in decay stage and crown class pre- and post-treatment is statistically significant only for the primary removal colony, a similar trend in reduced selection for suppressed roosts in later stages of decay was visible across all colonies in 2012. It is possible that by random chance roost removal caused the difference in roost decay stage and crown class in our findings, but given the lack of difference between roost dbh, height, and canopy openness in the primary removal colony, this seems unlikely. Higher summer temperatures in 2011 than in 2012 on our study site may have caused bats to select trees in more suppressed crown classes, thereby reducing solar heating of roosts. Mean minimum temperature during June–July was 1.78 C° greater in 2011 than in 2012 (National Oceanic and Atmospheric Administration station GHCND: USC00154955); similarly small temperature differences have been found to affect roost selection by Bechstein's bats (*Myotis bechsteinii*) [82] and development of juvenile greater mouse-eared bats (*Myotis myotis*) [83].

Patterns of northern long-eared bat roost use and association, as assessed through roost and social networks, displayed a mix of random and non-random characteristics. The overall character of roost networks relative to random networks was similar within and among treatments. Although there were minor differences in roost and social networks pre- and post-treatment, northern long-eared bat social network structure changes with reproductive condition [84, 85]. After accounting for reproductive condition, the character of the roost networks post-treatment differed only for roost network clustering. The change in roost network clustering from not significantly different from random networks to significantly greater than random networks also was reflected through increased social network density. An increase in roost network clustering and social network density may be an adaptive response to maintain colony stability after roost loss. Such an adaptive response to roost loss could suggest co-evolution between northern long-eared bats and these mixed mesophytic forests and other systems with similar stand dynamics and disturbance patterns, but replication of our study across more regions and forest types is required to document this.

For the secondary roost removal colony, we observed a segmented roost network and the only statistically significant difference in the distance moved between sequentially used roosts. Division of this network into 2 halves as a result of the removal of 24% of roosts would be consistent with previous simulation based outcomes showing that loss of approximately 20% of roosts generates a 50% chance of colony fragmentation [27]. Connection of the 2 halves of this network by a single roost may reflect an incomplete division of the colony. An incomplete division may indicate that colony fragmentation occurs incrementally as roosts are lost, an outcome that theoretically should be most likely to occur if individual roosts are important locations for social interaction. Incomplete colony fragmentation is consistent with our finding that the 2 sections of this colony shared a single roosting area—an observation that was contrary to our *a priori* prediction that colony fragmentation would result in random use of the roosting area, but that may be related to the difference in distances moved between roosts by bats in this colony. Alternately, apparent division also could be the result of unwarranted joining of two separate neighboring colonies as a result of chance use of single roost. Silvis *et al.* [27] speculated that roost sharing may be infrequent and inconsequential at the periphery of the roosting area for northern long-eared bats. In this case, the shared roost was not at the periphery of the colony roosting area and the roosting areas of the 2 sections of the colony overlapped extensively in terms of both extent and concentration of use. Research from other bat species in both temperate and tropical regions suggests that roosting areas are exclusive relatively to individual colonies [17, 30, 31]. Whether this apparent fragmentation is a result of roost removal treatments or some other process remains speculative.

Conclusions

In their review of conservation concerns for bats in the United States, Weller et al. [86] identified a need to transition conservation priorities from focal threats to diffuse threats. In the context of the White-nose Syndrome enzootic that is threatening many species, including the northern long-eared bat, with widespread extirpation, it is necessary to link focal and diffuse threats through understanding of the impacts of specific changes to roosting habitats. Although our study contains limited replicates of our individual treatments, it is to our knowledge the only study to perform targeted roost removal treatments for colonial bats in a temperate forest ecosystem. Clearly, caution should be taken in interpreting the results of individual treatments, particularly with regard to changes in roost and social network structure. However, our results are consistent with previous predictions and anecdotal observations that northern long-eared bats would be robust to low levels of roost loss [20, 22] particularly if loss of these naturally ephemeral roost resources are lost at or below rates of tree mortality / snag loss in temperate forests. Clearly, the maximum levels of annual or cumulative multi-year roost loss that northern long-eared bats can tolerate remains to be determined. It is important to consider that roosts were not limiting at our study sites similar to much of the temperate forested environments where northern long-eared bats occur [10, 87]. However, in more roost limited areas, e.g., in agricultural landscapes with greater forest fragmentation or in industrial forest settings skewed towards younger forest age classes, roost loss may have different consequences for northern long-eared bats.

Monitoring of sufficient numbers of colonies for robust inference is largely infeasible within a single study. Therefore, replication across studies is needed to better confirm or modify the patterns we have observed. With the ongoing spread of White-nose Syndrome in North America, and continued rapid declines in northern long-eared bat populations, replication of this study in disease-free areas is urgently needed. Moreover, a better understanding the impacts of roost loss, whether natural or anthropogenic, on survival and recruitment remains a critical gap in our knowledge of bat ecology.

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Author Contributions

Conceived and designed the experiments: WMF ERB AS. Performed the experiments: AS WMF ERB. Analyzed the data: AS WMF ERB. Contributed reagents/materials/analysis tools: WMF ERB. Wrote the paper: AS WMF ERB.

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CANDIDATE CONSERVATION AGREEMENT
FOR THE
KENTUCKY ARROW DARTER
(*Etheostoma spilotum*)

Adult male Kentucky arrow darter at Conservation Fisheries, Inc. facility in Knoxville, TN.
Photo credit: Kentucky Department of Fish and Wildlife Resources

BETWEEN

U. S. Fish and Wildlife Service, Kentucky Field Office
U.S. Forest Service, Daniel Boone National Forest

July 2015

INTRODUCTION

The Kentucky arrow darter (*Etheostoma spilotum*) is a candidate for federal listing under the Endangered Species Act (ESA) and is currently scheduled to be proposed for federal listing in 2015. Recent surveys by Thomas (2008, pp. 3-6) and the U.S. Fish and Wildlife Service (USFWS) (USFWS 2009, pp. 1-4; 2010, pp. 1-13) revealed that the Kentucky arrow darter has disappeared from large portions of its range. The overall decline of the Kentucky arrow darter can be attributed to a variety of human-related activities in the upper Kentucky River watershed. Activities such as coal mining, past and present silviculture, agriculture, gas/oil well exploration, development, and inadequate sewage treatment have all contributed to the degradation of streams within the range of the species (Branson and Batch 1972, pp. 513-516; Branson and Batch 1974, pp. 82-83; KDOW 2008, pp. 65-101; Thomas 2008, pp. 6-7).

A significant portion of the Kentucky arrow darter's remaining populations occur within the Daniel Boone National Forest (DBNF), with the majority occurring on the Redbird Ranger District. The DBNF's ownership and management contributes substantially to the conservation of the Kentucky arrow darter, making it a significant focus for conservation efforts associated with the species. Therefore, this Candidate Conservation Agreement (CCA) has been developed as a cooperative effort among the USFWS and DBNF to implement proactive Kentucky arrow darter conservation measures within the DBNF.

GOALS AND OBJECTIVES

This CCA is intended to conserve the Kentucky arrow darter on the DBNF by (a) protecting known populations and habitat, (b) reducing threats to its survival, (c) conserving the watersheds and ecosystems on which the species depends, (d) enhancing and/or restoring degraded habitat, and (e) monitoring the outcomes of these conservation efforts. This CCA is intended to establish a framework for the cooperation and participation of the USFWS and DBNF in the Kentucky arrow darter's protection, conservation, and management within the boundaries of the DBNF and addresses both the immediate and long-term conservation and management needs of the species as outlined in the conservation strategy for the species (USFWS 2014). Both parties believe that implementing these measures on the DBNF will assist in reducing the current and potential future threats to the species, thereby significantly contributing to the conservation of the species.

In addition to conserving the Kentucky arrow darter, the CCA may also provide conservation benefits to other federally-listed species and Regional Forester's Sensitive Species on the DBNF. These species are considered directly and/or indirectly dependent on aquatic resources that are shared with the Kentucky arrow darter. These species include, but are not limited to: gray bat (*Myotis griescens*), Indiana bat (*M. sodalis*), northern long-eared bat (*M. septentrionalis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), snuffbox (*Epioblasma triquetra*), and eastern sand darter (*Etheostoma pellucida*).

AUTHORITY

The authority for the respective parties to enter into this voluntary CCA derives from the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1544); the Fish and Wildlife Act of 1956, as amended [16 U.S.C. 742(a)-754]; and the Fish and Wildlife Coordination Act, as amended [16 U.S.C. 661-667(e)]. Section 2 of the ESA encourages parties to develop and maintain conservation programs as a key to safeguarding the nation's heritage in fish, wildlife, and plants. Section 2(c)(1) of the ESA, (16 U.S.C. 1531 (c)(1)), states, "the policy of Congress is that all federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes." Section 7 of the ESA requires federal agencies to review programs that they administer and to utilize such programs in furtherance of the purposes of the ESA.

In addition to the ESA, the Fish and Wildlife Coordination Act of 1956 provides that the Secretary of the Interior shall, "…take such steps as may be required for the development, advancement, management, conservation, and protection of fish and wildlife resources…" The Fish and Wildlife Coordination Act states that the Secretary is authorized "to provide assistance to, and cooperate with, Federal, State, and public or private agencies and organizations in the development, protection, rearing, and stocking of all species of wildlife, resources thereof, and their habitat…"

The USFWS monitors federal candidate species and at-risk species of concern and often facilitates conservation programs for these species. CCAs can help direct specific conservation efforts to these species and outline management practices that will prevent further declines of these species and their habitats. In some cases, conservation actions outlined in a CCA may preclude the need to list such species in the future.

The USFS is a land management agency responsible for 193 million acres of national forests and grasslands within 44 states, Puerto Rico, and the Virgin Islands. These lands serve as habitat for many native plant and animal species, including rare and endangered species. As a result, the USFS has implemented a national policy to specifically manage much of their land for the benefit of sensitive plant and animal species in order to prevent the need for federal listing (USFS Manual 2670).

On January 25, 1994, the USFWS and several other agencies entered into a Memorandum of Understanding (MOU), initiated by the USFS, in order to facilitate the conservation of candidate and other sensitive species. The purpose of the MOU was to establish a framework for cooperation in the conservation of species that are trending toward federal listing. The MOU calls for the development of Conservation Agreements that are intended to address site-specific and species-specific threats. This CCA, since it pertains to a species within the DBNF's boundaries, is also developed under the authority of the 1994 MOU.

http://www.fs.fed.us/biology/resources/pubs/mou_moa/fs_mou_listing_prevention_fy94_SMU_058.pdf

The DBNF's 2004 Revised Forest Land and Resource Management Plan (FLRMP) is a 10-15 year adaptive management plan to guide coordination of multiple uses (such as outdoor recreation, minerals, timber, watersheds, fish and wildlife, and wilderness, etc.) and promote sustained yields of products and services on the DBNF. The FLRMP is a framework for decision-making and does not commit the Forest Service to any specific project or local action. Rather, it describes general management direction, estimates production levels, and assesses the availability and suitability of lands for resource management practices. The FLRMP can be accessed at:

http://www.fs.usda.gov/detail/dbnf/landmanagement/?cid=fsbdev3_032595

The FLRMP is implemented through a series of project-level decisions based on appropriate site-specific analysis and disclosure. The FLRMP does not contain a commitment to select any specific project. Instead, it sets up a framework of Desired Future Conditions with Goals, Objectives, and Standards to guide project proposals. Projects are proposed to solve resource management problems, move the Forest environment toward Desired Future Conditions, and supply goods and services to the public.

FLRMP Goals, Objectives, and Standards, as well as land-use allocations, determine management direction. The FLRMP includes the following goals that are applicable to the purposes of this CCA: (1) manage for the long-term sustainability of diverse ecological systems; (2) manage for ecosystems which are unique and recognized as declining within Kentucky; and (3) enhance threatened, endangered, and sensitive species through restoration of the processes and habitats these populations require. FLRMP Standards, Goals, and Objectives that are specific to Kentucky arrow darter are discussed in more detail in the Conservation Strategy and Commitments section of this CCA.

COOPERATORS AND IMMEDIATE POINTS OF CONTACT

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SPECIES DESCRIPTION AND TAXONOMY

The Kentucky arrow darter is a relatively large darter reaching lengths of up to 125mm. The species has a long slender body, elongated pointed snout, and relatively large mouth (Kuehne and Barbour 1983, p. 71; Etnier and Starnes 1993, p. 523). Base color in males is often a pale yellow to greenish color, but breeding males have a bluish appearance with bright orange bars. The spinous dorsal fin exhibits a blue-green central band and a scarlet marginal band, while the soft dorsal fin is dark blue to black in color with orange speckling. The pelvic and anal fins are dark blue to black in color (Etnier and Starnes 1993, p. 523). However, females retain the pale yellow color year round. The head, breast and opercular flaps are naked, while the breast and nape are often fully scaled, and the infraorbital canal is fully developed. The dorso-lateral line consists of five to seven weak bands that often blend with eight to eleven lateral U-shaped bars, which often become indistinct in larger fish (Kuehne and Barbour 1983, p. 71; Etnier and Starnes 1993, p. 523). Often, there is a vertical bar at the caudal peduncle caused by the fusion of two caudal spots. The mean lateral scale count is less than 59, and the dorsal fin ray and pectoral fin ray counts are 13 and 14, respectively (Kuehne and Barbour 1983, p. 71; Etnier and Starnes 1993, p. 523).

The Kentucky arrow darter was described from the Kentucky River basin (Little Sturgeon Creek, Owsley County) as *Etheostoma nianguae spilotum* (Gilbert 1887, pp. 53-54). Bailey (1948, p. 84) regarded *E. spilotum* Gilbert as a subspecies of *E. sagitta* (Jordan and Swain), and this relationship was later supported by Kuehne and Bailey (1961, p. 1), who recognized two subspecies of *E. sagitta*: *E. s. sagitta* (arrow darter - endemic to the upper Cumberland River basin) and *E. s. spilotum* (Kentucky arrow darter - endemic to the upper Kentucky River basin). The two subspecies and *E. nianguae* (Niangua darter) Gilbert and Meek, a Missouri endemic, comprise the subgenus *Litocara* (Bailey 1948, pp. 79-84; Page 1983, p. 59; Etnier and Starnes 1993, p. 524).

Thomas and Johansen (2008, p. 46) questioned the subspecies status of *E. sagitta* by arguing that (1) the two subspecies, *E. sagitta sagitta* and *E. sagitta spilotum*, were distinguishable based on scale size and development of the lateral line (see note below); (2) the two subspecies existed in allopatry (separate ranges with no overlap); (3) the two subspecies lacked intergrades (intermediate forms); and (4) unpublished genetic data (mitochondrial DNA) suggested evolutionary independence of Kentucky and Cumberland basin populations (with no recent genetic exchange). Based on these analyses, the two arrow darter subspecies have been elevated to species rank (Page and Burr 2011, p. 569; Eschmeyer 2014, p. 1). The Cumberland arrow darter, *E. sagitta* (Jordan and Swain), is restricted to the upper Cumberland River basin in Kentucky and Tennessee, and the Kentucky arrow darter, *E. spilotum* Gilbert, is restricted to the upper Kentucky River basin in Kentucky.

Habitat

Kentucky arrow darters are facultative headwater stream fishes. Lotrich (1973) observed Kentucky arrow darters inhabiting first-, second-, and third-order streams. However, individuals were only found in third-order streams during summer months or prolonged periods of drought and stream stress. Additionally, during 2007 and 2008, Thomas (2008, p. 6) observed Kentucky arrow darters in streams ranging in size from first to third order, with 60 percent occurring in second order streams. The majority (72 percent) of these streams were in watersheds draining an area of 20 square kilometers (km^2) (7.7 square miles [mi^2]) or less.

Kentucky arrow darters are often found in pools or transitional areas between riffles and pools (runs and glides) in moderate-to high-gradient streams. Individuals were usually associated with bedrock, boulder, and cobble substrates and occasionally observed around woody debris. Stream widths ranged from 1.5 to 20 meters (m) (5 to 66 feet [ft]), and depths at which individuals were captured ranged from 10 to 45 centimeters (cm) (4 to 18 in). Many of these habitats, especially those in first order reaches, can be intermittent in nature. For example, Lotrich (1973, p. 394) observed riffle habitats in Clemons Fork (Breathitt County) that were completely dry by late summer. Clemons Fork continued to support Kentucky arrow darters, but these individuals and other fishes were crowded into isolated pools once drying occurred.

Male Kentucky arrow darters establish territories over riffles from March to May, where they are quite conspicuous in water 5 to 15 cm (2 to 6 in) deep (Kuehne and Barbour 1983, p. 71). Males fan out a depression in the substrate and defend these sites vigorously. Initial courtship behavior involves rapid dashes, fin-flaring, nudging, and quivering motions by the male followed by similar quivering responses of the female, who then precedes the male to the nest. The female partially buries herself in the substrate, is mounted by the male, and spawning occurs (Etnier and Starnes 1993, p. 523). It is assumed that the male continues to defend the nest until the eggs have hatched. Bailey (1948) described collected females as "bulging with eggs" in April, which is probably the peak spawning period.

Young Kentucky arrow darters can reach 50 mm TL by the end of the first year (Lotrich 1973, p. 384-385; Lowe 1979), and one-year olds are generally sexually mature and participate in spawning with older age classes (Etnier and Starnes 1993, p. 523). Lotrich (1973, p. 384) indicated mean length at age 2 of about 65 mm (2.6 in) and was unable to differentiate between older age classes (age 3+). Lowe (1979) reported four age classes, but growth was variable after age 1.

Lotrich (1973, p. 381) reported that Kentucky arrow darters captured in 1967 and 1968 from Clemons Fork fed primarily on mayflies, specifically the families Heptageniidae (genus *Stenonema*) and Baetidae. Mayflies comprised 77 percent of identifiable food items (420 of 542 items) in 57 arrow darter stomachs. Large arrow darters (individuals over 70 mm [2.8 in] TL) appeared to specialize on small crayfish, as 7 of 8 stomachs contained crayfish ranging in size from 11 to 24 mm (0.4 to 0.9 in). Lotrich (1973, p. 381) considered this to be noteworthy since stomachs of small arrow darters (<70 mm [2.8 in]) and stomachs of other darter species did not contain crayfish. He suggested that larger Kentucky arrow darters were utilizing a different energy source, thus removing themselves from direct competition for food with other fishes in first and second order streams. This would allow these larger individuals to exploit an abundant food source and survive in extreme headwater habitats. Other food items reported by Lotrich (1973, p. 381) and Etnier and Starnes (1993, p. 523) included larval blackflies (family Simuliidae) and midges (Chironomidae), with lesser amounts of caddisfly larvae, stonefly nymphs, and beetle larvae. Etnier and Starnes (1993, p. 523) reported that juveniles feed on microcrustaceans and dipteran larvae.

Status and Distribution

The Kentucky arrow darter occurred historically in at least 74 streams in the upper Kentucky River drainage of eastern Kentucky (Gilbert 1887, pp. 53–54; Woolman 1892, pp. 275–281; Kuehne and Bailey 1961, pp. 3–4; Kuehne 1962, pp. 608–609; Branson and Batch 1972, pp. 507–514; Lotrich 1973, p. 380; Branson and Batch 1974, pp. 81–83; Harker *et al.* 1979, pp. 523–761; Greenberg and Steigerwald 1981, p. 37; Branson and Batch 1983, pp. 2–13; Branson and Batch 1984, pp. 4–8; Kornman 1985, p. 28; Burr and Warren 1986, p. 316; Measel 1997, pp. 1–105; Kornman 1999, pp. 118–133; Stephens 1999, pp. 159–174; Ray and Ceas 2003, p. 8;

Kentucky State Nature Preserves Commission (KSNPC) unpublished data)). Currently, the species occupies 46 streams across 10 Kentucky counties: Breathitt, Clay, Harlan, Jackson, Knott, Lee, Leslie, Owsley, Perry, and Wolfe (Figure 1) (Thomas 2008, pp. 3–6; USFWS unpublished data). Eight of these streams have been discovered or established since 2000. Current populations occur in the following Kentucky River sub-drainages (with major tributaries):

- North Fork Kentucky River (Troublesome, Quicksand, Frozen, Holly, Lower Devil, Walker, and Hell Creek systems);
- Middle Fork Kentucky River (Big Laurel, Rockhouse, Hell For Certain Creek, and Squabble Creek systems);
- South Fork Kentucky River (Red Bird River, Hector Branch, and Goose, Bullskin, Buffalo, and Lower Buffalo Creek systems);
- Sturgeon Creek (Travis, Wild Dog, and Granny Dismal Creek systems);
- Silver Creek (a direct tributary of Kentucky River); and
- Red River (Rock Bridge Fork of Swift Camp Creek).

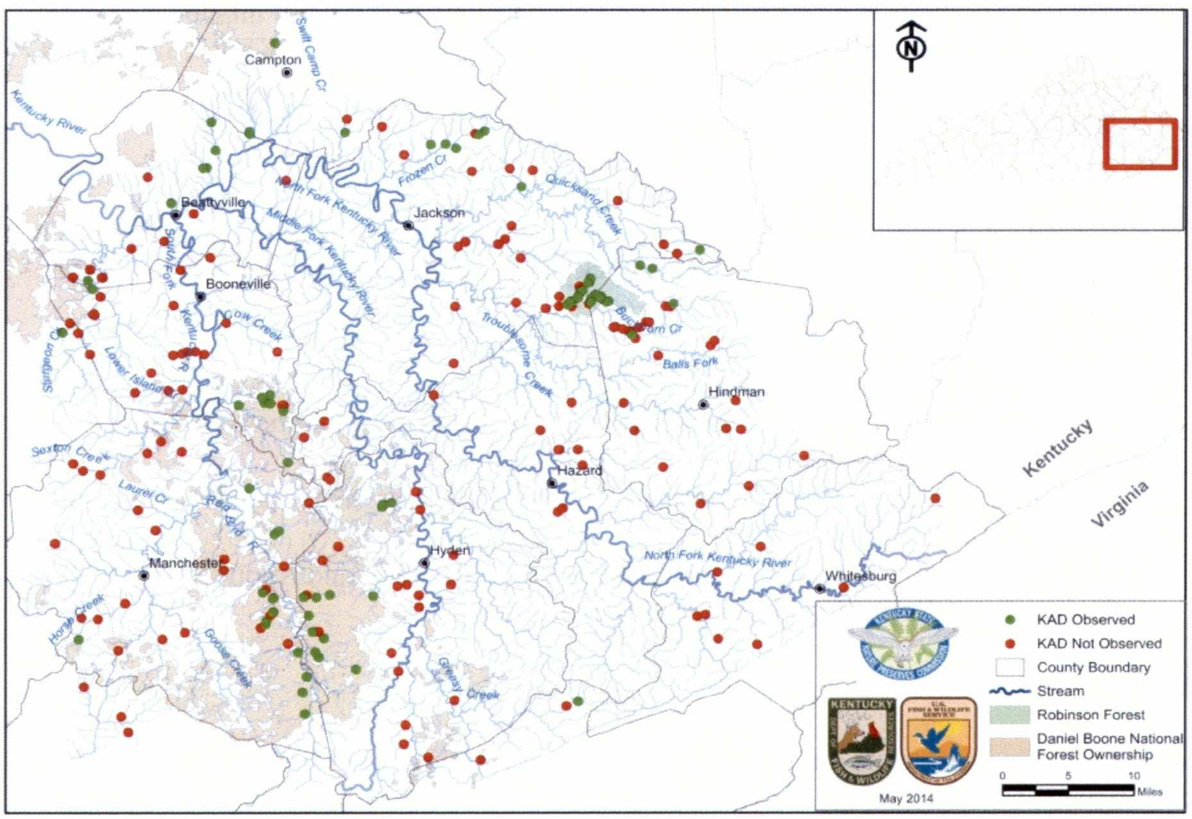

Figure 1. Current distribution of the Kentucky arrow darter based on surveys completed from 2007–2014.

Based on historical records and current data collected since 2007, the Kentucky arrow darter has declined significantly rangewide and has been eliminated from large portions of its former range, including 36 of 74 historical streams. Forty-four percent of the species' extirpations (16 streams) have occurred since the mid-1990s, and the species appears to have disappeared completely from several minor drainages (e.g., Sexton Creek, South Fork Quicksand Creek, Troublesome Creek headwaters). Most remaining populations are highly fragmented and restricted to short stream reaches.

Recent survey data (Thomas 2008, pp. 25–27; USFWS 2012, pp. 1–4) indicate that Kentucky arrow darters occur in low densities. Sampling reaches where arrow darters were observed had an average of only 3 individuals per 100-m (328-ft) reach and a median of 2 individuals per reach (range of 1 to 10 individuals). Surveys in 2011 by the DBNF from Laurel Fork and Cortland Branch of Left Fork Buffalo Creek (South Fork Kentucky River drainage) produced slightly higher capture rates (an average of 5 darters per 100-m (328-ft) sampling reach) (Mulhall pers. comm. 2014). The low abundance values (compared to other darters) are not surprising since Kentucky arrow darters generally occur in low densities, even in those streams where disturbance has been minimal (Thomas pers. comm. 2015).

Detailed information on population size is generally lacking for the species, but estimates have been completed for three streams: Clemons Fork (Breathitt County), Elisha Creek (Clay and Leslie Counties), and Gilberts Big Creek (Clay and Leslie Counties) (USFWS unpublished data). Based on field surveys completed in 2013 by Eastern Kentucky University (EKU), KSNPC, and the USFWS, population estimates included 986–2113 individuals (Clemons Fork), 592–1429 (Elisha Creek), and 175–358 (Gilberts Big Creek) (ranges reflect 95 percent confidence intervals).

Based on observed catch rates and habitat conditions throughout the upper Kentucky River basin, the most stable and largest populations of the Kentucky arrow darter appear to be located in the following drainages/streams:

- Quicksand Creek: Laurel Fork and Middle Fork;
- Red Bird River: several direct tributaries in Clay and Leslie Counties (Redbird Ranger District of DBNF) ;
- North Fork Kentucky River: Frozen and Walker Creeks in Breathitt and Lee Counties; and
- Buckhorn Creek: Clemons Fork and Coles Fork in Breathitt and Knott Counties (University of Kentucky's Robinson Forest).

THREATS

The Kentucky arrow darter's habitat and range have been destroyed, modified, and curtailed by a number of threats, including inputs of dissolved solids and elevation of instream conductivity, sedimentation/siltation, removal of riparian vegetation, bank erosion and channel instability, inputs of untreated sewage, and channel relocation or straightening. The sources of these threats include a variety of anthropogenic activities in the upper Kentucky River basin. Activities such as resource extraction (surface coal mining, silviculture, gas/oil well exploration), land development, rural residential land use, road construction and maintenance, inadequate sewage treatment, and agricultural practices have all contributed to the degradation of streams within the range of the species (Branson and Batch 1972, Branson and Batch 1974, KDOW 2008, Thomas 2008).

The species is also threatened due to the small, remnant nature of its populations. The isolated nature of these populations may prohibit the natural interchange of genetic material between populations, and the small population size may reduce the reservoir of genetic diversity within populations. A more detailed description of these threats can be found in USFWS (2014).

CONSERVATION STRATEGY AND COMMITMENTS

Kentucky arrow darter conservation is a top priority for USFWS and DBNF. The USFWS and DBNF share a variety of interests relative to this species and its habitat, and both agencies are willing to commit resources to conserve the species and its habitat. Over half of the species' extant streams occur on lands at least partially owned and managed by the DBNF, so conservation of these populations is essential to the species' recovery. Therefore, the premise of this CCA is to provide conservation commitments that will continue to protect, enhance, and monitor known populations and potential habitat of the Kentucky arrow darter on the DBNF.

In order to implement this strategy, both parties have identified shared responsibilities, as well as agency-specific commitments that will (1) avoid and minimize impacts to the Kentucky arrow darter on the DBNF; (2) obtain additional data, as research and monitoring opportunities arise; and (3) restore or enhance habitats for the species, thereby contributing to the overall protection and conservation of the species across its range.

Shared Responsibilities

The DBNF and USFWS agree to:

1. Continue to implement management activities that protect and benefit the Kentucky arrow darter and that avoid adverse impacts to the Kentucky arrow darter to the greatest extent possible.

2. Seek funding for carrying out the conservation actions identified below, and collaborate on cost-sharing opportunities as they become available. Both parties understand that all funding commitments made pursuant to this CCA are subject to budget authorizations and approval by the appropriate agency.

3. Meet on an annual basis to evaluate the activities identified in the Agency Responsibilities sections below and determine their effectiveness in conserving the Kentucky arrow darter.

4. Support educational programs involving the Kentucky arrow darter.

Agency Responsibilities

In consideration of the premises of this document, the respective responsibilities and provisions of each party are as follows:

The USFWS agrees to:

1. Continue to report the status of the Kentucky arrow darter, as required, through the annual Candidate Notice of Review (CNOR). The CNOR will be shared with the DBNF on an annual basis.

2. Provide the DBNF with an advanced review and evaluation of management plans and strategies in order to avoid or minimize potential impacts to the Kentucky arrow darter and to ensure that the most recent data regarding the Kentucky arrow darter is being utilized.

3. Provide the DBNF with recommendations on ways to avoid or minimize adverse impacts to the Kentucky arrow darter and its habitat during project review.

4. Seek funding for and support Kentucky arrow darter research, management, and habitat restoration opportunities. Current and future work that is supported by the USFWS includes funding for the following projects:

KDFWR and CFI Propagation / Reintroduction Study on DBNF
In 2005, KDFWR identified the Kentucky arrow darter as 1 of 251 Species of Greatest Conservation Need (SGCN) in its State Wildlife Action Plan (KDFWR 2005, entire). The species remains a SGCN in the most recent version of the plan (KDFWR 2013, pp. 61–62), which identifies conservation issues (threats), conservation actions, and monitoring strategies for 301 animal species belonging to 1 of 20 terrestrial and aquatic habitat guilds (i.e., collections of species that occur in the same habitat). In the original plan, KDFWR developed a priority list of research and survey needs for Kentucky's SGCN. In 2008, KDFWR attempted to address two of these needs by initiating a propagation and reintroduction study for the Kentucky arrow darter through the State Wildlife Grant Program (Ruble *et al.* 2010, entire) that is administered by the USFWS. The study was designed to document details on the species' reproductive biology and to begin conservation actions (e.g., propagation followed by reintroduction or augmentation) that would benefit the species. The KDFWR partnered with Conservation Fisheries Inc. (CFI) to develop successful spawning protocols and produce the offspring needed to augment populations within the species' current range.

From 2009 to 2011, a total of 145 captive-spawned, juvenile Kentucky arrow darters (originating from brood stock taken from Big Double Creek on the Redbird Ranger District) were produced by CFI, tagged (Northwest Marine Technologies elastomer tag), and introduced into Sugar Creek, Leslie County, a tributary of the Red Bird River in the Redbird Ranger District (Thomas and Brandt 2012, pp. 57–64). Attempts to relocate tagged darters in August 2009, October 2009, March 2010, January 2012, and February 2012, were unsuccessful, so KDFWR and CFI made the decision to abandon efforts at Sugar Creek and begin another reintroduction effort at Long Fork, another Redbird Ranger District stream and a tributary of Hector Branch in Clay County.

Since August 2012, a total of 1,447 captive-spawned Kentucky arrow darters (about 50–55 mm TL) have been tagged and reintroduced within a 1.5-km (0.9 mi) reach of Long Fork. Monitoring has been conducted on 14 occasions since the initial release using visual searches and seining methods. Tagged Kentucky arrow darters have been observed during each monitoring event, with numbers increasing from 18 (October 2012) to 86 (August 2013) (Thomas *et al.* 2014, p. 23). Tagged darters have been observed throughout the Long Fork mainstem, both upstream and downstream of the release points, and one tagged individual was observed in the receiving stream, Hector Branch, downstream of its confluence with Long Fork. The majority of individuals have been found in pools (depth of 20–61 cm (8–24 in)) with rock substrates, exposed bedrock, and some marginal cover (e.g., tree roots). Surveys in July, August, and October 2013, produced a total of 20, untagged young-of-year arrow darters, while surveys in March, July, August, and October 2013, produced 25 untagged young-of-year. These results indicate natural reproduction in Long Fork. Additional monitoring and releases are planned for 2015.

KSNPC Range-wide Distributional Study and Habitat Characterization

In 2013, KSNPC and the USFWS initiated a study to investigate the distribution, status, population size, and habitat use of the Kentucky arrow darter within the upper Kentucky River system. One important aspect of the study was to account for imperfect detection when surveying for the species. Studies that do not account for imperfect detection can often lead to an underestimation of the true proportion of sites occupied by a species and can bias assessments and sampling efforts (MacKenzie *et al.* 2002, entire; MacKenzie *et al.* 2005, entire). From June to September 2013, KSNPC and the USFWS visited 80 randomly-chosen sites (ranging from first- to third-order) across the upper Kentucky River basin in order to address these concerns. As expected, Kentucky arrow darters were rare during the study and were observed at only 7 of the 80 sites, including two new localities (Granny Dismal Creek in Owsley County and Spring Fork Quicksand Creek in Breathitt County) and one historical stream (Hunting Creek, Breathitt County) where the species was not observed during status surveys by Thomas (2008, pp. 1–33) and the USFWS (2012, pp. 1–4). Presently, KSNPC and the USFWS are in the data analysis stage of this project.

EKU Movement Study and Population Estimate

The USFWS and KDFWR are working with EKU on a study that is investigating Kentucky arrow darter movements, habitat characteristics, and population size in two DBNF streams, Gilberts Big Creek and Elisha Creek, in Clay and Leslie Counties (Harrel and Baxter 2013, entire). EKU is using PIT-tags and placed antenna systems to monitor intra- and inter-tributary movement patterns in both streams, and they have collected seasonal (Spring, Summer, and Fall of 2013) biotic and abiotic data from 20 100-m (328-ft) reaches to determine habitat use and population density/size for both streams. Preliminary results of this work include the following:

- 126 individuals were marked (pit-tagged);
- Population estimates were determined for Elisha Creek: 592–1429 individuals (Summer) and 661–1,359 (Fall) (range here and below reflects 95 percent confidence

intervals); and for Gilberts Big Creek: 175–358 (Summer);

- Data on maximum movement distances were determined: 4,078 m (2.5 mi) for a female Kentucky arrow darter that moved downstream in Gilberts Big Creek; and
- Data on other observed movements were calculated for 7 individuals: 134 m (439 ft) (upstream), 328 m (1,076 ft) (downstream), 351 (1,151 ft) (upstream), 900 m (2,952 ft) (upstream/ downstream), 950 m (3,116 ft) (downstream), 1,282 m (4,028 ft) (downstream) and 1,708 m (5,603 ft) (downstream).

5. Identify other project opportunities as they become available that could include: (1) securing funding for propagation, (2) surveying for new populations, and (3) working with the mining, oil and gas, transportation, forest resources, and agricultural industries to develop BMPs to protect the Kentucky arrow darter and its habitat.

6. Develop a long-term monitoring program for the species as personnel and funding allow.

7. Assist the DBNF in developing and implementing a task list to prioritize conservation and restoration needs of the Kentucky arrow darter within the DBNF, which would include identifying and rehabilitating areas that impede fish passage or have been impacted by oil and gas exploration in known or potential Kentucky arrow darter habitat.

8. Lead an annual Kentucky arrow darter meeting to discuss the results of implementing this CCA.

The DBNF agrees to:

1. Continue to support research to better determine the population numbers, range, habitat, behavior, and specific management requirements of the Kentucky arrow darter, as funding and personnel are available. The DBNF has agreed to provide support for the studies currently being funded by the USFWS (listed above), which are being completed, in part, on the DBNF. Support includes, but is not limited to, providing site access information and field assistance.

2. The DBNF will provide input to the USFWS's long-term monitoring program on the DBNF for the Kentucky arrow darter. DBNF will provide assistance in monitoring as personnel and funding allow.

3. Work with the USFWS to inventory and map natural gas lines, oil wells, roads, other facilities, land ownership, and mineral ownership within Kentucky arrow darter watersheds on the DBNF.

4. Work with the USFWS to evaluate the potential threat(s) posed by natural gas/oil development and surface coal mining within selected Kentucky arrow darter watersheds within the DBNF.

5. Seek opportunities to restore, enhance, and/or maintain Kentucky arrow darter habitat in coordination with FLRMP standards and implement those opportunities as funding and other resources allow. Current and future work includes the following projects:

- Elisha Creek Stream Restoration – This project improves habitat conditions within Elisha Creek, which is occupied by Kentucky arrow darters.

- Sugar Creek Aquatic Organism Passage – This project would replace an existing, perched culvert that is currently impeding Kentucky arrow darter movements within this watershed.

- Gilbert's Creek Improvement Project – This project improves habitat conditions in Gilbert Creek, which is occupied by Kentucky arrow darters, and also replaces an existing, deteriorating culvert that is currently impeding Kentucky arrow darter movement within this watershed.

- Big Double Creek Road Improvement Project – This project would repair an existing, deteriorating road that is contributing a significant amount of sediment into Big Double Creek, which is occupied by Kentucky arrow darters.

- Redbird River Watershed Collaboration – This is a partnership with Kentucky Pride to provide outreach to local residents and special interest groups that focuses on improving water quality within the Redbird River watershed, which includes streams occupied by Kentucky arrow darters. The PRIDE initiative is coordinated by Eastern Kentucky PRIDE, Inc., a nonprofit organization. It links citizens with the resources of local, state, and federal agencies to improve the region's water quality, clean up solid waste problems, and advance environmental education.

6. Develop and implement a task list to prioritize conservation and restoration needs of the Kentucky arrow darter within the DBNF, which would include, but not be limited to, identifying and rehabilitating areas that impede fish passage or have been impacted by oil and gas exploration in known or potential Kentucky arrow darter habitat.

7. Submit management plans and strategies to the USFWS for review so that the Service can make recommendations to avoid or minimize potential impacts to the Kentucky Arrow darter and to ensure the most-recent data regarding the Kentucky arrow darter is being utilized in the development of those management plans and strategies.

8. Participate in an annual Kentucky arrow darter meeting to discuss the results of implementing this CCA.

9. Continue to implement the Forestwide Standards and Prescription Area Standards that are included within the FLRMP that are considered beneficial to the Kentucky arrow darter and are listed below. While this list not all-inclusive, it provides examples of actions that will assist in conserving the Kentucky arrow darter and its habitat, as well as other federally-listed species, and Regional Forester's Sensitive Species that may inhabit the same areas.

FLRMP Forestwide Standards: Forestwide standards are mandatory standards that generally preclude or impose limitations on resource management activities/uses, and are within the authority and ability of the Forest Service to enforce. A project that deviates from a relevant

Standard may not be authorized unless the FLRMP is amended to modify, remove, or waive application of the Standard.

The following Forestwide standards are considered beneficial to the conservation of the Kentucky arrow darter because they (1) protect known/potential habitat, (2) avoid or minimize direct and indirect impacts to the Kentucky arrow dater and its habitat, (3) maintain or improve water quality within known or potential habitat for the species, (4) protect riparian habitat, and (5) protect aquatic resources from impacts associated with sediment and erosion:

- DB-ENG-3. Locate fords only where bottom and biological conditions will support the designed use. Maintain stream channel contour and grade when modifying a crossing.

- DB-ENG-5. When culverts are removed, restore stream banks and channels to a natural size and shape. Stabilize disturbed areas.

- DB-WLF-14. Activities that create a toxic water source (e.g. brine pits and oil catch basins) must be filled, covered, or otherwise modified in an environmentally appropriate manner to prevent contact with wildlife.

- DB-VEG-6. Do not permit use of stream channels for skid roads or trails.

- DB-VEG-8. Herbicides will be applied at the lowest rate effective in meeting project objectives and according to guidelines for protecting human and wildlife health. Application rate and work time must not exceed levels that pose an unacceptable level of risk to human or wildlife health. The USDA Forest Service, Southern Region standard for acceptable level of risk requires a Margin of Safety (MOS) > 100 or, Hazard quotient (HQ) < 1.0.

- DB-VEG-12. No herbicide is to be applied aerially.

- DB-VEG-18. Application equipment, empty herbicide containers, clothing worn during treatment, and skin are not to be cleaned in open water or wells. Mixing and cleaning water must come from a public water supply and be transported in separate, labeled containers.

- DB-VEG-19. No herbicide shall be applied within 30 horizontal feet of lakes, wetlands, perennial or intermittent springs (seeps) and streams. However, herbicides approved for aquatic use may be used when such treatment is required to control invasive plants.

- DB-VEG-21. Herbicide mixing, loading, or cleaning areas in the field are not to be located within 200 feet of private land, open water or wells, or other sensitive areas.

- DB-VEG-27. Resource management activities that may affect soil and/or water quality must follow applicable Kentucky Rules and Regulations for Water Quality Control and Kentucky's Best Management Practices for Forestry (BMPs) as a minimum to achieve soil and water quality objectives. When Forest Plan standards exceed Kentucky BMPs or water quality standards, Forest Plan standards shall take precedence.

- DB-FIRE-1. Slash burns are to be prescribed so they do not consume all litter and duff and alter structure and color of mineral soil on more than 20 percent of the burn area.

- DB-FIRE-2. Do not conduct a prescribed burn in an area where more than half of the soils are severely erodible with an average of less than one-half inch of litter and duff.

- DB-LAND-3. Prior to issuing new or re-issuing existing well/spring permits or diversions of water from streams or lakes, determine the in-stream flow or lake levels necessary to protect stream processes, aquatic and riparian habitats and communities, and recreation and aesthetic values.

Prescription Areas: A Prescription Area is an allocation of one or more parcels of land within which resource conditions and corresponding management emphasis are similar and have specific Goals, Objectives, and Standards. Some Prescription Areas describe previous designations; others address current issues and new management emphases. The DBNF has identified two Prescription Areas that are likely to help conserve the Kentucky arrow darter: (1) Riparian Corridor and (2) Right Fork of Elisha Creek Proposed Research Natural Area. These two Prescription Areas benefit the Kentucky arrow darter by imposing more-stringent Goals, Objectives, and Standards than would apply to the general Forest area. These additional Goals, Objectives, and Standards emphasize protection of the riparian area to maintain or improve water quality which has been identified as crucial to conserving Kentucky arrow darters.

RIPARIAN CORRIDOR PRESCRIPTION AREA

As described in the FLRMP, the Riparian Corridor Prescription Area (RCPA) encompasses all riparian areas, as well as adjacent associated upland components. A riparian area is functionally defined as a three-dimensional ecotone of interaction that includes both terrestrial and aquatic ecosystems. It is identified on the ground as one of the following: a perennial stream or other perennial water body (with the exception of artificial upland ponds and the Large Reservoirs Prescription Area), or intermittent stream, as well as the associated soils, vegetation and hydrology. The width of the RCPA varies but is always measured from the edge of the channel or bank. The RCPA encompasses, at a minimum, the 100-year flood plain or 100 feet from each bank for perennial streams and 50 feet from each bank for intermittent streams, whichever is greater.

Desired Future Condition (DFC) is defined in the FLRMP as land or resource conditions that are expected to result if goals and objectives are fully achieved. It is an integrated visualization of what the forest, management area, or prescription area should look like in the future. The DFC guides forest management actions. The DFC for the RCPA benefits the Kentucky arrow darter because the primary objective of the DFC is to retain, restore, and/or enhance the inherent ecological processes and functions of the associated aquatic, riparian, and upland components. Primarily, only natural processes (floods, erosion, seasonal fluctuations, etc.) modify the landscape and resources within the area. However, management may take place to:

a) Provide terrestrial or aquatic habitat improvement;
b) Favor recovery of native vegetation;
c) Sustain or enhance aquatic or riparian-associated species;
d) Control insect infestation and disease;
e) Comply with legal requirements;
f) Provide for public safety; and
g) Support other riparian functions and values.

The following Goals, Objectives, and Standards for the RCPA are specific to Kentucky arrow darter conservation. The Goals and Objectives guide the DBNF towards the Desired Future Condition for the RCPA, while the Standards are meant to be more restrictive than the Forestwide Standards, and are in-place to further conservation within the RCPA. By protecting and enhancing the riparian corridor, RCPA should (1) protect the riparian habitat of streams utilized by the Kentucky arrow darter; (2) improve or maintain water quality; (3) improve or maintain soil/bank stability in the riparian area; (4) improve or maintain the riparian area; (5) restore native cane to provide soil stabilization within riparian areas; (6) provide greater habitat connectivity; and (7) prioritize areas within which the Kentucky arrow darter is known to occur.

RCPA Goals and Objectives

- 1.E-Goal 1. Restore and maintain native aquatic biodiversity.

- 1.E-Objective 1.A. Ensure stable or improving trends of aquatic macro-invertebrate assemblages (e.g., aquatic insects, mollusks, etc.).

- 1.E-Goal 2. Restore and maintain native species composition as well as the structural diversity of plant communities in riparian areas and wetlands. This goal seeks to provide habitat for numerous vascular and nonvascular plants, amphibians, birds, and mammals associated at least in part with riparian areas.

- 1.E-Objective 2.A. Perpetuate native riparian forest type groups such as conifer-northern hardwoods, mesophytic hardwoods, or the river flood plain hardwood and eastern river front types.

- 1.E-Objective 2.D. In each Management Area, establish and maintain one to two percent of the riparian area along 4th order and larger streams (all ownerships) in canebrakes of up to ten acres. Existing openings will be used whenever possible. Approximately 50 percent will be in sparse overstory (<40 BA) trees. This objective seeks to restore cane to the riparian areas and provides habitat benefits for Swainson's warbler and the Kentucky arrow darter.

- 1.E-Objective 2.F. Prevent, control, or eradicate populations of non-native invasive species.

- 1.E-Goal 3. Maintain and restore the water quality (biological and chemical integrity) necessary to support healthy riparian, aquatic, and wetland ecosystems, and to ensure survival, growth, reproduction, and migration of aquatic or riparian-associated species.

- 1.E-Objective 3.A. Concentrate restoration efforts in watersheds with impaired water bodies on Kentucky's Clean Water Act, Section 303(d) list or in watersheds that are a high priority for protection.

- 1.E-Objective 3.B. Reduce the number of impaired water bodies on Kentucky's Clean Water Act, Section 303(d), list that are located within the DBNF.

- 1.E-Goal 4. Maintain and restore the physical integrity of aquatic ecosystems, including stream banks, substrate, shorelines, coarse woody debris, riffles, and other components of this habitat.

- 1.E-Objective 4.A. Human activities should not cause water temperatures in cool- and cold-water streams to exceed their natural seasonal temperature ranges.

- 1.E-Goal 5. Restore and maintain a stable sediment regime that includes the timing, volume, rate, and character of sediment input, storage, and transport.

- 1.E-Objective-5.A. Sustain sedimentation rates that maintain or improve biological conditions. Measure rates using best available channel stability techniques.

- 1.E-Objective-5.B. Where feasible, new roads should be located outside the Riparian Corridor. If a road is located in the Riparian Corridor, construct to protect riparian functions and values.

- 1.E-Goal 6. Provide for unrestricted movement of aquatic fauna, except for existing approved dams.

- 1.E-Objective 6.A. Remove or reconstruct artificial structures that impede the movement of aquatic organisms.

- 1.E-Objective 6.B. Reduce or remove contaminants that impede the movement of aquatic organisms.

- 1.E-Objective 6.C. Inventory within two years all artificial structures in streams with Proposed, Endangered, Threatened, or Sensitive (PETS) species. Each year improve, rehabilitate, or remove 20 percent of structures that adversely impact passage of aquatic organisms; give priority to passageways for aquatic PETS species.

- 1.E-Goal 7. Protect the riparian ecosystem while providing for a reasonable amount of compatible recreation.

- 1.E-Objective 7.A. Inventory dispersed camping sites within 100 feet of perennial streams, in conjunction with annual integrated inventories. Examine 20 percent of known sites annually and designate and rehabilitate or close. Give priority to sites in proximity to aquatic PETS species.

RCPA Standards

- 1.E-MIN-1. All federal mineral activity will be implemented in accordance with the Desired Future Condition and Standards of this Prescription Area; and, depending on site-specific determination, the Forest Service may specify that the surface is not to be disturbed during mineral exploration or development. New federal oil and gas leases will contain either a No-Surface-Occupancy stipulation or a Controlled-Surface-Use stipulation. A No-Surface-Occupancy stipulation (NSO) is a mineral leasing stipulation that prohibits occupancy or disturbance on all or part of the land surface to protect special values or uses. A Controlled-Surface-Use stipulation is a minerals leasing stipulation that refers to the special operational constraints that may modify a lessee's rights when resource values have been identified. Allowed use and occupancy (unless restricted by another stipulation) with identified resource values requiring special operational constraints that may modify the lease rights.

- 1.E-MIN-2. Do not remove common variety minerals, such as sand and gravel, from stream channels, except as necessary to reduce undesirable buildup at stream crossings.

- 1.E-MIN-3. Allow non-commercial mineral collection only under terms of a special use authorization where it does not adversely affect stream channel stability, substrate, aquatic species, or their habitat.

- 1.E-ENG-1. Construction of any new stream crossings must not adversely affect passage of aquatic organisms or alter stream flow. Exceptions may be allowed to prevent the upstream migration of undesired species.

- 1.E-ENG-2. Locate fords only where bottom conditions will support the designed use. Maintain stream channel contour and grade when modifying a crossing; armor the bottom with materials that will provide for movement of fish.

- 1.E-ENG-3. Where risks of resource damage are high, each road segment will be constructed and stabilized prior to starting another segment (stage construction). High-risk areas are those that contain landslide-prone areas, steep slopes, highly erosive soils, or PETS species.

- 1.E-WLF-1. Prohibit in-stream substrate disturbance by mechanical equipment from February 1 through July 31, if aquatic PETS species occur within one-quarter mile upstream and one mile downstream of the project site.

- 1.E-WLF-2. Where existing grassy openings cause adverse impacts to riparian and aquatic associated species, they will be rehabilitated or no longer maintained as a grassy opening.

- 1.E-WLF-3. New grassy openings will be established only where needed to provide habitat for aquatic or riparian-associated species.

- 1.E-REC-1. No new trails for off-highway vehicles, bicycles, horses, and other non-pedestrian modes of transportation are to be constructed within the area, except to approach and cross at designated sites, or where the trail location requires some encroachment (e.g. to accommodate steep slopes).

- 1.E-REC-2. Do not allow overnight tethering or corralling of horses or other livestock within 100 feet of stream courses or 300 feet of other water bodies. Maintain existing corral sites to limit impacts to water quality and riparian corridors.

- 1.E-REC-3. Any trail construction must be accomplished in accordance with relevant state Best Management Practices or Forest Service regional/national direction for erosion control (e.g., USFS Region 8 Trails South).

- 1.E-REC-4. Proposed or new facilities must be developed in accordance with Executive Orders 11988 (for 100-year flood plains) and 11990 (for wetlands). Alternative locations must be considered for all new facilities. Where none exist, potential impacts must be mitigated to moderate the severity of those impacts.

- 1.E-REC-5. Areas will be managed to meet or exceed Recreation Opportunity Spectrum experiences of semi-primitive non-motorized, semi-primitive motorized, and roaded natural areas. Recreation Opportunity Spectrum (ROS) is a framework for stratifying and defining classes of outdoor recreation environments, activities and experience opportunities along a spectrum defined by the following six classes of opportunities:
- Primitive – Mimimum modification.
- Semi-primitive non-motorized – Minimum modification. Motorized access is not allowed.
- Semi-primitive motorized – Minimum modification. Motorized access is allowed.
- Roaded natural – Moderate modification.
- Rural – Heavy modification.
- Urban – High degree of modification.

- 1.E-REC-6. New non-motorized trail construction is allowed to improve existing trail configuration and improve access to streams, lakes and the riparian corridor.

- 1.E-REC-7. Motorized and non-motorized trail reconstruction and relocation within the riparian corridor are allowed to reduce impacts to riparian and aquatic resources.

- 1.E-VEG-1. Cable logging corridors, cable sets, and tail trees may be installed in this Prescription Area only at designated locations. Full suspension will be required if logs are yarded across perennial or intermittent streams.

- 1.E-VEG-2. All motorized equipment must be serviced outside of riparian corridors.

- 1.E-VEG-3. Cut-and-leave will be the preferred method for control and suppression of insects and disease in the Riparian Corridor. Other control measures may be used when a condition poses a risk to stream stability, degrades water quality, adversely affects habitat for aquatic or riparian-associated species, poses a threat to public safety or facilities, or when the purpose or need for action will not be met.

- 1.E-VEG-4. Skid roads and skid trails used for management of adjacent Prescription Areas must not encroach upon the riparian corridor.

- 1.E-VEG-5. The removal of coarse woody debris (pieces greater than 3 feet long and 4 inches in diameter on the small end) is allowed only if it poses a risk to public safety or water quality, degrades habitat for aquatic or riparian-associated species, or when it poses a threat to private property or Forest Service infrastructures.

- 1.E-VEG-6. Collection of non-timber forest products within 50 feet of a perennial or intermittent stream is subject to the following restrictions:

    - Personal use moss collection is prohibited.

    - Collection of other species within this zone is limited to those species that cannot be feasibly collected elsewhere (e.g., no collection of Rhododendron is allowed within riparian areas because it can be collected on upland or midslope sites.).

    - For ground disturbing activities (transplants, root digging, etc.) a maximum of 10 plants will be allowed per permit, with no more than two permits sold to an individual per year.

    - Non-destructive activities (seed collection, cuttings, etc.) are allowed for all species unless otherwise prohibited.

- 1.E-FIRE-1. Do not construct prescribed firelines with heavy, mechanized equipment (e.g., trackhoes and bulldozers).

RIGHT FORK OF ELISHA CREEK PROPOSED RESEARCH NATURAL AREA

In addition to the conservation benefits provided by the RCPA designation, the DBNF has also proposed that the Right Fork of Elisha Creek (RFEC) be designated as a Research Natural Area

(RNA). A RNA is an "ecological area designated in perpetuity for research and education and/or to maintain biological diversity on National Forest System lands." The Vegetation Management and Protection Research Work Unit of the Southern Forest Experiment Station manages designated areas to maintain biological diversity, conduct non-manipulative research and monitoring, and foster education. Proposed RNAs, such as RFEC, are managed by the DBNF until they receive RNA-designation by the Forest Service Chief. This prescription area is currently being managed for old-growth forest stands according to the Desired Future Condition, Goals, Objectives, and Standards outlined below, until the time it is designated as a RNA.

The RFEC is located in the headwaters of the Right Fork of Elisha Creek, a tributary of the Redbird River in west central Leslie County, on the Redbird Ranger District. It is known habitat for the Kentucky arrow darter. Maintaining the RFEC in a natural condition assists in maintaining the riparian area surrounding Elisha Creek, thus supporting long-term conservation of the Kentucky arrow darter population in Elisha Creek.

The following Goals, Objectives, and Standards for this prescription area benefit the Kentucky arrow darter by limiting disturbance in the prescription area and by ensuring that management activities will maintain or improve the existing conditions within the riparian area surrounding the headwaters of Elisha Creek. If the area is designated as a RNA, additional conservation measures may be employed, which could provide additional benefits to the Kentucky arrow darter.

RFEC Goals and Objectives

- 1.A-Goal 1. Follow direction of and cooperate with the Southern Forest Experiment Station in management of these areas.

- 1.A-Objective 1.A. Management objectives for these areas will be determined by the Southern Forest Experiment Station. The management of Right Fork of Elisha Creek proposed Research Natural Area would be the responsibility of the DBNF until they are designated by the Forest Service Chief to be Research Natural Areas. This area is to be managed to retain the value that qualified it to be nominated as a Research Natural Area.

- 1.A-Objective 1.B. The Recreation Opportunity Spectrum objective is Semi-primitive Non-motorized.

- 1.A-Objective 1.C. Reroute existing trails outside of the Research Natural Area, unless approved by the management plan.

RFEC Standards

- 1.A-LAND-1. If Right Fork of Elisha Creek is designated as a Research Natural Area, it will remain in this prescription and be managed accordingly.

- 1.A-LAND-3. If the Right Fork of Elisha Creek Proposed Research Natural Area is not designated a special area, its stands will be inventoried and allocated into Prescription Area 1.I., Designated Old-Growth.

- 1.A-MIN-1. The surface is not to be disturbed during any federal mineral exploration or development activity; development of federally owned oil and gas is subject to the No-Surface-Occupancy stipulation.

- 1.A-MIN-2. No extraction permits will be issued for common variety minerals, e.g., sand and gravel.

AGREEMENT MANAGEMENT

The USFWS and DBNF agree and recognize that the effectiveness of all conservation measures and monitoring methods will be reviewed by both parties annually. Based on this annual review, appropriate modifications to the CCA will be incorporated as necessary and appropriate to further the goals of the CCA.

MODIFICATION OF AGREEMENT

This CCA can be modified with the written approval of the USFWS and USFS. Any proposed modifications shall be provided to each party.

In the event the Kentucky arrow darter is listed as a threatened or endangered species under the ESA, it is the intent of both parties that this agreement and its respective obligations shall remain in-effect as long as the agreement and the respective obligations do not violate the ESA or other applicable statute, the policies of either the USFWS or USFS, or result in unintended negative effects on the Kentucky arrow darter or its habitat. If the species is listed as threatened or endangered, this agreement will cease to be a "Candidate Conservation Agreement" and shall, instead, become a "Conservation Agreement", and all references to "Candidate Conservation Agreement" or "CCA" shall be automatically modified to "Conservation Agreement" and "CA", respectively.

DURATION OF AGREEMENT

The duration of this CCA is ten (10) years following the date of the last signature below, or until the FLRMP is revised. No obligation shall be in effect after expiration of this CCA, with the exception of normal provisions of the Endangered Species Act or other applicable statute.

The parties involved will annually review the CCA and its effectiveness to determine whether revision is necessary. During the last month in which it is valid, the CCA must be reviewed and either modified, renewed, or terminated. If any of the agreed-upon responsibilities of the CCA are no longer feasible or if termination of the CCA is desired, the requesting party will provide written notification to all Cooperators 30 days prior to terminating the agreement.

SIGNATURES

The parties identified herein have caused this Kentucky Arrow Darter Candidate Conservation Agreement to be executed as of the date of the last signatures shown on the following pages

CANDIDATE CONSERVATION AGREEMENT for the Kentucky Arrow Darter

08/31/2015

Tony Tooke Date
Regional Forester
Southern Region

CANDIDATE CONSERVATION AGREEMENT for the Kentucky Arrow Darter

8/31/15

Cynthia K. Dohner Date
Regional Director
USFWS – Southeast Region

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Programmatic Biological Opinion on Final 4(d) Rule for the Northern Long-Eared Bat and Activities Excepted from Take Prohibitions

U.S. Fish and Wildlife Service
Regions 2, 3, 4, 5, and 6

Prepared by:
U.S. Fish and Wildlife Service
Midwest Regional Office
Bloomington, Minnesota
January 5, 2016

Lynn Lewis
Lynn Lewis, Assistant Regional Director, R3

1/5/16
Date

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EXECUTIVE SUMMARY

This Endangered Species Act (Act) Biological Opinion (BO) addresses the effects to the northern long-eared bat (NLEB) resulting from the Service's finalization of a special rule under the authority of section 4(d) of the Act. It also evaluates activities that the Service proposes to prohibit and except from take prohibitions under the final 4(d) rule. In the request for intra-Service consultation, the Service proposes a framework for streamlined section 7 consultation for other federal actions that may affect the NLEB and are consistent with the provisions of the 4(d) rule. This is a programmatic intra-Service consultation, because it addresses multiple actions on a program basis conducted under the umbrella of the final 4(d) rule. The Service has not designated or proposed critical habitat for the NLEB; therefore, this BO does not address effects to critical habitat. Because we anticipate continued NLEB declines as white-nose syndrome (WNS) spreads, this BO will cover the next 7 years that the disease is minimally expected to spread and impact the NLEB throughout its entire range. The Service will reinitiate consultation by the end of 2022 or earlier if the standard reinitiation criteria are triggered.

The final rule addresses both purposeful take and incidental taking of the NLEB, with certain differences distinguished based on the occurrence of WNS as follows:

- The final 4(d) rule prohibits purposeful take of NLEBs throughout the species' range, except when (1) necessary to protect human health; (2) in instances of removal of NLEBs from human structures; or (3) the authorized capture and handling of NLEBs by individuals permitted to conduct these same activities for other bat species until May 3, 2016.
- The final 4(d) rule does not prohibit incidental take resulting from otherwise lawful activities in areas not yet affected by WNS (i.e., areas outside of the WNS zone).
- Within the WNS zone, the final 4(d) rule prohibits incidental take of NLEBs in their hibernacula, which may be caused by activities that disturb or disrupt hibernating individuals when they are present as well as the physical or other alteration of the hibernaculum's entrance or environment when bats are not present.
- Incidental take of NLEBs outside of hibernacula resulting from activities other than tree removal is not prohibited provided they do not result in the incidental take of NLEBs inside hibernacula.
- Incidental take resulting from tree removal is prohibited if it: (1) occurs within 0.25 miles (0.4 km) of known NLEB hibernacula; or (2) cuts or destroys known, occupied maternity roost trees or any other trees within a 150-foot (45-meter) radius around the known, occupied maternity tree during the pup season (June 1 to July 31).
- Removal of hazardous trees for the protection of human life and property is not prohibited.

Federal agencies can rely upon the finding of this BO to fulfill their project-specific section 7(a)(2) responsibilities if they utilize the optional framework as described. The framework requires prior notification of activities that may affect the NLEB, along with a determination that the action would not cause prohibited incidental take. Service concurrence with the action agency determination is not required, but the Service may advise the action agency whether additional information indicates project-level consultation for the NLEB is required. If the Service does not respond within 30 days, the action agency may consider its project responsibilities under section 7(a)(2) with respect to the NLEB fulfilled through this programmatic BO. Action agencies must also report if actions deviate from the determination, along with the surveys of any surveys.

The Action Area addressed in this BO includes the entire range of the NLEB within the United States, which includes all or portions of 37 States and the District of Columbia from Maine west to Montana, south to eastern Kansas, eastern Oklahoma, Arkansas, and east to South Carolina. Within the Action Area, the WNS zone currently includes all or most of the states within the species' range except North Dakota, Montana, South Dakota, and Wyoming.

Status of the NLEB

The disease WNS is the primary factor affecting the status of the NLEB, which has caused dramatic and rapid declines in abundance. Data support substantial declines in the Eastern range and portions of the Midwest range. We expect further declines as the disease continues to spread across the species' range. NLEBs continue to be distributed across much of the historical range, but there are many gaps where bats are no longer detected or captured, and in other areas, their occurrence is sparse given local declines and extirpations. Although significant NLEB population declines have only been documented due to the spread of WNS, other sources of mortality could further diminish the species' ability to persist as it experiences ongoing dramatic declines.

We estimate that the range-wide population of NLEBs is comprised of about 6.5 million adults. This population estimate was calculated for the purposes of assessing the potential relative impact of activities contemplated in this BO, and it has limitations and a substantial amount of uncertainty.

Effects of the Action

The NLEB is likely to be affected by many activities which are not prohibited in the final 4(d) rule. We address the general effects of different activities, which we categorized into 7 general groups: (1) capture and handling of NLEBs by individuals with section 10(a)(1)(A) permits for other listed bats or State permits until May 3, 2016; (2) removal from human structures; (3)

timber harvest; (4) prescribed fire; (5) forest conversion; (6) wind turbine operation; and (7) other activities that may affect the NLEB. The effects of category #1 are not addressed in this consultation.

Based on the available scientific literature, we identified various pathways by which environmental changes (stressors) caused by the Action may affect individual NLEB and the expected responses of individuals exposed to the stressors. General response categories include potentially increased fitness, reduced fitness, disturbance, and harm. We do not have enough information to quantify the effects of removal from human structures and the "other" category of activities that may affect the NLEB. For pathways associated with timber harvest, prescribed fire, and forest conversion, we estimate the number of NLEB individuals exposed by computing the expected overlap between the activities and NLEB-occupied habitats in each state. For wind turbine operation, we estimate the number of bats that could be killed using the current and projected amount of wind energy development and information on bat mortality rates.

Based on these estimations, we anticipate that up to 117,267 NLEB (1.2% of the total population) will be disturbed and 3,285 pups (0.1% of the total pup population) and 980 adults (less than 0.02% of the total adult population) will be harmed annually from timber harvest, prescribed fire, forest conversion, and wind turbine operation. We consider these numbers to be overestimates based on our methodology. Additional harm is anticipated for the unquantified effects from removal from human structures and "other" activities that may affect the NLEB; however, we do not expect the additional impacts to substantially change the total numbers estimated. In addition, we also expect that the numbers affected over time will be reduced as WNS continues to affect the range-wide population.

Although local populations could be affected by the implementation of the final 4(d) rule, most of the states have larger populations and more maternity colonies. In addition, less than 2.3% of NLEBs will be disturbed in all states, less than 1% of pups will be harmed in all states, and less than 1% of adults will be harmed in all states. Therefore, the vast majority of individuals and populations that survive WNS will be unaffected by these activities. Based on the relatively small numbers affected annually compared to the state population sizes, we conclude that adverse effects from timber harvest, prescribed fire, forest conversion, wind energy, and other activities will not lead to population-level declines in this species.

Conclusion

WNS is the primary factor affecting the status of the NLEB, which has caused dramatic and rapid declines in abundance, resulting in the local extirpation of the species in some areas. Our analysis of the effects of activities that may affect the NLEB, but do not cause prohibited take, indicates that the additional loss of individual NLEB resulting from these activities would not exacerbate the effects of WNS at the scale of states within its range. Even if all anthropogenic activities that might adversely affect NLEB ceased, we do not believe that the resulting reduction in adverse effects would materially change the devastating impact WNS has had, and will continue to have, on NLEB at the local population level or at larger scales.

After reviewing the current status of the NLEB, environmental baseline, effects of the Action, and cumulative effects, it is the Service's biological opinion that the Action, as proposed, is not likely to jeopardize the continued existence of the NLEB.

This BO has evaluated major categories of actions that may affect the NLEB, but for which incidental take is not prohibited. Accordingly, there are no reasonable and prudent measures or terms and conditions that are necessary and appropriate for these actions. Federal agencies may rely on this BO to fulfill their project-specific section 7(a)(2) responsibilities under the framework specified in this BO. Prohibited incidental take requires either a separate consultation (federal actions) or an incidental take permit (non-federal actions).

BIOLOGICAL OPINION

A Biological Opinion (BO) is the document required under the Endangered Species Act of 1973 (Act), as amended, that states the opinion of the U.S. Fish and Wildlife Service (Service) as to whether a proposed federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat.

The action evaluated in this BO is the Service's finalization of a special rule under the authority of section 4(d) of the Act for the northern long-eared bat (*Myotis septentrionalis*) (NLEB). Section 9 of the Act generally prohibits the "take" of a species listed as endangered. The Act and its implementing regulations (50 CFR 17) define take as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. The Act does not specify particular prohibitions for threatened species. Instead, under section 4(d), the Secretary of the Interior has the discretion to issue such regulations to provide for the conservation of threatened species, which may include prohibitions under section 9. This BO also evaluates activities that the Service proposes to prohibit and except from take prohibitions under the final 4(d) rule. In the request for intra-Service consultation, the Service proposes a framework for streamlined section 7 consultation for other federal actions that may affect the NLEB and are consistent with the provisions of the 4(d) rule. This is a programmatic intra-Service consultation, because it addresses multiple actions on a program basis under the umbrella of activities excepted from take prohibitions in the Service's final 4(d) rule.

"To jeopardize the continued existence of a listed species" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species (50 CFR §402.02). This BO examines whether projects and activities implemented that are likely to adversely affect the NLEB, but would not cause take prohibited under the final 4(d) rule , are likely to jeopardize the continued existence of the NLEB.

The Service anticipates that white-nose syndrome (WNS), the disease causing the decline of the species, will spread throughout the range of the NLEB by 2023-2028 (Federal Register [FR]80[63]:17974). In listing rule, we determined that the NLEB is not currently in danger of extinction throughout all of its range, but if similar declines occur after WNS spreads throughout its entire range, the NLEB may be in danger of extinction. We expect that the status of the species will continue to decline as WNS reaches new areas; therefore, this BO will cover the next 7 years that the disease is minimally expected to spread and impact the NLEB throughout its entire range. The Service will reinitiate consultation by the end of 2022 or earlier if the reinitiation criteria described in Section 7 (Reinitiation Notice) of this BO are triggered. We believe this is a reasonable approach given that the range-wide decline of the NLEB due to WNS may reveal that the action may affect the NLEB in a manner or to an extent not previously considered.

1 DESCRIPTION OF THE PROPOSED ACTION

1.1 BACKGROUND

The proposed action is the finalization of the interim 4(d) rule for the NLEB and evaluation of activities excepted from take prohibitions. This rule replaces an interim 4(d) rule established concurrently with the listing of the NLEB as a threatened species on April 2, 2015 (FR 80[63]:17974), under the Act. The interim 4(d) rule:

(1) prohibits purposeful take of NLEBs throughout the species' range, except in instances of removal of NLEBs from human structures;
(2) authorized capture and handling of NLEB by individuals permitted to conduct these same activities for other bats (for a period of 1 year after the effective date of the interim 4(d) rule);
(3) in areas not yet affected by white-nose syndrome (WNS), all incidental take resulting from any otherwise lawful activity is excepted from prohibition;
(4) in areas currently known to be affected by WNS, all incidental take prohibitions apply, except take attributable to forest management practices, maintenance and limited expansion of transportation and utility rights-of-way, prairie habitat management, and limited tree removal projects, provided these activities protect known maternity roosts and hibernacula; and
(5) removal of hazardous trees for the protection of human life or property is excepted from the take prohibition.

The listing and interim 4(d) rule went into effect on May 4, 2015, and the interim 4(d) rule remains in effect until a final 4(d) rule is published in the Federal Register.

1.2 U.S. FISH AND WILDLIFE SERVICE ACTION

The Service is finalizing the interim 4(d) rule for the NLEB. The final rule will address both purposeful take and incidental taking of the NLEB, with certain differences distinguished based on the occurrence of WNS. The final 4(d) rule prohibits purposeful take of NLEBs throughout the species' range, except when:

- necessary to protect human health;
- in instances of removal of NLEBs from human structures; or

- the authorized capture and handling of NLEBs by individuals permitted to conduct these same activities for other bat species until May 3, 2016.

After May 3, 2016, a permit pursuant to Section 10(a)(1)(A)[1] of the Act is required for the capture and handling of NLEBs outside of human structures. We define human structures as houses, garages, barns, sheds, and other buildings designed for human entry.

"Incidental taking" is defined at 50 CFR 17.3 as "any taking otherwise prohibited, if such taking is incidental to, and not the purpose of, an otherwise lawful activity." Incidental take within the context of the final 4(d) rule is regulated in distinct and separate manners relative to the geographic location of the proposed activity and the occurrence of WNS. The WNS zone provides the boundary for implementation of the final rule. It is defined as the set of counties with confirmed evidence of the fungus causing the disease (*Pseudogymnoascus destructans*, or Pd) or WNS, plus a 150-mile (241 km) buffer from the Pd-positive county line to account for the spread of the fungus from one year to the next. In instances where the 150-mile (241 km) buffer line bisects a county, the entire county is included in the WNS zone. The final 4(d) rule does not prohibit incidental take resulting from otherwise lawful activities in areas not yet affected by WNS (i.e., areas outside of the WNS zone).

Within the WNS zone, the final 4(d) rule prohibits incidental take of NLEBs in their hibernacula (which includes caves, mines, and other locations where bats hibernate in winter). Take of NLEBs inside of hibernacula may be caused by activities that disturb or disrupt hibernating individuals when they are present as well as the physical or other alteration of the hibernaculum's entrance or environment when bats are not present, if the activity will impair essential behavioral patterns (e.g., sheltering) and cause harm. Known hibernacula are defined as locations where one or more NLEBs have been detected during hibernation or detected at the entrance during fall swarming or spring emergence. Any hibernaculum with NLEBs observed at least once is considered a known hibernaculum as long as it remains suitable for NLEB use. A hibernaculum remains suitable for NLEBs even when Pd or WNS has been detected.

For NLEBs outside of hibernacula within the WNS zone, the final 4(d) rule establishes separate incidental take prohibitions for activities involving tree removal and those that do not involve tree removal. Incidental take of NLEBs outside of hibernacula resulting from activities other than tree removal is not prohibited provided they do not result in the incidental take of NLEBs inside hibernacula or otherwise impair essential behavioral patterns at known hibernacula. Incidental take resulting from tree removal is prohibited if it: (1) occurs within 0.25 miles (0.4 km) of known NLEB hibernacula; or (2) cuts or destroys known, occupied maternity roost trees or any other trees within a 150-foot (45-meter) radius around the known, occupied maternity tree during the pup season (June 1 to July 31). Removal of hazardous trees for the protection of human life

[1] Section 10(a)(1)(A) describes recovery/scientific permits issued for the enhancement of the survival of the species.

and property is not prohibited. Known, occupied maternity roost trees are defined as trees that have had female NLEBs or juvenile bats tracked to them or the presence of female or juvenile bats is known as a result of other methods. Known, occupied maternity roost trees are considered known roosts as long as the tree and surrounding habitat remain suitable for the NLEB.

The final 4(d) rule individually sets forth prohibitions on possession and other acts with unlawfully taken NLEBs, and on import and export of NLEBs. Under this rule, take of the NLEB is also not prohibited for the following: removal of hazardous trees for protection of human life and property; take in defense of life; and take by an employee or agent of the Service, of the National Marine Fisheries Service, or of a State conservation agency that is operating a conservation program pursuant to the terms of a cooperative agreement with the Service.

Section 4(d) of the Act states that the Secretary shall issue such regulations as she deems "necessary and advisable to provide for the conservation" of species listed as threatened species. The Service determined that the final 4(d) rule is necessary and advisable to provide for the conservation of the NLEB, because it provides for temporary protection of known maternity roost trees during the pup season and to known hibernacula within the WNS zone, and it prohibits most forms of purposeful take throughout the species range. The final rule describes how prohibiting certain types of take is not necessary for the long-term survival of the species, and it acknowledges the importance of addressing the threat of WNS as the primary measure to arrest and reverse the decline of the species.

1.3 OTHER FEDERAL AGENCY ACTIONS

Federal agency actions that involve activities that involve activities not prohibited under the final 4(d) rule may result in effects to the NLEB if the species is exposed to action-caused stressors. Incidental take resulting from these activities is not prohibited; however, the final 4(d) rule does not alter the requirements for consultation under section 7 of the Act, which apply to all federal actions that may affect listed species and designated critical habitat. Section 7(a)(2) of the Act, directs federal agencies, in consultation with the Secretary, to insure that their actions are not likely to jeopardize the continued existence of any listed species, or result in the destruction or adverse modification of designated critical habitat. Therefore, the purpose of section 7(a)(2) is broader than an evaluation of anticipated take and issuance of an Incidental Take Statement.

To address the broader purpose of 7(a)(2) for federal actions that may affect the NLEB but would not cause take prohibited under the final 4(d) rule, the Service's Headquarters Office has requested intra-agency formal consultation with the Service's Midwest Regional Office on the effects of all such federal actions. Because the Service has determined with the final 4(d) rule that regulating incidental take associated with the excepted activities is not necessary or advisable for the conservation of the NLEB, Service Headquarters proposes an optional framework for subsequent federal agency reliance on the findings of an intra-Service consultation that would streamline section 7(a)(2) compliance for such activities. The primary objective of the framework is to provide an efficient means for Service verification of federal agency determinations that their proposed actions are consistent with those evaluated in the intra-Service consultation and do not require an incidental take statement for the NLEB. Such verification is necessary because incidental take is prohibited in the vicinity of known hibernacula and known roosts, and these locations are continuously updated. We do not include specific action agencies or their specific actions in this BO; rather, we focus on the types of activities that may affect the NLEB and conduct our jeopardy analysis on these activities. Federal agencies may rely on this BO to fulfill their project-specific section 7(a)(2) responsibilities under the following framework:

1. For all federal activities that may affect the NLEB, the action agency will provide project-level documentation describing the activities that are excepted from incidental take prohibitions and addressed in this consultation. The federal agency must provide written documentation to the appropriate Service Field Office when it is determined their action may affect (i.e., not likely to adversely affect or likely to adversely affect) the NLEB, but would not cause prohibited incidental take. This documentation must follow these procedures:

    a. In coordination with the appropriate Service Field Office, each action agency must make a determination as to whether their activity is excepted from incidental taking prohibitions in the final 4(d) rule. Activities that will occur within 0.25 mile of a known hibernacula or within 150 feet of known, occupied maternity roost trees during the pup season (June 1 to July 31) are not excepted pursuant to the final 4(d) rule. This determination must be updated annually for multi-year activities.
    b. At least 30 days in advance of funding, authorizing, or carrying out an action, the federal agency must provide written notification of their determination to the appropriate Service Field Office.
    c. For this determination, the action agency will rely on the definitions of prohibited activities provided in the final 4(d) rule and the activities considered in this consultation.
    d. The determination must include a description of the proposed project and the action area (the area affected by all direct and indirect project effects) with sufficient detail to support the determination.
    e. The action agency must provide its determination as part of a request for coordination or consultation for other listed species or separately if no other species may be affected.
    f. Service concurrence with the action agency determination is not required, but the Service may advise the action agency whether additional information indicates consultation for the NLEB is required; i.e., where the proposed project includes an activity not covered by the 4(d) rule and thus not addressed in the Biological Opinion and is subject to additional consultation.
    g. If the Service does not respond within 30 days under (f) above, the action agency

may presume its determination is informed by best available information and consider its project responsibilities under section 7(a)(2) with respect to the NLEB fulfilled through this programmatic Biological Opinion.

2. Reporting
   a. For monitoring purposes, the Service will assume all activities are conducted as described. If an agency does not conduct an activity as described, it must promptly report and describe such departures to the appropriate Service Field Office.
   b. The action agency must provide the results of any surveys for the NLEB to the appropriate Service Field Office within their jurisdiction.
   c. Parties finding a dead, injured, or sick NLEB must promptly notify the appropriate Service Field Office.

If a Federal action agency chooses not to follow this framework, standard section 7 consultation procedures will apply.

Section 7(a)(1) of the Act directs Federal agencies, in consultation with and with the assistance of the Secretary (a function delegated to the Service), to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Service Headquarters provides to federal action agencies who choose to implement the framework described above several conservation recommendations for exercising their 7(a)(1) responsibility in this context. Conservation recommendations are discretionary federal agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. Service Headquarters recommends that the following conservation measures to all Federal agencies whose actions may affect the NLEB:

1. Perform NLEB surveys according to the most recent Range-wide Indiana Bat/NLEB Summer Survey Guidelines. Benefits from agencies voluntarily performing NLEB surveys include:
   a. Surveys will help federal agencies meet their responsibilities under section 7(a)(1) of the Act. The Service and partners will use the survey data to better understand habitat use and distribution of NLEB, track the status of the species, evaluate threats and impacts, and develop effective conservation and recovery actions. Active participation of federal agencies in survey efforts will lead to a more effective conservation strategy for the NLEB.
   b. Should the Service reclassify the species as endangered in the future, an agency with a good understanding of how the species uses habitat based on surveys within its action areas could inform greater flexibility under section 7(a)(2) of the Act. Such information could facilitate an expedited consultation and incidental take statement that may, for example, exempt taking associated with tree removal during the active season, but outside of the pup season, in known occupied habitat.
2. Apply additional voluntary conservation measures, where appropriate, to reduce the

impacts of activities on NLEBs. Conservation measures include:

a. Conduct tree removal activities outside of the NLEB pup season (June 1 to July 31) and/or the active season (April 1 to October 31). This will minimize impacts to pups at roosts not yet identified.
b. Avoid clearing suitable spring staging and fall swarming habitat within a 5-mile radius of known or assumed NLEB hibernacula during the staging and swarming seasons (April 1 to May 15 and August 15 to November 14, respectively).
c. Manage forests to ensure a continual supply of snags and other suitable maternity roost trees.
d. Conduct prescribed burns outside of the pup season (June 1 to July 31) and/or the active season (April 1 to October 31). Avoid high-intensity burns (causing tree scorch higher than NLEB roosting heights) during the summer maternity season to minimize direct impacts to NLEB.
e. Perform any bridge repair, retrofit, maintenance, and/or rehabilitation work outside of the NLEB active season (April 1 to October 31) in areas where NLEB are known to roost on bridges or where such use is likely.
f. Do not use military smoke and obscurants within forested suitable NLEB habitat during the pup season (June 1 to July 31) and/or the active season (April 1 to October 31).
g. Minimize use of herbicides and pesticides. If necessary, spot treatment is preferred over aerial application.
h. Evaluate the use of outdoor lighting during the active season and seek to minimize light pollution by angling lights downward or via other light minimization measures.
i. Participate in actions to manage and reduce the impacts of white-nose syndrome on NLEB. Actions needed to investigate and manage white-nose syndrome are described in a national plan the Service developed in coordination with other state and federal agencies (Service 2011).

1.4 ACTION AREA

The action area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

The "Action Area" for this consultation includes the entire range of the NLEB within the United States, which includes all or portions of the following 37 States and the District of Columbia: Alabama, Arkansas, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming. Within the Action Area, the WNS zone currently includes all or most of the states within the species' range except North Dakota, Montana, South Dakota, and Wyoming (Figure 1.1) (note: tables and figures for each major section of this BO appear at the end of the section). The WNS zone map is updated on the first of every month (http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSZone.pdf).

1.5 ACTIVITIES NOT EVALUATED IN THIS BIOLOGICAL OPINION

The following general categories of activities are prohibited under the final 4(d) rule within the WNS zone:

1. Activities resulting in the disruption or disturbance of NLEBs in their hibernacula.
2. Activities resulting in the physical or other alteration of a hibernaculum's entrance or its environment at any time of year.
3. Tree clearing activities within 0.25 miles of a known NLEB hibernaculum.
4. Tree clearing activities that result in cutting or destroying known, occupied maternity roost trees or any other trees within a 150 ft radius around the roost tree during the pup season (June 1 – July 31).

Separate project-specific section 7 consultation is required for these activities; therefore, they are not addressed further in this consultation.

1.6 TABLES AND FIGURES FOR DESCRIPTION OF THE ACTION

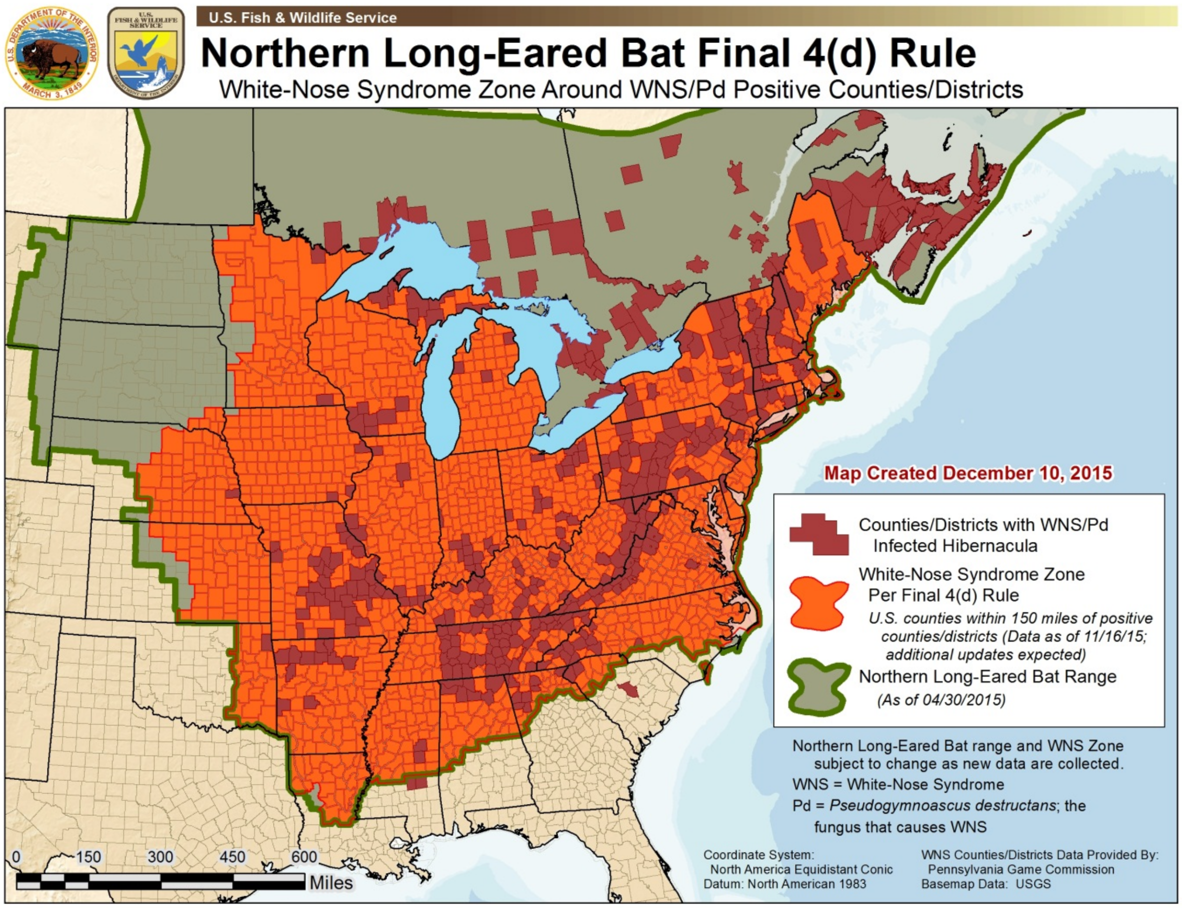

Figure 1.1. The NLEB WNS Zone around WNS/Pd positive counties or districts.

2 STATUS OF THE SPECIES/CRITICAL HABITAT

As described in Section 1, the Service listed the NLEB as a threatened species on April 2, 2015. The final rule determined that critical habitat designation for the NLEB was prudent, but not determinable at the time. The final listing rule describes the status of the species in detail and is hereby incorporated by reference. We summarize and paraphrase portions of the final rule in this section that are most relevant to an evaluation of the proposed Action. Additional information and citations can be found in the final listing rule.

2.1 SPECIES BACKGROUND & HABITAT

The NLEB is a temperate, insectivorous, migratory bat that hibernates in mines and caves in the winter and spends summers in wooded areas. The key stages in its annual cycle are: hibernation, spring staging and migration, pregnancy, lactation, volancy/weaning, fall migration and swarming. NLEB generally hibernate between mid-fall through mid-spring each year. The spring migration period likely runs from mid-March to mid-May each year, as females depart shortly after emerging from hibernation and are pregnant when they reach their summer area. Young are born between June and early July, with nursing continuing until weaning, which is shortly after young become volant (able to fly) in mid- to late-July. Fall migration likely occurs between mid-August and mid-October.

2.1.1 SUMMER HABITAT AND ECOLOGY

Suitable summer habitat for NLEB consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and may also include some adjacent and interspersed non-forested habitats. This includes forests and woodlots containing potential roosts, as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure.

After hibernation ends in late March or early April (as late as May in some northern areas), most NLEB migrate to summer roosts. For purposes of this BO, we define the NLEB active season as the period between emergence and hibernation from April 1 – October 31. We recognize that the active season is variable across the action area depending on latitude, elevation, and weather conditions; however, we believe this range captures most of the period throughout the range in most years. The spring migration period typically runs from mid-March to mid-May (Caire et al. 1979; Easterla 1968; Whitaker and Mumford 2009). The NLEB is not considered to be a long distance migrant (typically 40-50 miles). Males and non-reproductive females may summer near hibernacula, or migrate to summer habitat some distance from their hibernaculum.

After emergence, female NLEBs actively form colonies in the summer (Foster and Kurta 1999) and exhibit fission-fusion behavior (Garroway and Broders 2007), where members frequently coalesce to form a group, but composition of the group is in flux (Barclay and Kurta 2007). As part of this behavior, NLEBs switch tree roosts often (Sasse and Pekins 1996), typically every 2 to 3 days (Foster and Kurta 1999; Owen et al. 2002; Carter and Feldhamer 2005; Timpone et al. 2010). NLEB maternity colonies range widely in size (reported range of 7 to 100; Owen et al. 2002; Whitaker and Mumford 2009), although about 30-60 may be most common (Whitaker and Mumford 2009; Caceres and Barclay 2000; Service 2014).

NLEBs show interannual fidelity to roost trees and/or maternity areas. They use networks of roost trees often centered around one or more central-node roost trees (Johnson et al. 2012) with multiple alternate roost trees. NLEB roost in cavities, underneath bark, crevices, or hollows of both live and dead trees and/or snags (typically ≥3 inches dbh). NLEB are known to use a wide variety of roost types, using tree species based on presence of cavities or crevices or presence of peeling bark. NLEBs have also been occasionally found roosting in structures like buildings, barns, sheds, houses, and bridges (Benedict and Howell 2008; Krochmal and Sparks 2007; Timpone et al. 2010; Service 2014).

Summer home range includes both roosting and foraging areas, and range size may vary by sex. Maternity roosting areas have been reported to vary from mean of 21 to 179 acres (Owen et al. 2003; Broders et al. 2006; Lacki et al. 2009) to a high of 425 acres (Lacki et al. 2009). Foraging areas are six or more times larger (Broders et al. 2006; Henderson and Broders 2008). The distance traveled between consecutive roosts varies widely from 20 ft (Foster and Kurta 1999) to 2.4 miles (Timpone et al. 2010). Likewise, the distance traveled between roost trees and foraging areas in telemetry studies varies widely, e.g., a mean of 1,975 ft (Sasse and Perkins 1996) and a mean of 3,609 ft (Henderson and Broders 2008). Circles with a radius of these distances have an area of 281 and 939 acres. Based on reported maximum individual home range (425 acres) and travel distances between roosts and foraging areas described above (939 acres), we use 1,000 acres for purposes of this BO as the area a colony uses. An analysis of mist net survey data in Kentucky (Service 2014, unpublished data cited in the final listing rule) shows that most males and non-reproductive females are captured in the same locations as reproductively active females, suggesting substantial overlap in the summer home range of reproductive females and other individuals (94%).

NLEBs are typically born in late-May or early June, with females giving birth to a single offspring. Lactation then lasts 3 to 5 weeks, with pups becoming volant between early July and early August. For purposes of this BO and the final 4(d) rule, we define the pup season (i.e., the period of non-volancy) as June 1 – July 31.

2.1.2 WINTER HABITAT AND ECOLOGY

Suitable winter habitat (hibernacula) includes underground caves and cave-like structures (e.g. abandoned or active mines, railroad tunnels). There may be other landscape features being used by NLEB during the winter that have yet to be documented. Generally, NLEB hibernate from October to April depending on local climate (November-December through March in southern areas with emergence as late as mid-May in some northern areas).

Hibernacula for NLEB typically have significant cracks and crevices for roosting; relatively constant, cool temperatures (0-9 degrees Celsius) and with high humidity and minimal air currents. Specific areas where they hibernate have very high humidity, so much so that droplets of water are often seen on their fur. Within hibernacula, surveyors find them in small crevices or cracks, often with only the nose and ears visible.

NLEB tend to roost singly or in small groups (Service 2014), with hibernating population sizes ranging from just a few individuals to around 1,000 (Service unpublished data). NLEB display more winter activity than other cave species, with individuals often moving between hibernacula throughout the winter (Griffin 1940; Whitaker and Rissler 1992; Caceres and Barclay 2000). NLEB have shown a high degree of philopatry (i.e., using the same site multiple years) to the hibernacula used, returning to the same hibernacula annually.

2.1.3 SPRING STAGING AND FALL SWARMING HABITAT AND ECOLOGY

Upon arrival at hibernacula in mid-August to mid-November, NLEB "swarm," a behavior in which large numbers of bats fly in and out of cave entrances from dusk to dawn, while relatively few roost in caves during the day. Swarming continues for several weeks and mating occurs during the latter part of the period. After mating, females enter directly into hibernation but not necessarily at the same hibernaculum at which they had been mating. A majority of bats of both sexes hibernate by the end of November (by mid-October in northern areas).

Reproductively active females store sperm through the winter from autumn copulations. Ovulation takes place after the bats emerge from hibernation in spring. The period after hibernation and just before spring migration is typically referred to as "staging," a time when bats forage and a limited amount of mating occurs. This period can be as short as a day for an individual, but not all bats emerge on the same day.

In general, NLEB use roosts in the spring and fall similar to those selected during the summer. Suitable spring staging/fall swarming habitat consists of the variety of forested/wooded habitats where they roost, forage, and travel, which is most typically within 5 miles of a hibernaculum.

2.2 DISTRIBUTION AND RANGE

The NLEB ranges across much of the eastern and north central United States, and all Canadian provinces west to the southern Yukon Territory and eastern British Columbia (Figure 2.1) (Nagorsen and Brigham 1993; Caceres and Pybus 1997; Environment Yukon 2011). In the United States, the species' range reaches 37 states from Maine west to Montana, south to eastern Kansas, eastern Oklahoma, Arkansas, and east to South Carolina (Whitaker and Hamilton 1998; Caceres and Barclay 2000; Amelon and Burhans 2006). Historically, the species has been most frequently observed in the northeastern United States and in Canadian Provinces, Quebec and Ontario. However, throughout the majority of the species' range it is patchily distributed, and historically was less common in the southern and western portions of the range than in the northern portion of the range (Amelon and Burhans 2006).

The U.S. portion of the NLEB's range is discussed in this BO in four parts: Eastern, Midwest, Southern, and Western. This is done solely for purposes of analysis and discussion; there is currently no indication that these are distinct populations. The Eastern range comprises Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia. The Midwest range includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. The Southern range comprises Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, and Tennessee, and the Western range includes Kansas, Montana, Nebraska, North Dakota, South Dakota, and Wyoming.

Although NLEBs are typically found in low numbers in inconspicuous roosts, most records of NLEB are from winter hibernacula surveys (Caceres and Pybus 1997). There are currently 1,508 hibernacula known throughout the species' range in the United States (Table 2.1). The majority of the known hibernacula occur within the Eastern (39%) and the Midwest range (38), followed by 21 percent in the Southern range, and 2 percent in the Western range. Even prior to WNS, many hibernacula contained only a few (1 to 3) individuals (Whitaker and Hamilton 1998). There are likely many more unknown hibernacula.

There have also been many summer mist-net and acoustic surveys conducted within the range of the NLEB, but the surveys have not been complied into a central database across the species' range. The data is housed with the state natural resources programs, state natural heritage programs, or the local Service field offices. We are unable to report the total number of locations with NLEBs; however, we have compiled the total number of known maternity roost trees in each state (Table 2.1). There are 1,744 known maternity roost trees in 19 of 37 states, with 42% occurring in the Southern range, 30% in the Midwest, and 28% in the Eastern range. There are no known maternity roost trees in the Western range. There are limitations to these data because most states and natural heritage programs have not been tracking NLEB occurrences or individual roosts.

The current range and distribution of NLEB must be described and understood within the context of the impacts of WNS. Prior to the onset of WNS, the best available information on NLEB came primarily from surveys (primarily focused on Indiana bat or other bat species) and some targeted research projects. In these efforts, NLEB was very frequently encountered and was considered the most common myotid bat in many areas. Overall, the species was considered to be widespread and abundant throughout its historic range (Caceres and Barclay 2000). NLEBs continue to be distributed across much of the historical range, but there are many gaps within the range where bats are no longer detected or captured, and in other areas, their occurrence is sparse given local declines and extirpations.

2.3 STATUS AND THREATS

2.3.1 WHITE-NOSE SYNDROME

WNS is an emerging infectious wildlife disease caused by a fungus of European origin, Pd, which poses a considerable threat to hibernating bat species throughout North America, including the NLEB (Service 2011). WNS is responsible for unprecedented mortality of insectivorous bats in eastern North America (Blehert et al. 2009; Turner et al. 2011). No other threat is as severe and immediate for the NLEB as the disease WNS. There is no doubt that NLEB populations would be declining so dramatically without the impact of WNS. Since the disease was first observed in New York in 2007 (later biologists found evidence from 2006 photographs), WNS has spread rapidly in bat populations from the East to the Midwest and the South. As of November 2015, WNS or Pd was confirmed in 30 of the 37 states within the species' range (Figure 1.1; Table 2.2). Data support substantial declines in the Eastern range and portions of the Midwest range. In addition, there are apparent population declines at most hibernacula with WNS in the Southern range. We expect further declines as the disease continues to spread across the species' range.

Post-WNS hibernacula counts available from the northeast U.S. show the most substantial population declines for the NLEB. Turner et al. (2011) compared the most recent pre-WNS count to the most recent post-WNS count for six cave bat species and reported a 98 percent total decline in the number of hibernating NLEB at 30 hibernacula in New York, Pennsylvania, Vermont, Virginia, and West Virginia through 2011. For the final listing rule, the Service conducted an analysis of additional survey information at 103 sites across 12 U.S. States and Canadian provinces (New York, Pennsylvania, Vermont, West Virginia, Virginia, New Hampshire, Maryland, Connecticut, Massachusetts, North Carolina, New Jersey, and Quebec) and found comparable declines in winter colony size. At these sites, total NLEB counts declined by an average of 96 percent after the arrival of WNS; 68 percent of the sites declined to zero NLEB, and 92 percent of sites declined by more than 50 percent. Frick et al. (2015) consider the NLEB now extirpated from 69 percent of the hibernacula in Vermont, New York, Pennsylvania, Maryland, Virginia, and West Virginia that had colonies of NLEB prior to WNS. Langwig et al. (2012) reported that 14 populations of NLEB in New York, Vermont, and Connecticut became locally extinct within 2 years due to disease.

Long-term summer survey data (including pre- and post-WNS) for the NLEB, where available, corroborate the population decline evident in hibernacula survey data. For example, summer surveys from 2005 – 2011 near Surry Mountain Lake in New Hampshire showed a 98 percent decline in capture success of NLEB post-WNS, which is similar to the hibernacula data for the State (a 95 percent decline) (Moosman et al. 2013). Mist-netting data from Pennsylvania indicate that NLEB captures declined by 46 percent in 2011, 63 percent in 2012, 76 percent in 2013, and 94 percent in 2014, compared to the average pre-WNS capture rate between 2001 to 2007 (Butchkoski 2014; Pennsylvania Game Commission, unpublished data). The NLEB is more commonly encountered in summer mist-net surveys in the Midwest; however, similar rates of population decline are already occurring in Ohio and Illinois. Early reports also indicate declines in Missouri and Indiana (80 FR 17979-17980). Other data, much of it received as comments on the proposed listing rule from State wildlife agencies, demonstrate that various measures of summer NLEB abundance and relative abundance (mist net surveys, acoustic surveys) have declined following detection of WNS in the state.

Although the dispersal rate of Pd across the landscape and the onset of WNS after the fungus arrives at a new site are variable, it appears unlikely that any site within the range of the NLEB is not susceptible to WNS. Some evidence suggests that certain microclimatic conditions may hinder disease progression at some sites, but given sufficient exposure time, WNS has had similar impacts on NLEB everywhere the disease is documented. Absent direct evidence that some NLEB exposed to the fungus do not contract WNS, available information suggests that the disease will eventually spread throughout the species' range. As described in Section 1 of this BO, we anticipate that WNS will spread throughout the range of the NLEB by 2023-2028.

2.3.2 OTHER THREATS

Although significant NLEB population declines have only been documented due to the spread of WNS, other sources of mortality could further diminish the species' ability to persist as it experiences ongoing dramatic declines. The final listing rule for the NLEB describes known threats to the species under each of the five statutory factors for listing decisions, of which disease/predation, discussed above, is the dominant factor. We summarize here the findings of the final listing rule regarding the other four factors that are relevant to this consultation.

Human and non-human modification of hibernacula, particularly altering or closing hibernacula entrances, is considered the next greatest threat after WNS to the NLEB. Some modifications, e.g., closure of a cave entrance with structures/materials besides a bat-friendly gate, can cause a partial or complete loss of the utility of a site to serve as hibernaculum. Humans can also disturb hibernating bats, either directly or indirectly, resulting in an increase in energy-consuming arousal bouts during hibernation (Thomas 1995; Johnson et al. 1998).

During the summer, NLEB habitat loss is primarily due to forest conversion and forest management. Throughout the range of NLEB, forest conversion is expected to increase due to commercial and urban development, energy production and transmission, and natural changes. The 2010 Resources Planning Act Assessment projects forest losses of 16–34 million acres (or 4–8 percent of 2007 forest area) across the conterminous United States, and forest loss is expected to be concentrated in the southern United States, with losses of 9–21 million acres (USFS 2012). Forest conversion causes loss of potential habitat, fragmentation of remaining habitat, and if occupied at the time of the conversion, direct injury or mortality to individuals. Forest management activities, unlike forest conversion, typically result in temporary impacts to the habitat of NLEB, but like forest conversion, may also cause direct injury or mortality to individuals. The net effect of forest management may be positive, neutral, or negative, depending on the type, scale, and timing of various practices. The primary potential benefit of forest management to the species is perpetuating forests on the landscape that provide suitable roosting and foraging habitat.

Wind energy facilities are known to cause mortality of NLEB. While mortality estimates vary between sites and years, sustained mortality at particular facilities could cause declines in local populations. Wind energy development within portions of the species' range is projected to continue.

Climate change may also affect this species, as NLEB are particularly sensitive to changes in temperature, humidity, and precipitation. Climate change may indirectly affect the NLEB through changes in food availability and the timing of hibernation and reproductive cycles.

Environmental contaminants, in particular insecticides, other pesticides, and inorganic contaminants, such as mercury and lead, may also have detrimental effects on NLEB. Contaminants may bio-accumulate (become concentrated) in the tissues of bats, potentially leading to a myriad of sub-lethal and lethal effects. NLEBs may also be indirectly affected through a reduction in available insect prey.

Fire is one of the environmental stressors that contribute to the creation of snags and damaged trees on the landscape, which NLEB frequently use as summer roosts. Fire may also kill or injure bats, especially flightless pups. Prescribed burning is a common tool for forest management in many parts of the species' range.

There is currently no evidence that the natural or manmade factors discussed above (hibernacula modification, forest conversion, forest management, wind energy, climate change, contaminants, fire) have separately or cumulatively contributed to significant range-wide population effects on the NLEB prior to the onset of WNS. However, declines due to WNS have significantly reduced the number and size of NLEB populations in some areas of its range. This has reduced these populations to the extent that they may be increasingly vulnerable to other stressors that they may have previously had the ability to withstand. These impacts could potentially be seen on two levels. First, individual NLEB sickened or struggling with infection by WNS may be less able to survive other stressors. Second, NLEB populations impacted by WNS, with smaller numbers and reduced fitness among individuals, may be less able to recover making them more prone to extirpation. The status and potential for these impacts will vary across the range of the species.

2.4 POPULATION DYNAMICS

Hibernacula counts are generally the best census method for most bats that hibernate, because individuals are concentrated and relatively stationary. However, because the NLEB is difficult to detect in hibernacula, moves between hibernacula during the winter, and many hibernacula are likely not known, a range-wide population estimate for the species is not available. The NLEB is most widely dispersed on the landscape during the summer where it is most likely exposed, directly or indirectly (i.e., later in time), to the widely dispersed (i.e., not concentrated in a given area) activities that are excepted from take prohibitions under the 4(d) rule.

For purposes of this BO, we estimate NLEB numbers based on total forested acres in each state and assumptions about:

- state-specific occupancy rates;
- forested acres in each state;
- maternity colony home-range size;
- number of adult females per colony;
- overlap between adult male home range and maternity colony home range;
- overlap between maternity colonies; and
- landscape-scale adult sex ratio (we assume 1:1).

We explain these data and assumptions in the following sub-sections.

2.4.1 OCCUPANCY RATES

We requested summer survey results from the three most recent years available from our field offices to provide an estimate of recent occupancy rates. Field offices provided the total number of survey sites (typically mist-net surveys), by state and by year, and the number of sites that captured at least one NLEB. Occupancy rates were calculated using the proportion of sites occupied with NLEB from the total number of sites sampled (Table 2.3). Where no data were available, we used the post-WNS survey data provided by the Forest Service for National Forests within the respective state (Table 2.3). Some states have only 1 or 2 years of data, and others have 8 or more consecutive years of data. In most cases, the numbers and locations of these survey sites do not constitute a representative sample of the available forest habitat in each state. Regardless, the alternative to using these data is to consider the NLEB ubiquitous within forested habitat in each state, which would greatly overestimate occupancy. Instead, we use these data as the best available information from which to make inferences about the extent of NLEB occupancy in each state[2].

Table 2.2 identifies the years in which WNS was detected in the state. We compute pre- and post-WNS occupancy rates as the number of net sites with NLEB divided by the total number of bat capture sites in each state. We applied the occupancy rate listed in Table 2.3 to each state.

2.4.2 TOTAL FORESTED ACRES IN EACH STATE

We compiled the total forested acres for each state from the U.S. Forest Service's 2015 State and Private Forestry Fact sheets (available at http://stateforesters.org/regional-state). We assumed that all forested acres within each state are suitable for the NLEB, which probably overestimates habitat availability but it is not unreasonable given the NLEB's ability to use very small trees (≥ 3 in dbh). We could have estimated the amount of forest in each state in more detail, but our analysis of other factors unrelated to forest cover was limited to statewide data, so we used statewide data throughout the analysis for all factors.

[2] The occupancy data used in this analysis has many limitations and a substantial amount of uncertainty. Occupancy as used here is the proportion of suitable habitat that is likely to have NLEB present. This is sensitive to the accuracy of the suitable habitat data, the accuracy of the survey data used to estimate the occupancy, and biases in the survey data collection methodology. The definition of suitable habitat used for this analysis is necessarily very general (forested areas) to be applicable across the entire species range. The surveys used to generate the occupancy data were often very sparse and not designed for this purpose. Repurposing of the data may increase the effects of bias in distribution of sample points (in relation to both suitable habitat and bat distributions), sampling methodologies, and sampling timing. We believe that because much of the sampling was not targeted specifically at NLEB and often involves surveys for development or construction projects, survey locations are unlikely to be closely correlated to NLEB distributions, which may minimize the influence of some biases. However, the limitations of the available data and its biases are potentially significant to the occupancy estimates, and this creates uncertainty that we acknowledge. Given these factors, our estimates of population are meant as tool for assessing potential relative impact by providing a scale for comparison, not as a precise estimate of the northern long-eared bat populations.

Not every state is wholly within the range of the NLEB (Figure 2.1), and including the total forested acreage from states not fully within the species' range could greatly overestimate the population size. Therefore, we excluded states with less than 50% of its area within the species range, which eliminated Montana, Wyoming, Oklahoma, Louisiana, Alabama, Georgia, and South Carolina. The inclusion of the full states of Nebraska, Kansas, Mississippi, and North Carolina should compensate for any individuals not included in the excluded states. The list of states included, along with the total forested acres are reported in Table 2.4.

2.4.3 COLONY SIZE (NUMBERS OF BATS AND OCCUPIED AREA)

In addition to the occupancy rates described above, we rely in this BO primarily on colony characteristics reported in the literature to estimate state-wide bat numbers. NLEB colonies are comprised of variable numbers of adult females. Two important studies give a range of 30–60 adult females per colony (see Section 2.1.1). Given the number of colonies that a state likely supports (see Section 2.4.4) (see Section 2.4.4), we then estimate total NLEB numbers in the occupied available habitat using the number of females per colony and assuming a 1:1 adult female/adult male ratio and a maximum of 1 pup per female.

While colony sizes of 30-60 bats may be typical in areas unaffected by WNS, in areas with clear declines in bat populations, these estimates may no longer be appropriate. Declines in total population appear to exceed what could be explained by declines in occupancy rates alone. The total reproductive female population can be described as the product of the average colony size in females and the number of colonies:

[Total female reproductive population = Number of colonies * Mean females per colony] OR N=C*F

If the rate of total population decline exceeds the rate of decline in number of colonies (as described by declines in occupancy) there must also be an additional reduction in the average colony size as well.

Information about total population sizes or average colony sizes is not available on a wide scale. However, there are a few instances where we have obtained data that could be used to approximate rates of population decline without knowing the actual sizes of populations. In Pennsylvania, captures of bats per unit effort have been tracked for several years. Changes in this number of bats per unit effort captured across a wide area could be assumed to mirror changes in the total population for that area. So if the total population declined by 50%, we would expect to see a 50% decline in captures of bats per unit effort as well. The number of bats per unit effort in Pennsylvania declined to 22.3% of pre-WNS levels (averaging capture rates across 2012-2014). Over the same time period, occupancy declined 49.8%. Pre-WNS occupancy was 67.9% of suitable habitat, while the last three years of data indicate an occupancy rate of 33.8% of suitable habitat (0.338/0.679=0.498).

The change over time of the total female population is going to be a function of the change in the number of colonies and the change in the mean number of females per colony. Or, put another way, the change in females per colony over time can be described by the change in the number of colonies in relation to the change in total female population. So:

$N_t/N_0 = (C_t*F_t)/(C_0*F_0)$ OR $C_t = (N_t/N_0)*(C_0*F_0)/ F_t$ OR $C_t = (N_t/N_0)*C_0/(F_t/ F_0)$

Assuming changes in captures per unit effort is a good approximation for changes in the proportion of remaining bats, and using the decline in occupancy to represent the decline in the number of colonies, with a decline in occupancy of 49.8%, the average colony size is likely to have declined by 55% to approximately 20 bats per colony. (((0.223/1)*45)/(0.498)=20.2)

Similarly, Ohio has seen declines in captures per mist net site to 91.2% of pre-WNS levels, using the average of 2012-2014 rates. While likely to be less accurate to represent population declines than captures per unit effort, captures per mist net site may be a reasonable approximation for total population changes as well. Occupancy rates have been relatively stable in Ohio, increasing slightly from 39.6% over 2007-2010 to 42.1% over 2012-2014 (although with a large drop in 2014). Assuming the captures per mist net site is also a reasonable estimate of the rate of total population decline, a slightly increasing occupancy indicates that declines must be occurring within colonies. The average colony is likely to have declined 14%, to about 39 bats. (((0.912/1)*45)/(1.06) = 38.7)

WNS was first documented in Pennsylvania in 2008-2009 and in Ohio in 2010-2011 (Table 2.2). For the purposes of this BO, we assume that colonies are comprised of 20 females in all states where WNS was documented prior to the winter of 2010-2011 (Table 2.4). Rhode Island does not have any hibernacula; therefore, WNS has not been confirmed in the state. We assume that bats in summer habitat in Rhode Island have been affected by WNS in the surrounding states, and colonies are comprised of 20 females. For all states with WNS documented during or after the winter of 2010-2011, we assume colonies are comprised of 39 females. For states that do not have WNS (including states that have only documented Pd), we use 45 females per colony (the mid-point of the 30–60 range) as the basis for estimating bat numbers. For each colony present in a state, we assume a NLEB population is comprised of 20, 39, or 45 adult females and the same number of sympatric adult males and juveniles following parturition, depending on the status of WNS (Table 2.4).

As described in Section 2.1.1, we use 1,000 acres for purposes of this BO as the area a colony uses. Within this area, one or more members of a colony and sympatric adult males would likely appear in mist net or acoustic surveys. Such appearance is the basis for the occupancy rates we use to estimate the acreage of available forested habitat that NLEB may use during the active season in the states, which are given in Table 2.4.

Maternity roosting areas are a subset of the 1,000-acre colony size we use in this BO. As described above, Broders et al. (2006) and Henderson and Broders (2008) found that foraging areas were six or more times larger than maternity roosting areas. One sixth of our 1,000-acre colony size is 167 acres, which is within the range of other maternity roosting areas reported (Carter and Feldhamer 2005; Silvis et al. 2015). For purposes of this BO, we use a maternity roosting area of 167 acres. Table 2.5 shows our estimates of the percentage of each state that is used as maternity roost areas based on the number of expected colonies (Table 2.4) and 167 acres per colony.

2.4.4 OVERLAP

Lacking information about the degree of spatial overlap between NLEB maternity colonies, for this BO we assume that colonies do not overlap, e.g., we assume that 1,000 acres of occupied habitat supports one colony. Estimated or assumed occupancy rates in all of the states are all less than 70 percent (Table 2.3); therefore, it is unlikely that limited habitat availability would contribute to substantial colony-range overlap. If incorrect, the possible effect of this assumption is to underestimate the population size in each state (i.e., 1,000 acres supports more than 1 colony).

As described in Section 2.1.1, mist net survey data in Kentucky indicate substantial overlap in the summer home range of reproductive females and males and non-reproductive females (1,712 of 1,825 capture records, or 94 percent). The Service further analyzed this data to determine the percentage of capture locations for males and non-reproductive females that were not capture locations for reproductive female captures or within 3 miles of a reproductive female capture location (Service 2015b). Of 909 capture locations, 87 (9.57 percent) did not have reproductively active females and were more than 3 miles away from captures of reproductive females, suggesting a 100 – 9.57 = 90.43 percent overlap between the home range of individuals belonging to maternity colonies and other individuals. We lack state-specific information about the overlap between reproductively active females and other bats; therefore, for this BO, we assume the 90.43 percent overlap suggested by the Kentucky data. We multiply occupied forest acres by 0.9043 to compute the number of probable maternity colonies; e.g., 100,000 occupied acres × 0.9043 = 90,430 acres supporting 90,430 ÷ 1000 = 91 maternity colonies, rounding up any fractional remainder.

2.4.5 POPULATION ESTIMATES

Table 2.4 provides our estimates of the summer adult population size of NLEB in the 30 states included in the analysis. It relies on the total forested acres and the other assumptions described above; i.e., occupancy rates for each state in Table 2.3, 90.43 percent overlap between the range of males and maternity colonies, 1,000 acres per colony, no overlap between colonies, the number of adult females per colony (20, 39, or 45 depending on WNS), and a 1:1 male/female sex ratio. Here are example calculations for Iowa as reported in Table 2.4:

- 3,013,759 forested acres × 0.417 occupancy rate = 1,256,738 occupied acres;
- 1,256,738 occupied acres × 0.9043 overlap with males = 1,136,467 colony-occupied acres;
- 1,136,467 acres ÷ 1,000 acres per colony = 1,137 colonies;
- 1,137 colonies × 45 adult females per colony = 51,165 adult females; and
- 51,165 adult females + 1 adult male per female (or 51,165 adult males) = 102,330 total adults.

We estimate that the range-wide population of NLEBs is comprised of 6,546,718 adults based on these calculations and the assumption that the 30 states included in the analysis represent the range-wide population. Arkansas supports the largest population (863,850 adults; 13%), followed by Minnesota with 829,890 (13%). Delaware and Rhode Island support the smallest populations with 640 and 1,240 adults, respectively. Based on these estimates, the Midwest supports 43% of the total population followed by the Southern range (38%), the Eastern range (17%), and the Western range (2%).

It is likely that the state populations are overestimates in areas affected by WNS. We used the occupancy data from the last 3 years, but in nearly all WNS areas there is a clear downward trend and most data are at least a year old. Therefore, the occupation rates and resulting population estimates are likely lower in many areas.

2.5 ANALYSIS OF THE SPECIES/CRITICAL HABITAT LIKELY TO BE AFFECTED

As described in Section 1, the NLEB is likely to be adversely affected by the activities which are excepted from incidental take prohibitions in the final 4(d) rule. Many federally listed, proposed, and candidate species, and their designated or proposed critical habitats, occur within the Action Area for this consultation. However, the Service Headquarters has determined that the proposed action will have no effect on any other listed, proposed, or candidate species or designated or proposed critical habitats. The action is the Service's finalization the 4(d) rule for the NLEB. It sets forth the prohibitions for take under section 9(a)(1) of the Act and the exceptions to those prohibitions. It does not alter in any way the consultation requirements under section 7(a)(2) of the Act. Although this BO provides a framework for streamlined section 7 consultation for federal actions that are consistent with the provisions of the 4(d) rule, the framework only applies to the NLEB. Federal agencies will still be required to consult on activities that may affect other listed species within the Action Area. Therefore, only the NLEB will be considered further in this BO.

2.6 TABLES AND FIGURES FOR STATUS OF THE SPECIES

Table 2.1. Known NLEB hibernacula and known maternity roosts trees by state.

Range	State	Known Hibernacula	Known Occupied Maternity Roost Trees
Midwest	Iowa	2	14
Midwest	Illinois	44	39
Midwest	Indiana	69	193
Midwest	Michigan	77	25
Midwest	Minnesota	15	102
Midwest	Missouri	269	58
Midwest	Ohio	32	4
Midwest	Wisconsin	67	84
Eastern	Connecticut	8	0
Eastern	Delaware	2	0
Eastern	Maine	3	0
Eastern	Maryland	8	0
Eastern	Massachusetts	7	16
Eastern	New Hampshire	11	0
Eastern	New Jersey	9	47
Eastern	New York	90	27
Eastern	Pennsylvania	322	157
Eastern	Rhode Island	0	0
Eastern	Vermont	16	0
Eastern	Virginia	11	12
Eastern	West Virginia	104	231
Southern	Alabama	11	0
Southern	Arkansas	77	310
Southern	Georgia	6	20
Southern	Kentucky	122	254
Southern	Louisiana	0	0
Southern	Mississippi	0	0
Southern	North Carolina	29	101
Southern	Oklahoma	9	0
Southern	South Carolina	3	0
Southern	Tennessee	61	50
Western	Kansas	1	0
Western	Montana	0	0
Western	Nebraska	2	0
Western	North Dakota	0	0
Western	South Dakota	21	0
Western	Wyoming	0	0
	Total	1,508	1,744

Table 2.2. White-nose syndrome (WNS) and *Pseudogymnoascus destructans* (Pd) occurrence in the 37 States.

REGION	STATE	WNS or Pd Present?	First Winter WNS Confirmed	Documented WNS Mortality in Bats?
Midwest	Iowa	Pd	Pd only (2011-2012)	No
Midwest	Illinois	WNS	2012-2013	Yes
Midwest	Indiana	WNS	2010-2011	Yes
Midwest	Michigan	WNS	2014-2015	Yes
Midwest	Minnesota	Pd	Pd only (2011-2012)	No
Midwest	Missouri	WNS	2011-2012	Yes
Midwest	Ohio	WNS	2010-2011	Yes
Midwest	Wisconsin	WNS	2013-2014	Yes
Eastern	Connecticut	WNS	2008-2009	Yes
Eastern	Delaware	WNS	2009-2010	Yes
Eastern	Maine	WNS	2010-2011	Yes
Eastern	Maryland	WNS	2009-2010	Yes
Eastern	Massachusetts	WNS	2007-2008	Yes
Eastern	New Hampshire	WNS	2008-2009	Yes
Eastern	New Jersey	WNS	2008-2009	Yes
Eastern	New York	WNS	2006-2007	Yes
Eastern	Pennsylvania	WNS	2008-2009	Yes
Eastern	Rhode Island	No	NA	NA
Eastern	Vermont	WNS	2007-2008	Yes
Eastern	Virginia	WNS	2008-2009	Yes
Eastern	West Virginia	WNS	2008-2009	Yes
Southern	Alabama	WNS	2011-2012	Yes
Southern	Arkansas	WNS	2013-2014	Yes
Southern	Georgia	WNS	2012-2013	Yes
Southern	Kentucky	WNS	2010-2011	Yes
Southern	Louisiana	No	NA	NA
Southern	Mississippi	Pd	Pd only (2013-2014)	No
Southern	North Carolina	WNS	2010-2011	Yes
Southern	Oklahoma	Pd	Pd only (2014-2015)	No
Southern	South Carolina	WNS	2012-2013	Yes
Southern	Tennessee	WNS	2009-2010	Yes
Western	Kansas	No	NA	NA
Western	Montana	No	NA	NA
Western	Nebraska	Pd	Pd only (2014-2015)	No
Western	North Dakota	No	NA	NA
Western	South Dakota	No	NA	NA
Western	Wyoming	No	NA	NA

Table 2.3. NLEB summer state-wide occupancy estimates, based on summer survey results.

Range	State	Description	Pre-WNS Years (Combined)		Pre-WNS Occupancy Rate	Sum of 3 Most Recent WNS Years	WNS Impacted Occupancy Rate	Occupancy Rate Used
Midwest	IA	Total Mist Net Sites	2009-2011	24		0		
		Sites with NLEB Captures		10	41.7%	0	N/A	41.7%
	IL	Total Mist Net Sites	2009-2011	40		0		
		Sites with NLEB Captures		25	62.5%	0	N/A	62.5%
	IN	Total Mist Net Sites				283		
		Sites with NLEB Captures			N/A	106	37.5%	37.5%
	MI	Total Mist Net Sites	2004-2014	149		0		
		Sites with NLEB Captures		47	31.5%	0	N/A	31.5%
	MN	Total Mist Net Sites	2013-2014	121		0		
		Sites with NLEB Captures		71	58.7%	0	N/A	58.7%
	MO	Total Mist Net Sites				42		
		Sites with NLEB Captures			N/A	11	26.2%	26.2%
	OH	Total Mist Net Sites	2007-2010	733		2485		
		Sites with NLEB Captures		290	39.6%	1046	42.1%	42.1%
	WI	Total Mist Net Sites				78		
		Sites with NLEB Captures			N/A	35	44.9%	44.9%
Eastern	CT[$]	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	9.4%
	DE^	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	5.0%	5.0%
	ME*	Total Acoustic Sites				180		
		Sites with NLEB Captures			N/A	17	9.4%	9.4%
	MD^	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	5.0%	5.0%
	MA*	Total Acoustic Sites				132		
		Sites with NLEB Captures			N/A	9	6.8%	6.8%
	NH[#]	Total Mist Net Sites	2002-2004	13		173		
		Sites with NLEB Captures		12	92.3%	17	9.8%	9.8%
	NJ	Total Mist Net Sites	1995-2008	132		25		
		Sites with NLEB Captures		89	67.4%	8	32.0%	32.0%
	NY[+#]	Total Mist Net Sites	2000-2005	56		45		
		Sites with NLEB Captures		39	69.6%	15	33.3%	33.3%
	PA	Total Mist Net Sites	2001-2007	1069		1469		
		Sites with NLEB Captures		726	67.9%	497	33.8%	33.8%
	RI[$]	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	9.4%
	VT[+#]	Total Mist Net Sites	2000-2005			12		
		Sites with NLEB Captures			See NY	3	25.0%	9.8%
	VA[#]	Total Mist Net Sites	2010	27		60		
		Sites with NLEB Captures		27	100.0%	29	48.3%	48.3%
	WV	Total Mist Net Sites	1997-2008	508		97		
		Sites with NLEB Captures		401	78.9%	52	53.6%	53.6%

Table 3.1. Continued.

Range	State	Description	Pre-WNS Years (Combined)		Pre-WNS Occupancy Rate	Sum of 3 Most Recent WNS Years	WNS Impacted Occupancy Rate	Occupancy Rate Used
Southern	AL#	Total Mist Net Sites	2001-2011	179		38		
		Sites with NLEB Captures		48	26.8%	13	34.2%	34.2%
	AR#	Total Mist Net Sites	2009-2013	568		95		
		Sites with NLEB Captures		399	70.2%	62	65.3%	65.3%
	GA#	Total Mist Net Sites	2001-2011	62		18		
		Sites with NLEB Captures		37	59.7%	10	55.6%	55.6%
	KY	Total Mist Net Sites	2005-2010	503		305		
		Sites with NLEB Captures		263	52.3%	124	40.7%	40.7%
	LA$	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	34.2%
	MS$	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	34.2%
	NC#	Total Mist Net Sites	2000-2012	244		35		
		Sites with NLEB Captures		199	81.6%	14	40.0%	40.0%
	OK	Total Mist Net Sites	2013-2015	28		0		
		Sites with NLEB Captures		13	46.4%	0	N/A	46.4%
	SC$	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	34.2%
	TN#	Total Mist Net Sites	2000-2008	221		90		
		Sites with NLEB Captures		153	69.2%	37	41.1%	41.1%
Western	KS+	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	22.5%
	MT+	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	22.5%
	NE+	Total Mist Net Sites				0		
		Sites with NLEB Captures			N/A	0	N/A	22.5%
	ND+	Total Mist Net Sites	2009-2014	42		0		
		Sites with NLEB Captures		3	7.1%	0	N/A	22.5%
	SD+	Total Mist Net Sites	2003-2006	13		0		
		Sites with NLEB Captures		10	76.9%	0	N/A	22.5%
	WY+	Total Mist Net Sites	2010-2014	56		0		
		Sites with NLEB Captures		12	21.4%	0	N/A	22.5%

* Acoustic data used due to limited amount of mist net data

^ Statewide occupancy estimates from a more in-depth analysis used

Based on data from National Forests in the state

$ Data from nearby states used because statewide data was inadequate or unavailable

+ Data from multiple states were aggregated due to small datasets

Table 2.4. NLEB adult summer population estimates for the 30 states included in analysis.

Region	State	Forested Acres	Percent Occupancy	Occupied Acres	Maternity Colonies	Maternity Colony Size	Adult Females	Total Adults	Total Pups
Midwest	Iowa	3,013,759	41.7%	1,256,738	1,137	45	51,165	102,330	51,165
Midwest	Illinois	4,847,480	62.5%	3,029,675	2,740	39	106,860	213,720	106,860
Midwest	Indiana	4,830,395	37.5%	1,811,398	1,639	39	63,921	127,842	63,921
Midwest	Michigan	20,127,048	31.5%	6,340,020	5,734	39	223,626	447,252	223,626
Midwest	Minnesota	17,370,394	58.7%	10,196,421	9,221	45	414,945	829,890	414,945
Midwest	Missouri	15,471,982	26.2%	4,053,659	3,666	39	142,974	285,948	142,974
Midwest	Ohio	8,088,277	42.1%	3,405,165	3,080	39	120,120	240,240	120,120
Midwest	Wisconsin	16,980,084	44.9%	7,624,058	6,895	39	268,905	537,810	268,905
Eastern	Connecticut	1,711,749	9.4%	160,904	146	20	2,920	5,840	2,920
Eastern	Delaware	339,520	5.0%	16,976	16	20	320	640	320
Eastern	Maine	17,660,246	9.4%	1,660,063	1,502	39	58,578	117,156	58,578
Eastern	Maryland	2,460,652	5.0%	123,033	112	20	2,240	4,480	2,240
Eastern	Massachusetts	3,024,092	6.8%	205,638	186	20	3,720	7,440	3,720
Eastern	New Hampshire	4,832,408	9.8%	473,576	429	20	8,580	17,160	8,580
Eastern	New Jersey	1,963,561	32.0%	628,340	569	20	11,380	22,760	11,380
Eastern	New York	18,966,416	33.3%	6,315,817	5,712	20	114,240	228,480	114,240
Eastern	Pennsylvania	16,781,960	33.8%	5,672,302	5,130	20	102,600	205,200	102,600
Eastern	Rhode Island	359,519	9.4%	33,795	31	20	620	1,240	620
Eastern	Vermont	4,591,280	9.8%	449,945	407	20	8,140	16,280	8,140
Eastern	Virginia	15,907,041	48.3%	7,683,101	6,948	20	138,960	277,920	138,960
Eastern	West Virginia	12,154,471	53.6%	6,514,796	5,892	20	117,840	235,680	117,840
Southern	Arkansas	18,754,916	65.3%	12,246,960	11,075	39	431,925	863,850	431,925
Southern	Kentucky	12,471,762	40.7%	5,076,007	4,591	39	179,049	358,098	179,049
Southern	Mississippi	19,541,284	34.2%	6,683,119	6,044	45	271,980	543,960	271,980
Southern	North Carolina	18,587,540	40.0%	7,435,016	6,724	39	262,236	524,472	262,236
Southern	Tennessee	13,941,333	41.1%	5,729,888	5,182	20	103,640	207,280	103,640
Western	Kansas	2,502,434	22.5%	563,048	510	45	22,950	45,900	22,950
Western	Nebraska	1,576,174	22.5%	354,639	321	45	14,445	28,890	14,445
Western	North Dakota	759,998	22.5%	171,000	155	45	6,975	13,950	6,975
Western	South Dakota	1,910,934	22.5%	429,960	389	45	17,505	35,010	17,505
	Total	281,528,709	37.8%	106,345,057	96,183		3,273,359	6,546,718	3,273,359

Table 2.5. Estimated acreage of NLEB maternity roosting areas for the 30 states included in analysis.

Region	State	Forested Acres	Maternity Colonies[1]	Maternity Roost Area Acres (167 acres per Colony)	Percent of Forest Habitat Used as Maternity Roost Areas
Midwest	Iowa	3,013,759	1,137	189,879	6.30%
Midwest	Illinois	4,847,480	2,740	457,580	9.44%
Midwest	Indiana	4,830,395	1,639	273,713	5.67%
Midwest	Michigan	20,127,048	5,734	957,578	4.76%
Midwest	Minnesota	17,370,394	9,221	1,539,907	8.87%
Midwest	Missouri	15,471,982	3,666	612,222	3.96%
Midwest	Ohio	8,088,277	3,080	514,360	6.36%
Midwest	Wisconsin	16,980,084	6,895	1,151,465	6.78%
Eastern	Connecticut	1,711,749	146	24,382	1.42%
Eastern	Delaware	339,520	16	2,672	0.79%
Eastern	Maine	17,660,246	1,502	250,834	1.42%
Eastern	Maryland	2,460,652	112	18,704	0.76%
Eastern	Massachusetts	3,024,092	186	31,062	1.03%
Eastern	New Hampshire	4,832,408	429	71,643	1.48%
Eastern	New Jersey	1,963,561	569	95,023	4.84%
Eastern	New York	18,966,416	5,712	953,904	5.03%
Eastern	Pennsylvania	16,781,960	5,130	856,710	5.10%
Eastern	Rhode Island	359,519	31	5,177	1.44%
Eastern	Vermont	4,591,280	407	67,969	1.48%
Eastern	Virginia	15,907,041	6,948	1,160,316	7.29%
Eastern	West Virginia	12,154,471	5,892	983,964	8.10%
Southern	Arkansas	18,754,916	11,075	1,849,525	9.86%
Southern	Kentucky	12,471,762	4,591	766,697	6.15%
Southern	Mississippi	19,541,284	6,044	1,009,348	5.17%
Southern	North Carolina	18,587,540	6,724	1,122,908	6.04%
Southern	Tennessee	13,941,333	5,182	865,394	6.21%
Western	Kansas	2,502,434	510	85,170	3.40%
Western	Nebraska	1,576,174	321	53,607	3.40%
Western	North Dakota	759,998	155	25,885	3.41%
Western	South Dakota	1,910,934	389	64,963	3.40%
	Total	281,528,709	96,183	16,062,561	5.71%

[1] From Table 2.4

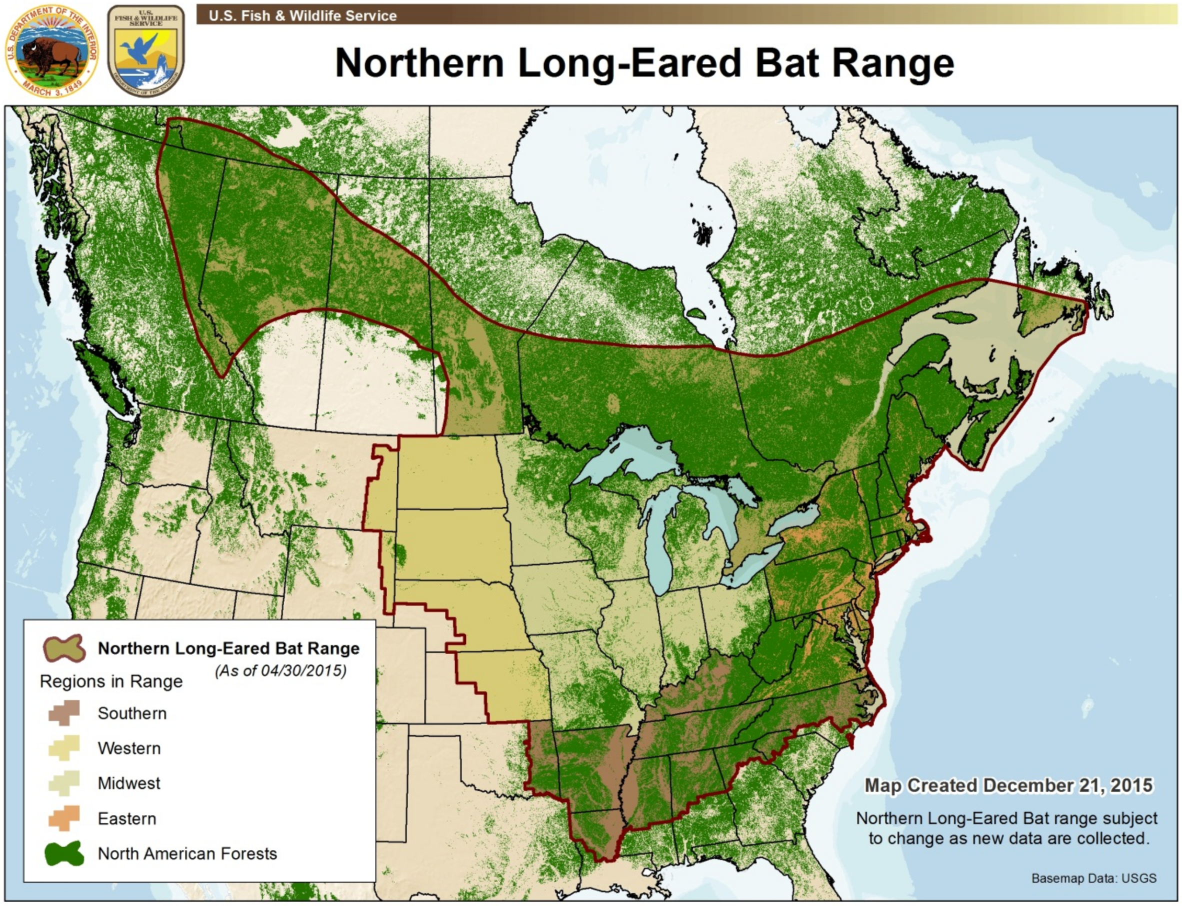

Figure 2.1. Range of the NLEB.

3 ENVIRONMENTAL BASELINE

Regulations implementing the Act (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the Action Area. Also included in the environmental baseline are the anticipated impacts of all proposed Federal projects in the Action Area that have undergone section 7 consultation, and the impacts of State and private actions which are contemporaneous with the consultation in progress. The environmental baseline is a "snapshot" of the species' health in the Action Area at the time of the consultation, and does not include the effects of the action under review.

Because the Action Area covers the entire range of the species within the United States, the environmental baseline is the same as the status of the species discussed in detail in Section 2. No further discussion is needed in this section.

4 EFFECTS OF THE ACTION

This section addresses the direct and indirect effects of the Action on the NLEB, including the effects of interrelated and interdependent activities. Direct effects are caused by the action and occur at the same time and place. Indirect effects are caused by the proposed action and are later in time but still are reasonably certain to occur.

The NLEB is likely to be affected by many activities which are excepted from incidental take prohibitions in the final 4(d) rule. Instead of describing all of the activities, we address the general effects of different activities, which we categorized into 7 general groups:

1. Capture and handling of NLEBs by individuals with section 10(a)(1)(A) permits for other listed bats or State permits until May 3, 2016
2. Removal from human structures
3. Timber harvest
4. Prescribed fire
5. Forest conversion
6. Wind turbine operation
7. Other activities that may affect the NLEB

The effects of category #1 are not addressed in this consultation because a separate section 10(a)(1)(A) permit and section 7 consultation will be required for those activities after May 3, 2016, as required by the final 4(d) rule. Until that time, we expect limited effects because NLEBs are currently hibernating and most surveys are conducted during the summer. Winter hibernacula surveys could affect the NLEB until May 3, 2016; however, researchers conducting winter surveys must have a section 10(a)(1)(A) permit for other listed bat species. The Service completed three BOs for the effects of existing bat section 10(a)(1)(A) permits on the NLEB in the Midwest, Mountain/Prairie and Southeast Regions. The adverse effects from winter hibernacula surveys are addressed in those BOs, which were non-jeopardy opinions.

The final 4(d) rule does not prohibit incidental take outside of the WNS zone. This effects analysis does not address the differences in prohibitions outside of the WNS zone because current actions that may affect the NLEB have not been shown to have significant impacts on NLEBs before WNS was detected. We expect that the impacts will be further reduced in the areas outside of the WNS zone because less than 2% of the total estimated population of NLEB occurs in the areas outside of the WNS zone (Section 2.4.5), and the habitat is more sparse (Figure 2.1). In addition, we anticipate that the WNS zone will expand further into the western states fairly quickly. Therefore, we did not attempt to analyze the different prohibitions between the zones.

4.1 EFFECTS ANALYSIS METHODOLOGY

For each of the remaining six categories of activities described above, we apply the following steps to analyze effects at the programmatic level:

- **Effects of the Activity –** We review best available science and commercial information about how the activity may affect the NLEB. Based on the literature review, we identify the stressor(s) (alteration of the environment that is relevant to the species) that may result from the proposed activity. For each stressor, we identify the circumstances for an individual bat's exposure to the stressor (overlap in time and space between the stressor and a NLEB). Given exposure, we identify the likely individual response(s), both positive and negative. For this consultation, we group responses into one of four categories: (1) potentially increased fitness (e.g., increased access to, or availability of, prey organisms); (2) reduced fitness (e.g., reduced food resources, reduced suitable roosting sites); (3) disturbance (e.g., day-time disturbance in a maternity roosting area, causing bats to flee and increasing the likelihood of injury or predation); and (4) harm (e.g., harvesting a tree occupied by adults and flightless bat pups resulting in death or injury; predation resulting from disturbance). This analysis is captured in the Exposure-Response Table (Table 4.1). This table provides the complete record of the effects analysis for this species and is intended to be read in concert with and support this effects analysis section.
- **Quantifying Effects to Individuals –** Estimating the numbers of individuals of a species exposed to stressors in a programmatic consultation is difficult because programs do not usually specify with sufficient detail when and where projects will occur relative to the species' occurrence. For this consultation, we have very little site-specific data about NLEB distribution and abundance in the Action Area; however, we do not assume that the species is ubiquitous, which would grossly overestimate effects. We do not have

enough information to quantify the effects of the pathways associated with removal from human structures and the "other" category of activities that may affect the NLEB. These effects are discussed in general in the sections below. For pathways associated with timber harvest, prescribed fire, and forest conversion, we apply the annual average acreage of the activity, NLEB occupancy rates, and NLEB density within occupied areas to estimate individual-level effects (numbers of individual bats included in the pathway), which we describe in Section 4.1.2.2 below. For wind turbine operation, we estimate the number of bats that could be killed using the current and projected amount of wind energy development and information on bat mortality rates, which we describe in Section 4.1.5.2 below.

We then aggregate all of the effects to individuals and examine:

- **Population-level Effects –** We evaluate the aggregated consequences of the effects to individuals/habitat on the fitness of the population(s) to which those individuals belong. This step closes with our conclusions on the likely fate or ultimate response of the population(s) and is couched in terms of population fitness (i.e., persistence and reproductive potential, long and short-term).
- **Species Range-wide** - This step determines whether the anticipated reductions in population fitness will reduce the likelihood of survival and recovery of the species by reducing its range-wide reproduction, numbers, or distribution (RND). If the Service and other action agencies have insured that the population-level risks do not noticeably, detectably, or perceivably reduce the likelihood of progressing towards or maintaining the RND needs, then the action is not likely to appreciably reduce the likelihood of both survival and recovery of the species.

4.2 REMOVAL FROM HUMAN STRUCTURES

4.2.1 EFFECTS OF REMOVAL FROM HUMAN STRUCTURES

As described in Section 2.1.1., NLEBs have occasionally been found roosting in human structures such as barns, houses, and sheds. Humans and bats often conflict when bats roost in human structures. Public misconception and health concerns from rabies, bat droppings, and urine often result in the need to remove bats from human structures. Many techniques used to remove bats are harmful and may result in mortality, including poisoning, trapping (e.g., cages, sticky traps), exterminating, and translocating (WNS Conservation and Recovery Working Group 2015). Bats can also be removed through humane methods (if used during the proper time of year) such as eviction/venting and exclusion. Eviction/venting refers to the use of one-way doors and exits to remove bats from a structure by utilizing their natural tendency to leave the roost at night. Exclusion refers to closing gaps and sealing holes to prevent bats from entering or re-entering a structure (WNS Conservation and Recovery Working Group 2015). Eviction and exclusion are widely-used, popular methods because poisons and traps are messy and might result in dead bats rotting in walls and attics.

Table 4.1 shows the four pathways we identified for NLEB responses to removal from human structures and the range of individual responses expected. The use of rodenticides and sticky traps to remove bats is likely to result in mortality. NLEBs may also be euthanized for rabies testing. Roost closure during the maternity season has been documented to result in lower reproductive success (Brigham and Fenton 1986). Attempts to evict or exclude bats at this time can result in the death of flightless young, as well as an increase in the number of adult bats and orphaned pups that enter the living space, potentially heightening the risk of human/bat contact (WNS Conservation and Recovery Working Group 2015). In addition, NLEBs can be indirectly affected through the loss of the roost by exclusion if additional energy is required during their search for a new roost site when NLEBs return to the site after hibernation.

The WNS Conservation and Recovery Group, in coordination with states and wildlife control operators, recently developed Best Management Practices (BMPs) for bat control activities in human structures (WNS Conservation and Recovery Working Group 2015) to ensure that adverse effects are minimized. The National Wildlife Control Operators Association recently released a new training on bat standards, affecting at least 48 wildlife control operators in 20 States within the NLEB range that are Certified Wildlife Control Professionals. This certification requires training, seminars, and continued education, and we anticipate that these professionals (and probably others) will follow the bat standards.

States within the range of the NLEB vary in requirements for removal of bats from human structures. States with state- or federally-listed bat species may require permits for bat removal or may require wildlife control operators to use BMPs when removing or excluding bats from houses or structures. Within the range of the NLEB, only Maine, Montana, and the Dakotas do not have another state- or federally-listed bat species, so it is likely that many of these states already have a program to recommend or require BMPs for bat removal prior to the NLEB listing in 2014. We surveyed states to determine if: (1) wildlife control operators are required to obtain authorization for bat removal or exclusions; (2) BMPs are required or recommended; and (3) exclusions and evictions are conducted outside of the NLEB maternity season.

We were able to speak with representatives from state natural resource programs in Illinois, Wisconsin, Michigan, Missouri, Minnesota, Ohio, Vermont, and South Carolina. Five of the eight states require authorization for wildlife control operators to remove or exclude bats from buildings. Of these five states, all but Michigan require that evictions and exclusion occur after NLEB pups are capable of flight, unless in the unusual case of a severe health hazard. Even though three states do not require authorization for wildlife control operators, only two states

(Missouri and Michigan) do not communicate or recommend BMPs for bat exclusion or removals.

We also obtained rabies testing data from the state health departments in New York and Missouri. If a single or pair of bats enter a household, wildlife control operators generally trap the bats and euthanize them for rabies testing. These data indicate that an average of 7 NLEBs were killed per year for rabies testing during the most recent three years. In both New York and Missouri, NLEB make up a small fraction (typically less than 2%) of the bats in houses.

Although removal from human structures can result in NLEB mortality, we anticipate that few bats are impacted per year in each state based on the relatively rare use of human structures, the implementation of bat removal BMPs (either required or recommended) throughout most of the range of the NLEB, and the relatively small amount of NLEBs killed for rabies testing.

4.3 TIMBER HARVEST

Timber harvest is one of two categories of forest management described in this BO. Unlike forest conversion, forest management maintains forest habitat on the landscape, and the impacts from management activities are for the most part considered temporary in nature. Impacts from forest management are expected to range from positive (e.g., maintaining or increasing suitable roosting and foraging habitat within NLEB home ranges) to neutral (e.g., minor amounts forest removal, areas outside NLEB summer home ranges or away from hibernacula) to negative (e.g., death of adult females or pups or both).

Timber harvest is the removal of trees associated with forest management. It includes a wide variety of practices from selected harvest of individual trees to clearcutting. Timber harvest is often partitioned according to the forest management treatment type used to accomplish the harvest: even-aged management; uneven-aged management; thinning; and salvage/sanitation. It is conducted for a variety of purposes including, but not limited to, harvests (commercial and non-commercial) for timber production and for ecosystem restoration, endangered/threatened/sensitive species conservation, stand regeneration for forest health, wildlife habitat improvement, insect and disease control, and fuel reduction. All of these activities are categorized under the general category of timber harvest for the purposes of this BO.

4.3.1 EFFECTS OF TIMBER HARVEST

<u>Literature Review</u>

The best available data indicate that the NLEB shows a varied degree of sensitivity to timber-harvesting practices. Menzel et al. (2002) found NLEB roosting in intensively managed stands in West Virginia. At the same study site, Owen et al. (2002) concluded that NLEB roosted in areas with abundant snags, and that in intensively managed forests of the central Appalachians, roost availability was not a limiting factor. Perry and Thill (2007) tracked NLEB in central Arkansas and found roosts in eight different forest classes, of which 89 percent were in three classes of mixed pine-hardwood forest. The mixed pine-hardwood forest stands that supported most of the roosts were partially harvested or thinned, unharvested (50–99 years old), or harvested by group selection.

Timber harvest accomplished through thinning, group selection, and individual selection may create canopy openings in an otherwise densely-forested setting, which may promote more rapid development of bat pups. In central Arkansas, Perry and Thill (2007) found female NLEB bat roosts were more often located in areas with partial harvesting than males, with more male roosts (42 percent) in un-harvested stands than female roosts (24 percent). They postulated that females roosted in relatively more open forest conditions because they may receive greater solar radiation, which may increase developmental rates of young or permit young bats a greater opportunity to conduct successful initial flights (Perry and Thill 2007). Cryan et al. (2001) found several reproductive and non-reproductive female NLEB roosts in recently harvested (less than 5 years) stands in the Black Hills of South Dakota where snags and small stems (dbh of 5 to 15 cm (2 to 6 inches)) were the only trees left standing. In this study, however, the largest colony (n=41) was found in a mature forest stand that had not been harvested in more than 50 years. Lacki and Schwierjohann (2001) stated that silvicultural practices could meet both male and female roosting requirements by maintaining large-diameter snags, while allowing for regeneration of forests.

Forest patch size and contiguity are factors that appear to influence habitat use by NLEB. Henderson et al. (2008) observed gender-based differences in mist-net capture rates of NLEB on Prince Edward Island related to forest patch size. The area of deciduous stands had a consistent positive relationship with the probability of presence of both males and females, but males were found more often in smaller stands than females. In southeastern Missouri, Yates and Muzika (2006) reported that NLEB showed a preference for contiguous tracts of forest cover (rather than fragmented or open landscapes) for foraging or traveling, and that different forest types interspersed on the landscape increased the likelihood of occupancy.

In West Virginia, Owen et al. (2003) radio-tracked nine female NLEB that spent their foraging and travelling time in the following habitat types (in descending order of use):

- 70–90-year-old stands without harvests in more than 10–15 years (“intact forest”) (mean use 52.4 percent);

- 70–90 year-old stands with 30–40 percent of basal area removed in the past 10 years ("diameter-limit harvests") (mean use 42.9 percent);
- open areas (clearcuts and roads) (clear cut = all trees > 2.5 cm (1.0 inch) dbh removed) (mean use 4.6 percent); and
- clearcuts with approximately 4.5 m^2/ha (19.6 ft^2/acre) tree basal area remaining ("deferment harvests") (mean use 0.03 percent).

Habitat selection differed significantly relative to habitat availability, with diameter-limit harvests ranking as the strongest habitat preference, where percent use exceeded percent availability for 7 of the 9 bats.

In Alberta, Canada, NLEB avoided the center of clearcuts and foraged more in intact forest than expected (Patriquin and Barclay 2003). On Prince Edward Island, Canada, female NLEB preferred to forage in areas centered along creeks running through forests (Henderson and Broders 2008). In mature forests on the Sumter National Forest in northwestern South Carolina, 10 of the 11 stands in which NLEB were detected were mature stands (Loeb and O'Keefe 2006). Within those mature stands, NLEB were recorded more often at points with sparse or medium-density vegetation than at points with dense vegetation, suggesting that small openings within forest stands facilitate commuting and/or provide suitable foraging habitat. However, in southwestern North Carolina, Loeb and O'Keefe (2011) found that NLEB rarely used forest openings, but often used roads.

At Fort Knox in Kentucky, Silvis et al. (2014) tracked three maternity colonies of NLEB to evaluate their social and resource networks, i.e., roost trees. Roost and social network structure differed between maternity colonies, and roost availability was not strongly related to network characteristics or space use. In model simulations based on the tracking data, removal of more than 20 percent of roosts initiated social network fragmentation, with greater loss causing more fragmentation. The authors suggested that flexible social dynamics and tolerance of roost loss are adaptive strategies for coping with ephemeral conditions in dynamic forest habitats. Sociality among bats may contribute to reproductive success, and fragmented colonies may experience reduced success.

In the same Fort Knox study area with the same three maternity colonies, Silvis et al. (2015) removed during winter a primary maternity roost tree from one colony, 24 percent of the secondary roosts from another colony, and none from the third. Neither removal treatment altered the number of roosts used by individual bats, but secondary roost removal doubled the distances moved between sequentially used roosts. Overall location and spatial size of colonies was similar pre- and post-treatment. Patterns of roost use before and after removal treatments also were similar. Roost height, diameter at breast height, percent canopy openness, and roost species composition were similar pre- and post-treatment. NLEB use a wide range of tree species and sizes as roosts, and potential roosts were not limited in the treatment areas.

Although the literature we reviewed contains no reports of NLEB mortality resulting from tree harvest, there have been three documented instances of Indiana bat adults and pups killed or injured when an occupied roost tree was felled. Indiana bats and NLEB are closely related and have similar behavior (i.e., forest-dwelling, forming maternity colonies, roosting in trees in the summer). Cope et al. (1974) reported the first felling of an occupied Indiana bat maternity roost tree in Wayne County, Indiana. The landowner observed bats exiting the tree when it was bulldozed down. The original account stated that eight bats (2 adult females and 6 juveniles) were “captured and identified as Indiana bats,” and that about 50 bats flew from the tree. Although the original account did not specify how the eight bats were captured, J. Whitaker (Indiana State University, pers. comm., 2005) recounted that those bats were killed or disabled, retrieved by the landowner, and subsequently identified by a biologist. In another case, Belwood (2002) reported on the felling of a dead maple in a residential lawn in Ohio. One dead adult female and 33 non-volant young were retrieved by the researcher. Three of the young bats were already dead when they were picked up, and two more died subsequently. The rest were apparently retrieved by adult bats that had survived. In a third case, 11 dead adult female Indiana bats were retrieved (by people) when their roost was felled in Knox County, Indiana (J. Whitaker, pers. comm., 2005).

These accounts suggest that some individuals, including non-volant pups, can survive the felling of a maternity roost tree. It is not possible to infer injury rates from these studies. It is only possible to crudely estimate mortality rates from the Belwood case. If we assume that there were 66 individuals in the tree (the 33 pups observed plus 1 dead adult female and 32 presumed additional adult females who retrieved their pups), the overall survival rate was high at 91%. Only 1 adult bat was observed dead (about 3% of adults), and the juvenile mortality rate was about 15%. We acknowledge that timber harvest operations in a forest bear little resemblance to these three instances, but available evidence indicates that both adults and pups can be killed when an occupied roost tree is felled. For the purposes of this consultation, we assume that 15% of non-volant bats have the potential to be harmed, and 3% of adult bats could be killed or injured in a felled tree. Adults may be at greater risk during the spring during colder temperatures and increased use of torpor. It is also possible that trees felled adjacent to roost trees could strike roosting bats and result in injury or death.

Disturbance associated with harvest activity could cause NLEB to flee or abandon day-time roosts, which increases the likelihood of predation. This may also result in females aborting or not being impregnated depending on the time of year. Gardner et al. (1991) reported that Indiana bats continued to roost and forage in an area with active timber harvest, but this will depend on the scale of harvest and whether there is any remaining suitable habitat. Callahan (1993) attributed the abandonment of a primary maternity roost tree to disturbance from a bulldozer clearing brush adjacent to the tree.

Surface-disturbing activities in the vicinity of hibernacula may affect bat populations if those activities result in changes to the microclimate (temperature, humidity, and air flow) of the cave or mine (Ellison et al. 2003). Tree removal in karst areas can alter soil characteristics, water quality, local hydrology to the extent that it alters cave microclimates and affects bats (Bilecki 2003, Hamilton-Smith 2001). Bats in hibernation are susceptible to dehydration due to high evaporative loss from their naked wings and large lungs (Perry 2013). Richter et al. (1993) documented temperature increases resulting from structural modifications to a cave entrance that substantially reduced its suitability for bats. The creation of new openings or filling in existing openings could also result from obstructing cave entrances with dirt or logging slash.

Summary of Exposure-Response Table

Table 4.1 shows the five pathways we identified for NLEB responses to timber harvest and the range of individual responses expected. The primary alteration of the environment associated with timber harvest that is relevant to the NLEB is the removal of trees that provide roosts or serve as foraging, spring staging, or fall swarming habitat. Removing occupied trees is likely to kill or injure pups and adults. Loss of forest habitat decreases opportunities for growth and successful reproduction. Alteration of hibernacula can harm NLEBs. The disturbance (noise, exhaust from machinery, etc.) that accompanies harvest activities may result in disturbance because fleeing during daylight increases the likelihood of predation. A small subset of disturbed individuals may be harmed. Thinning mid-story clutter may have a beneficial effect on the suitability of adjacent maternity roost trees when done when bats are not present. The species' responses to these stressors depends on the type of harvest (e.g., thinning, salvage, even-aged management, clear cut, etc.) and the context of exposure, i.e., when and where it occurs.

4.3.2 METHODOLOGY FOR QUANTIFYING EFFECTS OF TIMBER HARVEST

To estimate the potential impacts of timber harvest through 2022, we calculated the average annual amount of timber harvest in states within the NLEB's range using data available through the USDA Forest Service's Forest Inventory Analysis (available only on internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp; accessed November 2015). This database reports the total harvest (acres) of federal, state and local, and private entities by state for various combinations of years. We used the most recent combination of years available and calculated the mean annual harvest (Table 4.2). We assumed that the mean annual harvest from recent years will be consistent through the period of this consultation and recognize that many types of harvest leave a remaining forest that is available for NLEB use. The information in this database may be overestimated for certain states and underestimated for others. For instance, we estimated that 163,971 acres would be harvested on average in National Forests in South Dakota; however, the U.S. Forest Service is currently projecting up 35,000 acres of harvest annually. In Illinois, the database reports 0 acres of harvest, but the Forest Service projects 1,300 acres of average annual harvest.

Similar to the population estimation methods in Section 2.4.2, we excluded a state from our analyses if less than 50% of it is within the NLEB range. These estimates are likely conservative and underestimate the number of acres harvested; however, some harvest reports may reflect a few tree removals and not necessarily a clear cut or selected harvest. We anticipate that 3,669,077 acres will be harvested annually through 2022, which is 1.3% of the available forested habitat, or 9.1% over seven years (Table 4.2). Timber harvest is expected to occur in similar proportions in the Midwest, Eastern, and Southern ranges (29, 35, and 34%, respectively), but only about 2% of the total harvest will occur in the Western range. We anticipate that habitat losses from timber harvest will be temporary.

We further analyzed these data by partitioning the average annual acreage expected during the NLEB active season and the pup season. Lacking a breakdown of the acres harvested during the active and non-volant seasons, we assume that timber harvest will occur with equal frequency throughout the year. The NLEB active season (April 1 – October 31) is 214 days, or 58.6% of the year. The NLEB non-volant season (June 1 – July 31) is 61 days, or 16.7% of the year. Therefore, the average annual acres of timber harvest during the active season is 58.6% of the total average annual acres, and 16.7% of the total timber harvest is estimated to occur in the non-volant season.

For spatial exposure to stressors, we must consider that timber harvest and NLEB-occupied areas may occur anywhere within the forested acreage of each state, but we recognize there are some forests in National or State Parks or Wilderness areas that may not be subject to harvest. NLEB occupancy estimates vary by state from about 9 to 60 percent (see section 2.4.1). It is possible for timber harvest, which annually affects about 1.3 percent of the available forested habitat, to occur entirely on the 5 to 65 percent of the habitat in each state that we consider occupied, or not at all, because we have no information indicating whether certain activities are more or less likely to occur in occupied areas. Therefore, our effects analyses compute the expected (probable) degree of spatial overlap between activities and occupied areas as the product of two independent probabilities, namely, the percentage of the forested habitat that is proposed for timber harvest multiplied by the percentage of the forested habitat that the NLEB occupies in a particular manner, e.g., for roosting or foraging.

The following example demonstrates our methodology for estimating individual-level direct effects corresponding to the stressor-exposure-response pathway for timber harvest during the non-volant season (June 1–July 31) within a maternity roost, which may kill or injure non-volant pups.

a. State A, with 500,000 acres of forested habitat, will annually harvest 2,500 acres (0.5 percent of the total habitat) during the non-volant season.
b. State A has a 30 percent occupancy rate for NLEB, i.e., 150,000 acres of State A are within the active-season home range of individuals of this species.
c. We assume that individuals belonging to maternity colonies collectively occupy 90 percent (co-capture rate of reproductive females with males and non-reproductive females; see section 2.4 for the basis of this and other NLEB distribution and abundance assumptions) of these 150,000 acres, or 0.90 × 150,000 = 135,000 acres.
d. We assume maternity colonies do not overlap and occupy 1,000 acres each; therefore State A supports 135,000 ÷ 1,000 = 135 colonies.
e. We assume that individuals in a maternity colony roost in trees within an area of 167 acres; therefore, the colonies of State A occupy 135 × 167 acres = 22,545 acres for roosting, which is 4.5 percent of State A.
f. State A has not yet been affected by WNS; therefore, each colony supports 45 non-volant pups during the harvest time frame (1 pup per adult female, section 2.4).

In this example, 2,500 acres (0.5 percent) of the forested acres in the state are proposed for harvest during the non-volant season, and 22,545 acres (4.5 percent) harbors non-volant pups. The mathematically expected (probable) degree of spatial overlap is the product of the two percentages, or 0.5 percent × 4.5 percent = 0.0225 percent, which is 112.7 acres of the 500,000 acres in State A. To estimate the number of bat pups affected, we multiply the density of bat pups in maternity roosting areas (45 pups per 167 acres) by the expected acreage of overlap: (45 ÷ 167) × 112.7 = 30.3, which we round up to 31 pups. We aggregate the results of this type of analysis for all timber harvest actions within a state and across all 30 states included in the analysis, which provides a basis for estimating the total expected effects of multiple project-level actions at a scale not exceeding the total amount of timber harvest estimated per year.

Consistent with the example above, our calculations for estimating the effects corresponding to each stressor-exposure-response pathway that we quantify are presented in tabular form in section 4.3. Each table lists the 30 states with the following six columns of data:

a. annual, active-season, or non-volant-season extent (acres) of timber harvest (or the proposed activity causing the stressor), depending on the pathway;
b. total forest habitat acres;
c. percent of the forest habitat receiving the activity (a ÷ b);
d. percent of the forest habitat that NLEB use at a time and in a manner (from section 2.4) that the stressor could affect causing a specific type of individual response;
e. expected overlap (acres) of the activity and the bat-occupied area (b × c × d); and
f. expected number of individuals affected (e × bat density in the occupied area).

In the final step of the calculations described above, the density we multiply by the expected area of overlap depends on the manner in which NLEB use the habitat exposed to the stressor. In the preceding example, non-volant pups in maternity roosting areas are the individuals responding to the stressor, and the density is 45 pups per 167 acres (0.2695). Based on the data and assumptions identified in section 2.4 about NLEB populations in the Action Area, we use the following NLEB densities in computing column "e" of each effects estimation table:

Habitat	NLEB individuals	Density for 45 females per Maternity Colony	Density for 39 females per Maternity Colony	Density for 20 females per Maternity Colony
Summer home range	Adult females and sympatric adult males	0.0814	0.0362	0.0705
Maternity roosting areas	Non-volant pups	0.2695	0.1198	0.2335
Roosting areas	Adult females, volant juveniles, and sympatric adult males	0.8084	0.3593	0.7006

This methodology generates results in terms of numbers of individual NLEB affected, but we must acknowledge its inherent imprecision. It relies on assumptions about state-specific occupancy rates and applies values for colony size, sex ratios, etc., that we believe are reasonable and based on best available information, but which are either uncertain or variable across the Action Area. Although it is coarse, this methodology provides a transparent basis for quantifying effects for interpretation relative to the status of the species, which is the purpose of an effects analysis in a BO.

4.3.3 QUANTIFYING EFFECTS OF TIMBER HARVEST

We quantify the two pathways expected to result in direct effects to the NLEB: disturbance from fleeing human activity (Table 4.3), and harm from removing occupied roost trees (Table 4.4 for pups and Table 4.5 for adults). Human disturbance from timber harvest during the active season (April – October) within maternity roosting areas may disturb up to 76,846 volant NLEB annually (Table 4.3). A small subset of these disturbed individuals may be harmed. Timber harvests that remove occupied roost trees during the non-volant season may harm up to 1,109 pups annually (Table 4.4). Removal of occupied roost trees during the active season may harm up to 247 adults annually (Table 4.5).

In addition to these two pathways, timber harvest activities could alter the flow of air and water through unknown hibernacula which could also harm NLEBs. We do not have enough information to quantify the effects of this pathway because we do not know where projects will occur relative to the unknown hibernacula that are likely on the landscape. Although the alteration of unknown hibernacula is reasonably certain to occur, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed (i.e., not concentrated in a given area) nature of timber harvest activities. In addition, the hibernacula often selected by NLEB are "large, with large passages" (Raesly and Gates 1987), and may be less affected by relatively minor surficial micro-climatic changes that might result from timber harvest around unknown roosts. Further, bats rarely hibernate near the entrances of structures (Grieneisen 2011). Davis et al (1999) reported that partial clearcutting "appears not to affect winter temperatures deep in caves."

We also do not quantify the potential reductions in fitness that may result as indirect effects from loss of habitat. We anticipate that 1.3% (3,669,077 acres) of available habitat will be harvested annually through 2022; however, we anticipate that habitat losses from timber harvest will be temporary. In addition, the NLEB does not appear to be limited by habitat, as demonstrated by a great deal of plasticity within its environment (e.g., living in highly fragmented forest habitats to contiguous forest blocks from the southern United States to Canada's Yukon Territory) in the absence of WNS. Therefore, reductions in fitness from habitat loss are anticipated to be small. Further, timber harvest practices that reduce mid-story clutter likely also benefit NLEB habitat and may increase fitness of local NLEB populations. We do not quantify the potential increases in fitness because we lack the scientific support to interpret the degree to which survival or reproductive success rates of local populations may be influenced; however, management of existing forests is likely to maintain roosting or foraging habitat.

4.4 PRESCRIBED FIRE

Prescribed fire is the other category of forest management described in this BO. Prescribed burning is deliberately burning wild-land fuels under specified environmental conditions in a predetermined area with a predetermined fire-line intensity and rate of movement in order to attain resource management objectives. It is typically classified as dormant-season and growing-season burning. The seasonality varies by latitude and elevation, but the dormant season is generally October –April and the growing season is April 15 – August 15. Dormant-season burning is primarily used to reduce the buildup of hazardous fuels and thereby reduce the likelihood of catastrophic wildfires or to achieve ecological stand objectives. Growing-season burning is used for site preparation, control of undesirable species, and restoration and maintenance of fire-dependent plant communities and associated wildlife. Most growing season burning takes place in the spring and fall; however, growing season burning occurs through the active and pup seasons in the rest of the range. For example, we recently completed programmatic consultations for the NLEB with the U.S. Forest Service on Forest Plans in their Southern and Eastern regions, which includes the Midwest, Southern, and Eastern ranges of the NLEB. Twenty-one and 16 percent of prescribed burning was projected to occur during the pup season (defined by the Forest Service as May 1 to July 30) in the Southern and Eastern regions, respectively.

4.4.1 EFFECTS OF PRESCRIBED FIRE

Literature Review

Perry (2012) provides a review of fire effects on bats in the eastern oak region of the U.S., and Carter et al. (2002) provides a similar review for bats in the southeastern and mid-Atlantic states. Forest-dwelling bats, including the wide-ranging NLEB, were presumably adapted to the fire-driven disturbance regime that preceded European settlement and fire suppression in many parts of the eastern U.S. Concurrent changes in habitat conditions preclude any reasonable inferences about the overall impact of fire suppression on populations of forest-dwelling bats. It is apparent that fire may affect individual bats directly (negatively) through exposure to heat, smoke, and carbon monoxide, and indirectly (both positively and negatively) through habitat modifications and resulting changes in their food base (Dickinson et al. 2009).

Direct Effects – Summer Roosting

Little is known about the direct effects of fire on cavity and bark roosting bats, such as the NLEB, and few studies have examined escape behaviors, direct mortality, or potential reductions in survival associated with effects of fire. Dickinson et al. (2009) monitored two NLEB (one male and one female) in roosts during a controlled summer burn. Within 10 minutes of ignition near their roosts, both bats flew to areas that were not burning. Among four bats they tracked before and after burning, all switched roosts during the fire, with no observed mortality. Rodrigue et al. (2001) reported flushing a *Myotis* bat from an ignited snag during an April controlled burn in West Virginia.

Carter et al. (2002) suggested that the risk of direct injury and mortality to southeastern forest-dwelling bats resulting from summer prescribed fire is generally low. During warm temperatures, bats are able to arouse from short-term torpor quickly. Most adult bats are quick, flying at speeds > 30 km/hour (Patterson and Hardin 1969), enabling escape to unburned areas. NLEB use multiple roosts, switching roost trees often (see *Summer Roosting Behavior* in Section 2.4.3), and could likely use alternative roosts in unburned areas, should fire destroy the current roost. Non-volant pups are likely the most vulnerable to death and injury from prescribed fire. Although most eastern bat species are able to carry their young for some time after they are born (Davis 1970), the degree to which this behavior would allow females to relocate their young if fire threatens the nursery roost is unknown.

Dickinson et al. (2010) used a fire plume model, field measurements, and models of carbon monoxide and heat effects on mammals to explore the risk to the Indiana bat and other tree-roosting bats during prescribed fires in mixed-oak forests of southeastern Ohio and eastern Kentucky. Carbon monoxide levels did not reach critical thresholds that could harm bats in low-intensity burns at typical roosting heights for the Indiana bat (8.6 m) (28.2 ft). NLEB roost height selection is more variable, but on average lower (6.9 m) (22.8 ft) than the Indiana bat (Lacki et al. 2009b). In this range of heights, direct heat could cause injury to the thin tissue of bat ears. Such injury would occur at roughly the same height as tree foliage necrosis (death) or where temperatures reach 60 °C (140 °F). Most prescribed fires for forest management are planned to avoid significant tree scorch.

Direct and Indirect Effects – Winter Roosting

Little is known about the direct effects of fire on bats in adjacent caves and mines. Smoke and noxious gases could enter caves and mines, depending on airflow characteristics and weather conditions (Carter et al. 2002; Perry 2011). Although smoke from winter fires may not reach toxic levels in caves and mine, introduced gases could arouse bats from hibernation, causing energy expenditure and reduced fitness (Dickinson et al. 2009). Caviness (2003) observed smoke intrusion into hibernacula during winter burning in Missouri, but did not observe any bat arousal. Fire could alter vegetation surrounding the entrances to caves and mines, which could indirectly affect temperature and humidity regimes of hibernacula by modifying airflow (Carter et al. 2002, Richter et al. 1993).

Indirect Effects – Roost Availability/Suitability

Fire can affect the availability of roosting substrate (cavities, crevices, loose bark) by creating or consuming snags, which typically provide these features, or by creating these features in live trees. Although stand-replacing or intense wildfires may create large areas of snags, the effects of multiple, low-intensity prescribed burning on snag dynamics are less obvious, especially for forests consisting mostly of fire-adapted species. Low-intensity, ground-level fire may injure larger hardwood trees, creating avenues for pathogens such as fungi to enter and eventually form hollow cavities in otherwise healthy trees (Smith and Sutherland 2006). Fire may scar the base of trees, promoting the growth of basal cavities or hollowing of the bole in hardwoods (Nelson et al. 1933, Van Lear and Harlow 2002). Repeated burning could potentially create forest stands with abundant hollow trees. Trees located near down logs, snags, or slash may be more susceptible to damage or death, and aggregations of these fuels can create clusters of damaged trees or snags (Brose and Van Lear 1999, Smith and Sutherland 2006).

Bats are known to take advantage of fire-killed snags and continue roosting in burned areas. Boyles and Aubrey (2006) found that, after years of fire suppression, initial burning created abundant snags, which evening bats (*Nycticeius humeralis*) used extensively for roosting. Johnson et al. (2010) found that after burning, male Indiana bats roosted primarily in fire-killed maples. In the Daniel Boone National Forest, Lacki et al. (2009a) radio-tracked adult female NLEB before and after prescribed fire, finding more roosts (74.3 percent) in burned habitats than in unburned habitats. Burning may create more suitable snags for roosting through exfoliation of bark (Johnson et al. 2009a), mimicking trees in the appropriate decay stage for roosting bats.

In addition to creating snags and live trees with roost features, prescribed fire may enhance the suitability of trees as roosts by reducing adjacent forest clutter (see *Canopy Cover/Closure* in Section 2.4.3). Perry et al. (2007) found that five of six species, including NLEB, roosted disproportionally in stands that were thinned and burned 1-4 years prior but that still retained large overstory trees. Boyles and Aubrey (2006) found evening bats used burned forest exclusively for roosting.

Indirect Effects – Summer Foraging

Adult insects are the predominant prey of NLEB (see Section 2.2.4 Foraging Behavior). On the Daniel Boone National Forest, Lacki et al. (2009a) found that abundance of coleopterans (beetles), dipterans (flies), and all insects combined captured in black-light traps increased following prescribed fires. The mechanism of this increase is presumably the new growth of ground vegetation that a burn stimulates. In fecal samples of NLEB, lepidopterans (moths), coleopterans, and dipterans were the three most important groups of insect prey, with dipteran consumption increasing after burning. NLEB appeared to track the observed changes in insect availability, i.e., home ranges were closer to burned habitats following fires than to unburned habitats, but home range size did not vary before and after fires.

Summary of Exposure-Response Table

Table 4.1 shows the eight pathways we identified for NLEB responses to prescribed fire and the range of individual responses expected. In general, exposure to prescribed burning can cause direct adverse responses (disturbance, injury, death) and indirect adverse and beneficial responses via changes to roosting and foraging resources and forest health maintenance. Stressors caused by burning include heat and smoke during the actual movement of a fire through forested areas and fire-induced changes in vegetation structure and composition. Bat exposure to these direct and indirect stressors depends on timing of the burn and how bats may use the burned area, e.g., for roosting, foraging, spring staging, fall swarming, or hibernation in a cave/mine where the entrance is within or near the burned area.

4.4.2 METHODOLOGY FOR QUANTIFYING EFFECTS OF PRESCRIBED FIRE

To estimate the potential impacts of prescribed fire through 2022, we compiled the mean, minimum, and maximum acres of prescribed burns in each state from 2002 to 2014 (Table 4.6) using data available through the National Interagency Fire Center (available on internet: https://www.nifc.gov/fireInfo/fireInfo_stats_prescribed.html; accessed November 2015). We assumed the mean annual use of prescribed fire from 2002-2014 will be consistent through the period of this consultation. Similar to the population estimation methods in Section 2.4.2, we excluded a state from our analyses if less than 50% of it is within the NLEB range.

These data represent the total amount of prescribed burning in each state without regard to habitat type. We further parsed these data using information from the 2012 National Prescribed Fire Use Survey Report (Melvin 2012) to exclude burned grassland habitats as these are not relevant to the NLEB. The burn report estimated the percent of prescribed fire used to manage grassland or agriculture habitat and forested land in 2012. We recognize that this percentage likely varies to some degree every year, but we assume that the proportion of prescribed fire in forested habitat is similar. We use the mean annual acres of prescribed fire in forested habitat reported in Table 4.6 for the purposes of this BO. We anticipate that 648,908 acres will be burned annually through 2022, which is 0.2% of the available forested habitat (Table 4.2). The majority of prescribed burning is expected to occur in the Southern range (64%), followed by 29% in the Midwest, 4% and 3% in the Eastern and Western ranges, respectively.

Similar to timber harvest, we lack a breakdown of the acres burned during the active and non-volant seasons, and we assume that prescribed burning will occur with equal frequency throughout the year. Therefore, the average annual acres of prescribed burning during the active season are 58.6% of the total average annual acres, and 16.7% of the total is estimated to occur in the non-volant season. This estimate is similar to the recent estimates from programmatic consultations for the NLEB on U.S. Forest Service lands, where 21 and 16 percent of prescribed burning was projected to occur during the pup season (defined by the Forest Service as May 1 to July 30) in the Southern and Eastern regions, respectively. This may be an overestimate for the western range.

We use the same methods described for timber harvest (see Section 4.1.2.2) to estimate individual-level effects corresponding to the stressor-exposure-response pathways for prescribed burning. Our calculations for each pathway that we quantify are presented in tabular form in Section 4.3.

4.4.3 QUANTIFYING EFFECTS OF PRESCRIBED FIRE

We quantify the two pathways expected to disturb or harm the NLEB: disturbance from fleeing the fire (Table 4.7), and harm to pups from heat and smoke during the non-volant season (Table 4.8). Prescribed fires during the active season within maternity roosting areas may disturb up to 19,417 volant NLEB annually through fleeing and increased predation (Table 4.7). A small subset of disturbed individuals may be harmed. Prescribed burning during the non-volant season may harm up to 1,859 pups annually (Table 4.8).

In addition to these two pathways, prescribed burning could alter the flow of air and water through unknown hibernacula and also harm NLEBs. We do not have enough information to quantify the effects of this pathway because we do not know where projects will occur relative to the unknown hibernacula that are likely on the landscape. Although the alteration of unknown hibernacula may occur, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of prescribed burning. In addition, Caviness (2003) reported that prescribed burns were found to have no notable influence on bats hibernating in various caves in the Ozark National Forest. All bats present in caves at the beginning of the burn were still present and in "full hibernation" when the burn was completed, and bat numbers increased in the caves several days after the burn. There were minute changes in relative humidity and temperature during the burn and elevated short-term levels of some contaminants from smoke were noted.

We also do not quantify the potential reductions or increases in fitness that may result as indirect effects from the loss of roost trees (adverse) or the creation of roost trees, increased prey availability, or reduction of mid-story clutter (beneficial). We anticipate that only 0.2% of available habitat will be burned annually, and any habitat losses from prescribed fire will be temporary. In addition, the NLEB does not appear to be limited by roost trees, as demonstrated through a great deal of plasticity within its environment (e.g., roosting in a wide variety of trees and sizes). Therefore, reductions in fitness from habitat loss are anticipated to be small. Further, prescribed fire likely also benefits NLEB habitat and may increase fitness of local populations as described above. We do not quantify the potential increases in fitness because we lack the scientific support to interpret the degree to which survival or reproductive success rates of local populations may be influenced; however, management of existing forests is likely to maintain roosting or foraging habitat.

4.5 FOREST CONVERSION

Forest conversion is the loss of forest to another land cover type (e.g., grassland, cropland, development). For the purposes of this BO, we define forest conversion as any activity that removes forested habitat that is suitable for the NLEB. This includes, but is not limited to, tree removal from commercial or residential development, energy production and transmission (oil, gas, solar, wind), mining, agriculture, transportation, military training, and other ecosystem management. Unlike forest management, forest conversion permanently removes forested habitat on the landscape, or in some cases, there is no forest for decades as in the case of mining.

4.5.1 EFFECTS OF FOREST CONVERSION

In the final listing rule for the NLEB, we note that forest conversion could result in the following impacts: (1) loss of suitable roosting or foraging habitat; (2) fragmentation of remaining forest patches, leading to longer flights between suitable roosting and foraging habitat; (3) removal of (fragmenting colonies/networks) travel corridors; and (4) direct injury or mortality from the removal of occupied roosts during active season clearing. Forest conversion could also alter the flow of air and water through unknown hibernacula and impact NLEBs.

The literature review for timber harvest describes the loss of suitable roosting or foraging habitat, direct injury or mortality from removal of occupied roost, and alteration of hibernacula (see section 4.1.2.1). Fragmentation of forests patches and travel corridors may result in longer flights to find alternative suitable habitat and colonial disruption. NLEBs emerge from hibernation with their lowest annual fat reserves and return to their summer home ranges. Because NLEBs have summer home range fidelity (Foster and Kurta 1999; Patriquin et al. 2010; Broders et al. 2013), loss or alteration of forest habitat may put additional stress on females when returning to summer roost or foraging areas after hibernation. Females (often pregnant) have limited energy reserves available for use if forced to seek out new roosts or foraging areas. Hibernation and reproduction are the most energetically demanding periods for temperate-zone bats, including the NLEB (Broders et al. 2013). Bats may reduce metabolic costs of foraging by concentrating efforts in areas of known high prey profitability, a benefit that could result from the bat's local roosting and home range knowledge and site fidelity (Broders et al. 2013). Cool spring temperatures provide an additional energetic demand, as bats need to stay sufficiently warm or enter torpor. Entering torpor comes at a cost of delayed parturition; bats born earlier in the year have a greater chance of surviving their first winter and breeding in their first year of life (Frick et al. 2010). Delayed parturition may also be costly because young of the year and adult females would have less time to prepare for hibernation (Broders et al. 2013). Female NLEBs typically roost colonially, with their largest population counts occurring in the spring (Foster and Kurta 1999), presumably as one way to reduce thermal costs for individual bats (Foster and Kurta 1999). Therefore, similar to other temperate bats, NLEBs have multiple high metabolic demands (particularly in spring) and must have sufficient suitable roosting and foraging habitat available in relatively close proximity to allow for successful reproduction.

Table 4.1 shows the six pathways we identified for NLEB responses to forest conversion and the range of individual responses expected. The primary alteration of the environment associated with forest conversion that is relevant to the NLEB is the removal of trees that provide roosts or serve as foraging, spring staging, or fall swarming habitat. Removing occupied trees is likely to kill or injure pups and adults. Fragmentation and loss of forest habitat decreases opportunities for growth and successful reproduction. Alteration of hibernacula can harm NLEBs. The disturbance (noise, exhaust from machinery, etc.) that accompanies conversion activities may result in disturbance because fleeing during daylight increases the likelihood of predation. A small subset of disturbed individuals may be harmed. The species' responses to these stressors depend on the timing, location, and extent of the removal. In areas with little forest or highly fragmented forests (e.g., western U.S. edge of the range, central Midwestern states; see Figure 1.1, above), impact of forest loss would be disproportionately greater than similar-sized losses in heavily forested areas (e.g., Appalachians and northern forests). Also, the impact of habitat loss within a NLEB's home range is expected to vary depending on the scope of removal.

4.5.2 METHODOLOGY FOR QUANTIFYING EFFECTS OF FOREST CONVERSION

To estimate the potential impacts of forest conversion through 2022, we examined the total forested acres in each state from 2001 to 2011 using the National Land Cover Datasets (Homer et al. 2015). We calculated the approximate acres of forest lost per state per year by subtracting the acres of total forest in 2011 from the forested acres in 2001 and calculating the annual loss over the 10 year period (Table 4.9). We assume that the mean annual forest conversion from 2001-2011 will be consistent through the period of this consultation. Similar to the population estimation methods in Section 2.4.2, we excluded a state from our analyses if less than 50% of it is within the NLEB range. We anticipate that 914,237 acres will be converted from forested habitat annually through 2022, which is 0.3% of the available forested habitat per year and 2.3% of the available habitat through 2022 (Table 4.2). The majority of the expected forest conversion will occur in the Southern range (53%), followed by the Eastern range (26%), Midwest (19%). Only about 2% of the total conversion will occur in the Western range.

Similar to timber harvest, we lack a breakdown of forest conversion during the active and non-volant seasons, and we assume that it will occur with equal frequency throughout the year. Therefore, the average annual acres of forest conversion during the active season are 58.6% of the total average annual acres, and 16.7% of the total is estimated to occur in the non-volant season.

We use the same methods described for timber harvest (see Section 4.1.2.2) to estimate individual-level effects corresponding to the stressor-exposure-response pathways for prescribed burning. Our calculations for each pathway that we quantify are presented in tabular form in Section 4.3.

4.5.3 QUANTIFYING EFFECTS OF FOREST CONVERSION

We quantify the two pathways expected to disturb or harm the NLEB: disturbance from fleeing human activity (Table 4.10), and harm from removing occupied roost trees (Table 4.11 for pups and Table 4.12 for adults). Human disturbance from forest conversion during the active season (April – October) within maternity roosting areas may disturb up to 21,004 volant NLEB annually (Table 4.10). Forest conversion activities that remove occupied roost trees during the non-volant season may harm up to 317 pups annually (Table 4.11). Removal of occupied roost trees during the active season may harm up to 83 adults annually (Table 4.12).

In addition to these two pathways, forest conversion could alter the flow of air and water through unknown hibernacula and also harm NLEBs. We do not have enough information to quantify the effects of this pathway because we do not know where projects will occur relative to the unknown hibernacula that are likely on the landscape. Although the alteration of unknown hibernacula is reasonably certain to occur, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of forest conversion activities. In addition, the hibernacula often selected by NLEB are "large, with large passages" (Raesly and Gates 1987), and may be less affected by relatively minor surficial micro-climatic changes that might result from forest conversion around unknown roosts. Raesly and Gates (1987) evaluated external habitat characteristics of hibernacula and reported that for the NLEB the percentage of cultivated fields within 0.6 miles (1 km) the hibernacula was greater (52.6 percent) for those caves used by the species, than for those caves not used by the species (37.7 percent), suggesting that the removal of some forest around a hibernacula can be consistent with the species needs.

We also do not quantify the potential reductions in fitness that may result as indirect effects from loss of habitat. We anticipate that 0.3% (914,237 acres) of available habitat will be converted annually through 2022. We anticipate that habitat losses from forest conversion will be permanent. However, the NLEB does not appear to be limited by habitat, as demonstrated by a great deal of plasticity within its environment (e.g., living in highly fragmented forest habitats to contiguous forest blocks from the southern United States to Canada's Yukon Territory) in the absence of WNS. Therefore, reductions in fitness from habitat loss are anticipated to be small.

4.6 WIND TURBINE OPERATION

Wind energy development is rapidly increasing throughout the NLEB's range. Iowa, Illinois, Oklahoma, Minnesota, Kansas, and New York are within the top 10 States for wind energy capacity (installed megawatts) in the United States (AWEA 2013). There is a national movement towards a 20 percent wind energy sector in the U.S. market by 2030 (United States Department of Energy (US DOE) 2008). Through 2012, wind energy has achieved its goals in installation towards the targeted 20 percent by 2030 (AWEA 2015a). If the target is achieved, it would represent nearly a five-fold increase in wind energy capacity during the next 15 years (Loss et al. 2013). While locations of future wind energy projects are largely influenced by ever-changing economic factors and are difficult to predict, sufficient wind regimes exist to support wind power development throughout the range of the NLEB (USDOE 2015a), and wind development can be expected to increase throughout the range in future years. Wind energy facilities have been constructed in areas within a large portion of the range of the NLEB.

4.6.1 EFFECTS OF WIND TURBINE OPERATION

Significant bat mortality has been witnessed associated with utility-scale (greater than or equal to 0.66 megawatt (MW)) wind turbines along forested ridge tops in the eastern and northeastern United States and in agricultural areas of the Midwest (Johnson 2005; Arnett et al. 2008; Cryan 2011; Arnett and Baerwald 2013; Hayes 2013; Smallwood 2013). Recent estimates of bat mortality from wind energy facilities vary considerably depending on the methodology used and species of bat. Arnett and Baerwald (2013) estimated that 650,104 to 1,308,378 bats had been killed at wind energy facilities in the United States and Canada as of 2011, and expected another 196,190 to 395,886 would be lost in 2012. Other bat mortality estimates range from "well over 600,000… in 2012" (Hayes 2013; [but see Huso and Dalthorp 2014]) to 888,000 bats per year (Smallwood 2013), and mortality can be expected to increase as more turbines are installed on the landscape. The majority of bats killed include migratory foliage-roosting species the hoary bat (*Lasiurus cinereus*) and eastern red bat, and the migratory, tree- and cavity-roosting silver-haired bat (Arnett et al. 2008; Cryan 2011; Arnett and Baerwald 2013). NLEBs are rarely detected as mortalities, even in areas where they are known to be common on the landscape.

The Service reviewed post-construction mortality monitoring studies at 62 unique operating wind energy facilities in the range of the NLEB in the United States and Canada. In these studies, 41 NLEB mortalities were documented, comprising less than 1 percent of all bat mortalities. Northern long-eared bat mortalities were detected throughout the study range at 29 percent of the facilities, including: Illinois, Indiana, Maryland, Michigan, Missouri, New York, Pennsylvania, West Virginia, and Ontario. There is a great deal of uncertainty related to extrapolating these numbers to generate an estimate of total NLEB mortality at wind energy facilities due to variability in post-construction survey effort and methodology (Huso and Dalthorp 2014). Bat mortality can vary between years and between sites, and detected carcasses are only a small percentage of total bat mortalities. Despite these limitations, Arnett and Baerwald (2013) estimated that wind energy facilities in the United States and Canada killed between 1,175 and 2,433 NLEBs from 2000 to 2011.

There are three impacts of wind turbines that may explain proximate causes of bat fatalities, which include: (1) bats collide with turbine towers; (2) bats collide with moving blades; or (3) bats suffer internal injuries (barotrauma) after being exposed to rapid pressure changes near the trailing edges and tips of moving blades (Cryan and Barclay 2009). Researchers have recently indicated that traumatic injury, including bone fractures and soft tissue trauma caused by collision with moving blades, is the major cause of bat mortality at wind energy facilities

(Rollins et al. 2012; Grodsky et al. 2011). Grodsky et al. (2011) suggested that these injuries can lead to an underestimation of bat mortality at wind energy facilities due to delayed lethal effects. However, the authors also noted that the surface and core pressure drops behind the spinning turbine blades are high enough (equivalent to sound levels that are 10,000 times higher in energy density than the threshold of pain in humans) to cause significant ear damage to bats flying near wind turbines (Grodsky et al. 2011). Bats suffering from ear damage would have a difficult time navigating and foraging, as both of these functions depend on the bats' ability to echolocate (Grodsky et al. 2011). While earlier papers indicated that barotrauma may also be responsible for a considerable portion of bat mortality at wind energy facilities (Baerwald et al. 2008), in a more recent study, researchers found only 6 percent of wind turbine killed bats at one site were possibly killed by barotrauma (Rollins et al. 2012). In a separate study, Grodsky et al. (2011) found that 74 percent of carcasses had bone fractures and more than half had mild to severe hemorrhaging in the middle or inner ears; thus it is difficult to attribute individual fatalities exclusively to either direct collision or barotrauma.

Table 4.1 shows the two pathways we identified for NLEB responses to wind turbine operation and the range of individual responses expected. The primary impact to bats from operation of wind facilities is death resulting from collision with operating turbines. It is also possible that NLEBs could be disturbed by sound from turbine operation; however, studies have found no evidence to suggest that bats are likely to be affected (Szewczak and Arnett 2006; Horn et al. 2008). We do not address sound from turbine operation further in this BO. We include the potential impacts from construction under forest conversion.

4.6.2 QUANTIFYING EFFECTS OF WIND TURBINE OPERATION

This section describes the approach for determining the current and future wind energy development conditions and the estimation of potential fatalities from wind energy through the duration of this consultation in 2022.

We compiled the installed wind power capacity (megawatts [MW]) as identified by the American Wind Energy Association (AWEA) for each state within the NLEB's range through 2014 (AWEA 2014). Similar to the population estimation methods in Section 2.4.2, we excluded a state from our analyses if less than 50% of it is within the NLEB range. There is currently no installed wind power capacity in the excluded states of Louisiana, Alabama, Georgia, and South Carolina, but there was 5,857 MW of installed capacity in Montana, Wyoming, and Oklahoma as of 2014. To determine if excluding these states was reasonable, we also examined a wind development pressure map (Figure 4.1) developed using the Federal Aviation Administration's wind turbine data (Service 2015a, unpublished data). We concluded that a small amount of potential wind energy development was within the species' range in Montana, Wyoming, and Oklahoma; however, the inclusion of the full states of Nebraska and Kansas should compensate for any impacts not included in the excluded states. The total amount of installed wind capacity for the remaining states within the range of the NLEB was 28,294 MW at the end of 2014 (Table 4.13).

To estimate the potential impacts of future wind energy development through 2022, we used the Department of Energy's 2020 and 2030 build-out projections from the interactive map developed using data from with their 2015 Wind Vision Report (http://energy.gov/maps/map-projected-growth-wind-industry-now-until-2050; USDOE 2015b). The total amount of installed wind capacity by 2020 for states with more than 50% of their area within the NLEB range is projected to be 44,100 MW (Table 4.13). Lacking annual projections, we assumed that the annual build-out from 2014 to 2020 would be the mean of the total build-out over the six year period. We estimated build-out in 2021 and 2022 by taking the difference between the 2030 and 2020 projections and assuming the annual build-out in 2021 and 2022 would be the mean of the total build-out through 2030. The total amount of installed wind capacity by 2022 for states with more than 50% of their area within the NLEB range is projected to be 55,006 MW. The total capacity of wind energy is anticipated to nearly double in the next seven years.

The best source of information available to estimate anticipated future impacts to bats from collision with wind turbines is data from post-construction monitoring studies of existing wind facilities. Species composition data from these studies can be used to estimate the level of NLEB mortality by assuming the proportion of documented fatalities of NLEB, relative to the fatalities of all other bat species, represents the proportion of NLEB fatalities expected in other projects situated in similar geographic areas. It is important to use data that are as representative as possible of the conditions in the area for which mortality is being estimated because multiple variables are likely to influence mortality rates at wind energy facilities, including location relative to bat areas of activity, turbine height, rotor-swept area, turbine cut-in speed (i.e., the minimum speed required to produce energy), geographic location, elevation, topographic location, surrounding habitat types, time of year, and weather conditions. Uncertainty regarding variations in the relative densities of different species of bats across the landscape and over time are an additional source of error in this estimation. However, we used the data from the draft Midwest Wind Energy Habitat Conservation Plan (MWE HCP) as a surrogate for the full range of the species because the post construction mortality studies have not been compiled at the range-wide scale of the NLEB. The estimates from the MWE HCP represent the best available data for this consultation, but we acknowledge the uncertainty of these estimates for the Eastern, Southern, and Western portions of the species' range.

The number of NLEBs that may be impacted by wind development in each state was calculated following these steps[3]: (1) determine the anticipated bat fatality rate for the geographic area of

[3] The MWE HCP is currently in development with the Service, a coalition of eight Midwestern states, and representatives of the wind energy industry. Much of the following information in this section comes from the draft

interest based on the results of post-construction monitoring studies; (2) determine the proportion of the NLEB among fatalities in post-construction monitoring studies in the applicable range of the NLEB; and (3) multiply the proportion of the NLEB by the expected fatality rate to derive the expected number of total fatalities of the NLEB. For example, if the total estimated bat mortality from regional data is 12 bats/MW/year (or 1,200 bats/year for a 100 MW facility), and the number of NLEB fatalities among all bat fatalities was 1 out of 100 (or 1%), the total estimated mortality of the NLEB would be 12 fatalities/year.

1. *determine the anticipated bat fatality rate for the geographic area of interest based on the results of post-construction monitoring studies*

   The studies used to estimate all bat fatality rates for the MWE HCP were limited to those that were conducted in the eight Midwestern states within the range of the covered bat species in the MWE HCP (i.e., Indiana bat, NLEB, little brown bat). The following additional criteria were used to select post-construction monitoring studies: (1) the search interval had to be weekly or more frequent; (2) studies had to correct for carcass persistence and searcher efficiency using site-specific data; (3) the search interval had to be shorter than the mean carcass persistence rate; (4) only include the mortality rate for the most robust study method for studies that reported more than one mortality rate; and (5) only include the bat fatality estimates from control turbines for curtailment study projects. These studies were further modified to account for unsearched areas where bats were expected to fall by applying a correction factor (sensu Hull and Muir 2013) if the study included search areas smaller than 100 m search radii. Fatality rates must also be representative of the period over which future mortality is being estimated; therefore, rates were adjusted to account for bat mortality that occurred during from April 1 to October 31, which is inclusive of the time frame within which all NLEB mortalities have been documented.

   Based on these criteria, 17 fatality monitoring studies were selected to estimate fatality of all bats within the MWE HCP states. Of these 17 studies, two were conducted in Minnesota, three in Wisconsin, three in Iowa, four in Illinois, two in Indiana, and three in Ohio. Reported bat fatality rates (adjusted as described above) were variable across projects and ranged from a low of 1.42 bats/MW/study period at the Big Blue project in Minnesota (Fagen Engineering, LLC 2014), to 38.25 bats/MW/study period at the Cedar Ridge project in Wisconsin (BHE Environmental 2010). The mean bat fatality rate was 17.55 bats/MW/year. This estimate is similar to pre-WNS values surveys in Maryland (15.61 bats/MW; Young et al. 2011) and Pennsylvania (14.4 bats/MW; Taucher et al.

MWE HCP being written by Leidos, Inc. The analytical process used here was developed and approved by the Service; therefore, the data derived from this study currently represents the best available information to inform this analysis.

2012), which addresses some of the uncertainty of using Midwest estimates for the entire range.

2. *determine the proportion of the NLEB among fatalities in post-construction monitoring studies in the applicable range of the NLEB*

   The MWE HCP used 71 studies to estimate species composition for NLEBs. This was a larger pool than the more restrictive studies used to determine the all bat fatality rate because the purpose was to capture all available data on NLEB mortality in the Midwest. Of these 71 studies, three species of long-distance migrants made up the highest percentage of fatalities, totaling 88% of the 8,934 bat carcasses documented across all studies. Eastern red bats had the highest number of fatalities (3,893 bat carcasses or 44%), followed by hoary bats (2,328 bat carcasses or 26%), and silver-haired bats (1,621 bat carcasses or 18%). The next most common species found among fatalities were big brown bats (519 bat carcasses or 6%), followed by little brown bats (339 bat carcasses or 4%). NLEBs made up 0.09% (8 bat carcasses out of 8,934) of the fatality pool.

3. *multiply the proportion of the NLEB by the expected fatality rate to derive the expected number of total fatalities of the NLEB*

   Based on the estimated percentage of NLEBs (0.09%) among the mean bat fatality rate (17.55/MW/year), the mean estimated NLEB fatalities/MW/year was 0.0158. This NLEB fatality rate was then applied to the current installed wind capacity and projected build-out through 2022 to determine an estimated number of NLEB fatalities that would occur during each year over the term of this consultation assuming no avoidance and minimization measures would be in place. Based on these assumptions, we estimated that 5,654 NLEB fatalities could result from the projected wind capacity of 55,006 MW through 2022 (3,575 NLEBs from current facilities and 2,078 NLEBs from projected build-out; Table 4.13). There was an estimated 447 mortalities in 2014, and annual estimates increase every year by 42 individuals from 2015-2020 and 86 individuals in 2021 and 2022 for a total of 869 individuals in 2022. These are over-estimates because they do not account for avoidance and minimization measures that are currently applied at wind facilities, especially within the range of the endangered Indiana bat and it does not account for declines from WNS, especially in the Eastern range.

   Operational adjustments can be made to minimize mortality of bat species at wind facilities through two primary methods: (1) turbines are "feathered," or rendered near motionless below the normal manufacturer's cut-in speed, and (2) the cut-in speed is raised to a wind speed higher than the normal manufacturer's cut-in speed during periods and in areas of greatest risk for bats. These adjustments have been found to significantly reduce bat mortality because bat activity and mortality have been shown to have an inverse relationship with wind speed (Arnett et al. 2013). Some facilities within the range of the NLEB have already instituted these operational adjustments to avoid take of Indiana bats or as required by Indiana bat Habitat Conservation Plans. In addition, the wind industry has recently announced new best management practices establishing voluntary operating protocols, which they expect “to reduce impacts to bats from operating wind turbines by as much as 30 percent” (AWEA 2015b). According to AWEA, the agreement “involves wind operators’ voluntarily limiting the operations of turbines in low-wind speed conditions during the fall bat migration season, when research has shown bats are most at risk of collision” (AWEA 2015b). Given the large numbers of other bat species impacted by wind energy (Hein et al 2013) and the economic importance of bats in controlling agricultural or forest pest species (Boyles et al 2011), we anticipate that these new standards will be adopted by most wind energy facilities and ultimately required by wind-energy-siting regulators at state and local levels. It is possible that total fatalities will be reduced by as much as 50% if we include the effects of additional curtailment that is ongoing at many projects and the effects of WNS on the overall population.

4.7 OTHER ACTIVITIES THAT MAY AFFECT THE NLEB

The NLEB is likely to be affected by a variety of other activities which are excepted from incidental take prohibitions in the final 4(d) rule that are not covered by the general categories for removal from human structures, forest management, forest conversion, and wind turbine operation. These activities include, but may not be limited to:

- Disturbance/noise from with human activities not associated with timber harvest or forest conversion
- Lighting
- Use of pesticides for pest and vegetation control
- Spills/chemical contamination
- Water quality alteration
- Collision
- Noise from munitions, detonations, and training vehicles/aircraft
- Use of military training smoke and obscurants
- Bridge maintenance, repair, or replacement
- Subsurface drilling or blasting for utility line and road installation
- Use of waste pits to store contaminated fluids

4.7.1 EFFECTS OF OTHER ACTIVITIES

Disturbance/Noise

Noise and vibration and general human disturbance are stressors that may disrupt normal feeding, sheltering, and breeding activities of the NLEB. Many activities may result in increased noise/vibration/disturbance that may result in effects to bats. Significant changes in noise levels in an area may result in temporary to permanent alteration of bat behaviors. The novelty of these noises and their relative volume levels will likely dictate the range of responses from individuals or colonies of bats. At low noise levels (or farther distances), bats initially may be startled, but they would likely habituate to the low background noise levels. At closer range and louder noise levels (particularly if accompanied by physical vibrations from heavy machinery and the crashing of falling trees) many bats would probably be startled to the point of fleeing from their day-time roosts and in a few cases may experience increased predation risk. For projects with noise levels greater than usually experienced by bats, and that continue for multiple days, the bats roosting within or close to these areas are likely to shift their focal roosting areas further away or may temporarily abandon these roosting areas completely.

There is limited literature available regarding impacts from noise (outside of road/traffic) on bats. Gardner et al. (1991) had evidence that an NLEB conspecific, Indiana bat, continued to roost and forage in an area with active timber harvest (see the timber harvest Section above regarding other similar studies for NLEB). They suggested that noise and exhaust emissions from machinery could possibly disturb colonies of roosting bats, but such disturbances would have to be severe to cause roost abandonment. Callahan (1993) noted that the likely cause of the bats in his study area abandoning a primary roost tree was disturbance from a bulldozer clearing brush adjacent to the tree.

Indiana bats have also been documented roosting within approximately 300 meters of a busy state route adjacent to Fort Drum Military Installation (Fort Drum) and immediately adjacent to housing areas and construction activities on Fort Drum (US Army 2014). Bats roosting or foraging in all of the examples above have likely become habituated to the noise/vibration/disturbance.

Table 4.1 shows the pathway we identified for NLEB responses to noise/disturbance, and it is possible that NLEBs will be disturbed by noise/disturbance. A small subset of disturbed individuals may be harmed. Although some adverse effects to NLEBs are reasonably certain to occur from noise or disturbance, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%.

Lighting

Bat behavior may be affected by lights when traveling between roosting and foraging areas. Foraging in lighted areas may increase risk of predation or it may deter bats from flying in those areas. Bats that significantly alter their foraging patterns may increase their energy expenditures resulting in reduced reproductive rates. This depends on the context (e.g., duration, location, extent, type) of the lighting.

Some bats seem to benefit from artificial lighting, taking advantage of high densities of insects attracted to light. For example, 18 species of bats in Panama frequently foraged around streetlights, including slow-flying edge foragers (Jung and Kalko 2010). However, seven species in the same study were not recorded foraging near streetlights. Bat activity differed among color of lights with higher activity at bluish-white and yellow-white lights than orange. Bat activity at streetlights varied for some species with season and moonlight (Jung and Kalko 2010). In summary, this study suggests highly variable responses among species to artificial lighting.

Some species appear to be adverse to lights. Downs et al. (2003) found that lighting of *Pipistrellus pygmaeus* roosts reduced the number of bats that emerged. In Canada and Sweden, *Myotis* spp. and *Plecotus auritus* were only recorded foraging away from street lights (Furlonger et al. 1987, Rydell 1992). Stone et al. (2009) found that commuting activity of lesser horseshoe bats (*Rhinolophus hipposideros*) in Britain and was reduced dramatically and the onset of commuting was delayed in the presence of high pressure sodium (HPS) lighting. Stone et al. (2012) also found that light-emitting diodes (LED) caused a reduction in *Rhinolophus hipposideros* and *Myotis* spp. activity. In contrast, there was no effect of lighting on *Pipistrellus pipistrellus*, *Pipistrellus pygmaeus*, or *Nyctalus/Eptesicus* spp.

Although there is limited information regarding potential neutral, positive, or negative impacts to NLEB from increased light levels, slow-flying bats such as *Rhinolophus*, *Myotis*, and *Plecotus* species have echolocation and wing-morphology adapted for cluttered environments (Norberg and Rayner 1987), and emerge from roosts when light levels are low, probably to avoid predation by diurnal birds of prey (Jones and Rydell 1994). Therefore, we would generally expect that NLEB would avoid lit areas. In Indiana, Indiana bats avoided foraging in urban areas and Sparks et al. (2005) suggested that it may have been in part due to high light levels. Using captive bats, Alsheimer (2012) also found that the little brown bat (*M. lucifugus*), was more active in the dark than light.

Table 4.1 shows the pathway we identified for NLEB responses to lighting, and it is possible that NLEBs will experience reduced fitness from lighting. Although some adverse effects to NLEBs are reasonably certain to occur from lighting, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%.

Pesticides

Herbicides and other pesticides may be used to control pests and weed species including noxious or invasive plants. Treatments typically occur in spring, early summer, or fall. Treatments can be applied either by hand, from a truck mounted boom sprayer withspray heads designed to minimize drift, or aerially. Herbicide and other pesticide applications typically occur during the day when bats are roosting, and often in the morning to avoid and minimize wind-induced drift.

Long-term sublethal effects of environmental contaminants, such as herbicides and other pesticides, on bats are largely unknown; however, environmentally relevant exposure levels of various contaminants have been shown to impair nervous system, endocrine, and reproductive functioning in other wildlife (Yates et al. 2014, Köhler and Triebskorn 2013, Colborn et al. 1993). Moreover, bats' high metabolic rates, longevity, insectivorous diet, migration-hibernation patterns of fat deposition and depletion, and immune impairment during hibernation, along with potentially exacerbating effects of WNS, likely increase their risk of exposure to and accumulation of environmental toxins (Secord et al. 2015, Yates et al. 2014, Geluso et al. 1976, Quarles 2013, O'Shea and Clark 2002).

Table 4.1 shows the pathway we identified for NLEB responses to the use of herbicides and other pesticides, and it is possible that NLEBs will experience reduced fitness and harm depending on the specific circumstances. Bats may drink contaminated water or forage in affected or treated areas and thus may eat insects exposed to chemicals. Bats may also be directly exposed to herbicides or other pesticides sprayed in roosting areas. Although some adverse effects to NLEBs are reasonably certain to occur from herbicides and other pesticide use, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%. In addition, all herbicides and other pesticides must be used in accordance to their label instructions, which are designed to minimize water contamination and adverse effects to wildlife.

Spills/Chemical Contamination

Accidents during project operation could result in the leakage of hazardous chemicals into the environment which could affect water quality resulting in reduced densities of aquatic insects that bats consume. If an accident occurred and hazardous chemicals leaked into the environment, a rapid response from state and/or federal agencies would limit the size of the spill area. However, if chemicals did reach surface waters (streams and wetlands), a short-term reduction in both aquatic and terrestrial insects could occur, thus reducing the spring, summer, or autumn prey base for foraging NLEB. If this occurred, it would be localized, thus allowing foraging NLEBs to move nearby and continue foraging.

Table 4.1 shows the pathway we identified for NLEB responses to spills and chemical contamination, and it is possible that NLEBs will experience reduced fitness and harm depending on the specific circumstances. Bats may drink contaminated water or forage in affected areas with the potential to eat insects exposed to chemicals. Although some adverse effects to NLEBs are reasonably certain to occur from spills and chemical contamination, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%. In addition, all projects are typically required to follow state and/or federal wetland permitting, stormwater management, and water quality standards.

Water Quality Alteration

Some projects may result in permanent loss from wetland and/or stream fill or temporarily reduce water quality from dust and sedimentation. Table 4.1 shows the pathway we identified for NLEB responses to water quality alteration. Activities that reduce quantity or quality of water sources and foraging habitat may impact bats, even if conducted while individuals are not present. Standard construction BMPs (e.g., silt fencing) will minimize erosion and subsequent sedimentation, thus reducing potential impacts on aquatic ecosystems. Since potential impacts from sedimentation are expected to be localized, foraging bats should have alternative drinking water and foraging locations. The surrounding landscape will continue to provide an abundant prey base of both terrestrial and aquatic insects during project construction, operation, and maintenance. Therefore, any potential direct effects to bats from a reduction in water quality are anticipated to be insignificant.

Collision

Collision has been documented for Indiana bats and other myotids. The Indiana bat recovery plan indicates that bats do not seem particularly susceptible to vehicle collisions, but it may threaten local populations in certain situations (Service 2007). Russell et al. (2009) assessed the level of mortality from road kills on a bat colony in Pennsylvania and collected 27 road-killed little brown bats and 1 Indiana bat. This study also cited unpublished data from the Penssylvania Game Commission documenting NLEB collision mortality. Curtis et al. (2014) indicates that a dead NLEB was found along a road in Kansas and was thought to have collided with a vehicle. Collision has been documented for other *Myotis* in Europe (Lesinski et al. 2011). Collision risk of bats varies depending on time of year, location of road in relation to roosting/foraging areas), the characteristics of their flight, traffic volume, and whether young bats are dispersing (Lesinski 2007, Lesinski 2008, Russell et al. 2009, Bennett et al. 2011).

It can be difficult to determine whether roads pose greater risk for bats colliding with vehicles or greater likelihood of deterring bat activity in the area (thus decreasing risk of collision). Many studies suggest that roads may serve as a barrier to bats (Bennett and Zurcher 2013, Bennett et al. 2013, Berthinussen and Altringham 2011, Wray et al. 2006). In most cases, we expect there will be a decreased likelihood of bats crossing roads (and therefore, reduced risk of collision) of increasing size (lanes).

Table 4.1 shows the pathway we identified for NLEB responses to collision, and we anticipated that NLEBs will be killed from collision with vehicles. Although some mortality is reasonably certain to occur, we anticipate that relatively small numbers of bats will be impacted per year in each state because of the decreased likelihood of bats crossing major roads. Also, we anticipate the likelihood of mortality will be reduced by the widely dispersed of new road construction and occupancy rates that are typically less than 50%.

<u>Noise from Munitions, Detonations, and Training Vehicles, Aircraft</u>

Recent studies have indicated that anthropogenic noise can alter foraging behavior and success of bats, including some gleaning species like the NLEB (Bunkley et al. 2015; Schaub et al. 2008; Siemers and Schaub 2011). Table 4.1 shows the pathway we identified for NLEB responses to noise from military training operations, and it is possible that NLEBs will be disturbed. A small subset of disturbed individuals may be harmed. However, studies indicate that indicate bats do not avoid active ranges or alter foraging behavior during night-time maneuvers, and NLEBs are expected to become habituated to noise disturbance (Whitaker & Gummer 2002; Service 2010; USFWS 2009). Although some adverse effects to NLEBs may occur from noise from military operations, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%.

<u>Use of Military Training Smoke and Obscurants</u>

Smoke/obscurants are used to conceal military movements and help protect troops and equipment in combat conditions. Although they would be primarily used during the day, smoke/obscurants may be deployed at night. Training on military installations may include, but is not limited to, smokes and obscurants such as fog oil, colored smoke grenades, white phosphorous, and graphite smoke. Research indicates that prolonged dermal and respiratory exposures to these items, except for the graphite smoke, could have adverse effects on roosting and foraging Indiana bats (Service 1998; Service 2012; Driver et al. 2002; USWFS 2009; NRC 1999). Given the similar roosting behavior and foraging locations of the NLEB, it is likely they will also be adversely affected by these smokes and obscurants.

Table 4.1 shows the pathway we identified for NLEB responses to the use of smokes and obscurants, and it is possible that NLEBs will be harmed depending on the specific circumstances. Although some adverse effects to NLEBs are reasonably certain to occur, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the limited use of these chemicals and occupancy rates that are typically less than 50%. In addition, many military installations already limit the use of smokes and obscurants in areas that may affect the Indiana bat, further reducing the impact to NLEBs.

Bridge Maintenance, Repair, or Replacement

NLEBs have been found using bridges for day and night roosts in Illinois, Louisiana, Iowa, and Missouri (Feldhamer et al. 2003; Ferrara and Leberg 2009; Kiser et al. 2002; Benedict and Howell 2008; Droppelman 2014). Altering or removing bridges when occupied by NLEBs is expected to result in adverse effects. Bridge alteration refers to any bridge repair, retrofit, maintenance, and/or rehabilitation work activities that modifies the bridge to the point that it is no longer suitable for roosting.

Table 4.1 shows the two pathways we identified for NLEB responses to bridge work and it is possible that NLEBs will experience reduced fitness and harm depending on the specific circumstances. We expect that NLEBs will be killed or injured bats during activities conducted while bats are present, and the removal of roosts can reduce fitness. Although some adverse effects to NLEBs are reasonably certain to occur from bridge maintenance, repair, or replacement, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%.

Subsurface Drilling or Blasting

Surface-disturbing activities (such as drilling or blasting) in the vicinity of hibernacula may affect bat populations if those activities result in changes to the microclimate (temperature, humidity, and air flow) of the cave or mine (Ellison et al. 2003).

Table 4.1 shows the two pathways we identified for NLEB responses to drilling and blasting, and it is possible that NLEBs will be harmed. These activities can alter the flow of air and water through unknown hibernacula. Although the alteration of unknown hibernacula is reasonably certain to occur, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of timber harvest activities.

Use of Waste Pits to Store Contaminated Fluids

The oil and gas industry (and possibly other industries) occasionally use of temporary waste pits to store materials removed from drilling, including sand used during hydraulic fracturing treatments, wellbore cuttings, bentonite drilling muds, and fluids. These waste pits have been documented to attract and entrap wildlife. Bats may drink contaminated water or become trapped in waste pits and die. Table 4.1 shows the pathway we identified for NLEB responses to waste pits, and it is possible that NLEBs will be harmed. Although some adverse effects to NLEBs are reasonably certain to occur from the use of waste pits, we anticipate that relatively small numbers of bats will be impacted per year in each state based on the widely dispersed nature of activities and occupancy rates that are typically less than 50%.

4.8 CONSERVATION MEASURES IN THE 4(D) RULE

In BOs, we consider how conservation measures included in the proposed action may reduce the severity of effects or the probability of exposure. Prohibitions adopted under the final 4(d) will reduce the severity of effects or the probability of exposure of NLEB to the full scope of activities that may affect the species through regulatory processes under section 7 and section 10 the Act. Under the final 4(d) rule, incidental take involving tree removal in the WNS zone is not prohibited if two conservation measures are followed. The first measure is the year-round application of a 0.25-mile radius buffer (which is equivalent to 125.7 acres) around known NLEB hibernacula. The second conservation measure involves the temporary protection of known, occupied maternity roost trees. Incidental take is prohibited if the activity cuts or destroys a known, occupied maternity roost tree and other trees within a 150-foot radius around the maternity roost tree (which is equivalent to 1.6 acres) during the pup season (June 1-July 31). The 150 ft buffer covers 1.6 acres around a known maternity roost tree. In addition, incidental take is prohibited in hibernacula within the WNS zone; therefore, regardless of the buffer size, NLEBs are protected from take while in known hibernacula when they are most vulnerable.

To determine how these conservation measures reduce the severity of effects or probability of exposure, we compared the acreages affected by the conservation measures to the total forested habitat within the range of the NLEB (Table 4.14). As described in section 2.2, there are currently 1,508 known hibernacula and 1,412 known maternity roost trees. The year-round protection of forested habitat around hibernacula results in a total of 189,556 acres (0.05% of the total forested habitat) in 31 of 37 states (84% of the range) where activities that may affect the NLEB are subject to regulatory processes under sections 7 and 10 of the Act. The temporary protection of known, occupied maternity roosts results in a total of 2,259 acres (<0.001% of the total forested habitat) in 17 of 37 states (46% of the range) where activities that may affect the NLEB are subject to the same regulatory processes.

These two conservation measures are beneficial in that they protect known hibernating populations from take and help protect known maternity colonies from direct harm by temporarily protecting known maternity roost trees during the pup season. However, because known maternity roost trees likely represent a small fraction of the total, the beneficial effect of this conservation measure, which reduces the severity of effects, does not significantly reduce the probability of exposure. Additionally, known roost trees may be cut either before June 1st or after July 31st in compliance with the 4(d) rule, or during that time period with either an incidental take permit under section 10, or an incidental take statement under section 7. The hibernacula conservation measure is more protective in scope (i.e., timing, location, and severity). The severity of the effects and probability of exposure are somewhat reduced, but this beneficial effect extends only to known hibernacula. Like known maternity roost trees, known hibernacula likely represent a small fraction of the total.

4.9 SUMMARY OF IMPACTS OF INDIVIDUALS

Table 4.15 combines the total annual estimated effects of the activities quantified for timber harvest, prescribed fire, forest conversion, and wind turbine operation. Because fatalities from wind turbine operation increase every year between 2015 and 2022, we report the average annual wind fatalities over the time-frame of this consultation. Based on these estimations, we anticipate that up to 117,267 NLEB will be disturbed and 3,285 pups and 980 adults will be harmed annually from timber harvest, prescribed fire, forest conversion, and wind turbine operation.

The disturbance associated with timber harvest, prescribed burning, and forest conversion within maternity roosting areas during the active season (April – October) can cause volant bats to flee their roosts and expend additional energy while exposed to day-time predators. Our methodology computes the number of NLEB affected annually as 117,267 bats (or 1.2% of the population) (Table 4.16). We recognize that not all of the NLEB roosting in an activity area will necessarily respond to disturbance by fleeing their roosts, likely depending on the disturbance intensity and proximity; therefore, we consider this to be an overestimate. Table 4.16 shows that 66 percent of the potential disturbance in maternity roosting areas is due to timber harvest, 18 percent to forest conversion, and 17% to prescribed burning. Disturbance that disrupts normal behavior patterns and creates the likelihood of injury to listed species (e.g., causing a nocturnal species to travel during daylight hours) may result in harm.

Timber harvest, prescribed burning, and forest conversion may also occur in maternity roosting areas during the non-volant season (June 1 – July 31). Heat and smoke from prescribed burning, and tree removal from the other activities, may kill or injure a non-volant pup, who cannot flee the threat unless carried by its mother, which we do not presume precludes this potential harm. We estimate that up to 3,285 NLEB pups (0.1 percent of the total pup population) are exposed to potentially lethal habitat modification annually (Table 4.17). Prescribed burning may affect 56.6

percent of the total pup population (Table 4.17). The potential for death or injury resulting from prescribed burning depends largely on site-specific circumstances, e.g., fire intensity near the maternity roost tree and the height above ground of pups in the maternity roost tree. Not all fires through maternity roosting areas will kill or injure all pups present, but our methodology in this BO estimates that all potentially vulnerable individuals within the expected area of activity/occupancy overlap are affected. We therefore consider this to be an overestimate. Timber harvest and forest conversion account for 33.8 and 9.6 percent of the estimated harm to non-volant pups, respectively (Table 4.17). Unlike prescribed burning, we did not assume that all potentially vulnerable individuals within the expected area of activity/occupancy overlap are affected. We assumed that 15 percent of pups would be injured or killed when their roost tree was felled.

Wind turbine operation and tree removal from timber harvest and forest conversion may also kill or injure adults when they are struck by turbines or when occupied roost trees are felled. We estimate that up to 980 NLEB adults (less than 0.02 percent of the total adult population) are exposed to potentially lethal wind turbines and habitat modification annually (Table 4.18). Wind turbine operation accounts for 66.3% of the adult mortality, followed by timber harvest (25.2%) and forest conversion (8.5%) (Table 4.18). As discussed in Section 4.1.5.2, we believe the wind fatalities may be overestimated by as much as 50% after accounting for population reductions from WNS and current and future curtailment. The adult mortality from tree removal is not as likely to be overestimated because we did not assume that all potentially vulnerable individuals within the expected area of activity/occupancy are affected.

Additional harm is anticipated for unquantified effects from removal from human structures and “other” activities that may affect the NLEB; however, we do not expect the additional impacts to substantially change the total numbers reported in Table 4.15 for reasons discussed above (see section 4.1). In addition, we consider some of the numbers for harm and disturbance in this section to be overestimates as discussed, and we also expect that the numbers affected over time will be reduced as WNS continues to affect the range-wide population. As populations decline as a result of WNS, the chances of any particular activity affecting northern long-eared bats becomes more remote.

4.10 IMPACTS TO POPULATIONS

As described above, individual NLEBs may experience decreased reproductive success and survival as a result of implementation of the final 4(d) rule. Of importance here though, is how these potential adverse effects to individual bats affect the overall health and viability of populations present within the action area. This is best done by looking at the maternity colony and hibernacula populations; however, we do not have enough information about local populations or when and where projects will occur relative to the species’ occurrence.

The finest-scale of analysis we have to examine effects on local populations is at the state level. States vary greatly in the number of maternity colonies estimated per state (Table 2.5). States in the Eastern range generally have the lowest estimated number of maternity colonies, ranging from 16 maternity colonies in Delaware to 6,984 colonies in West Virginia. States with small numbers of maternity colonies are likely at greater risk of extirpation from impacts to individuals. For example, Delaware has 16 maternity colonies estimated to be comprised of 20 females each, for a total adult population size of 640 individuals. Activities implemented according to the final 4(d) rule could disturb 9 individuals in Delaware per year, along with harm to 3 pups and 2 adults per year. If all the annual impacts occurred within one maternity colony, it is possible that the colony would be reduced by at least 10% in one year (2 adults killed from a colony with 20 females = 10%), and potentially more if the 3 pups were also killed. Losses to very small populations may not be sustainable at the local-level. It is possible that the loss of 10% of the maternity colony could result in the loss of that colony, but it is unlikely that that level of impact would occur within a single maternity colony every year. However, areas hardest hit by WNS are likely at greatest risk (i.e., currently much of the Eastern range).

Although local populations could be affected by the implementation of the final 4(d) rule, most of the states have larger populations and more maternity colonies. In addition, less than 2.3% of NLEBs will be disturbed in all states (Table 4.16), less than 1% of pups will be harmed in all states (Table 4.17), and less than 1% of adults will be harmed in all states (Table 4.18). Therefore, the vast majority of individuals and populations that survive WNS will be unaffected by these activities.

Where the species has substantially declined as a result of WNS, the surviving members of the population may be resilient or resistant to WNS. These surviving populations are particularly important to the persistence of the populations. The individual effects analysis indicates that some additional impacts will occur as a result this action. We do not know at this time if the impacts from this action are additive; however, even if the potential mortality from these activities is additive to the impacts from WNS, it is likely that the species will persist in these states based on the number of maternity colonies and widely-dispersed nature of the activities.

Based on the relatively small numbers affected annually compared to the state population sizes, we do not anticipate population-level effects to the NLEB. We conclude that adverse effects from timber harvest, prescribed fire, forest conversion, wind energy, and other activities will not lead to population-level declines in this species. Because we do not anticipate population-level impacts from our action, our analysis of effects to the NLEB is complete.

4.11 INTERRELATED AND INTERDEPENDENT ACTIONS

An interrelated activity is an activity that is part of the proposed action and depends on the proposed action for its justification. An interdependent activity is an activity that has no independent utility apart from the action under consultation. At this time, we are unaware of actions that are interrelated and interdependent with the final 4(d) rule that have not already been considered in this BO.

4.12 TABLES AND FIGURES FOR EFFECTS OF THE ACTION

Table 4.1. Exposure-response analysis for activities conducted in accordance with the final 4(d) rule that may affect the NLEB.

Activity	Subactivity	Stressor	Exposure (time)	Exposure (space)	Resource Affected	Individual Response	Interpretation
Removal from Human Structures	Exclusion	Using exclusion to make a known roost unsuitable	Year-round; indirect effect	All occupied areas except hibernacula	Adults	Reduced fitness	Loss of structures where bat colonies have demonstrated repeated could reduce fitness through additional energy expenditure while searching for a new roost site.
Removal from Human Structures	Rodenticides and sticky traps	Using rodenticides and sticky traps to remove bats	Active season, daytime; direct effect	Roosting areas (maternity and non-maternity)	Individuals	Injury, mortality; harm	Activities conducted while bats are present are likely to kill or injure individuals. We expect this threat to be reduced through the implementation of BMPs for bat removal.
Removal from Human Structures	Eviction Devices	Using eviction or exclusionary devices to remove bats	Active season, daytime; direct effect	Roosting areas (maternity and non-maternity)	Pups	Injury, mortality; harm	Use of exclusionary devices during the non-volant period is likely to result in the death of pups because females cannot return to take care of their young. However, many states require that exclusions be conducted outside of the non-volant period to minimize impacts.
Removal from Human Structures	Rabies testing	Euthanizing bats for rabies testing during removal	Active season, daytime; direct effect	Roosting areas (maternity and non-maternity)	Individuals	Injury, mortality; harm	Rabies testing will kill adults and volant juveniles. Data from MO and NY indicate that an average of 7 bats were killed bats per year during the most recent three years.
Forest Management	Timber Harvest	Reducing mid-story clutter adjacent to roost trees	Year-round; indirect effect	Maternity roosting areas	Vegetation near roost trees	Beneficial through maintenance or improvement of habitat	Beneficial through increased solar radiation on roosts; improved access to roosts; travel corridors to foraging areas; however, we are unable to quantify the degree of benefit in terms of increased survival or reproductive success.
Forest Management, Forest Conversion	Timber Harvest, Construction Activities	Removing unoccupied roost trees	Winter; indirect effect	Maternity roosting areas	Trees	Reduced fitness	Removal of roost trees where bat colonies have demonstrated repeated could reduce fitness through additional energy expenditure while searching for a new roost site.
Forest Management, Forest Conversion	Timber Harvest, Construction Activities	Removing trees that provide habitat used for foraging, swarming, or staging	Year-round; indirect effect	All occupied areas except hibernacula	Insect prey, forest cover that supports (shelters) bat activity	Reduced fitness; energy expenditure for relocating from traditional use areas to alternative habitat	Loss of forest habitat decreases opportunities for growth and successful reproduction. Depending on location and size of the harvest, forest cover removal in the summer home range may cause a shift in home range or relocation. Loss of habitat in staging/swarming areas near hibernacula may cause a similar shift in habitat use for larger numbers of individuals, due to their seasonal concentration in these areas, and may reduce fall mating success and/or reduced fitness in preparation for spring migration
Forest Management, Forest Conversion, Other	Timber Harvest, Construction Activities, Most other subactivities	Disturbance (noise, machinery exhaust, activity) associated with human activities	Active season, daytime; direct effect	Roosting areas (maternity and non-maternity)	Individuals	Disturbance (fleeing); harass	Fleeing disturbance during daylight hours increases the likelihood of predation
Forest Management, Forest Conversion, Other	Timber Harvest, Construction Activities	Altering the flow of air and water through hibernacula.	Winter (direct effect) and active season (indirect effect)	Near hibernacula	Individuals	Arousal from hibernation; reduced fitness, mortality; take in the form of harm.	Response depends on proximity of tree removal to hibernacula entrances, airflow patterns, and local hydrology. Sufficient modification may cause injury or mortality (take in the form of harm).
Forest Management, Forest Conversion	Timber Harvest, Construction Activities	Removing occupied roost trees	Active seasos; direct effect	Maternity roosting areas	Individuals	Injury, mortality; harm	Removing occupied trees is likely to kill or injure pups and adults. For the purposes of this consultation, we assume that 15% of non-volant bats and 3% of adults may be injured or killed.
Forest Conversion	Construction Activities	Removal of forested habitat	Year-round; indirect effect	All occupied areas except hibernacula	Trees	Reduced fitness	Fragmentation of forests patches and travel corridors may result in longer flights to find alternative suitable habitat and colonial disruption.
Forest Management	Prescribed Burning	Creating snags, creating roost features in live trees	Year-round; indirect effect	All occupied areas except hibernacula	Trees	Beneficial through maintenance or improvement of habitat	Beneficial through greater availability of suitable roosts increasing opportunities for successful reproduction, more efficient use of forest habitat however, we are unable to quantify the degree of benefit in terms of increased survival or reproductive success

Table 4.1. Continued.

Activity	Subactivity	Stressor	Exposure (time)	Exposure (space)	Resource Affected	Individual Response	Interpretation
Forest Management	Prescribed Burning	Stimulating growth of ground cover and insect populations	Growing-season following the burn; indirect effect	Foraging areas	Insect prey	Beneficial through maintenance or improvement of habitat	Beneficial through greater availability of insect prey increasing foraging efficiency; however, we are unable to quantify the degree of benefit in terms of increased survival or reproductive success
Forest Management	Prescribed Burning	Thinning mid-story clutter adjacent to roost trees	Growing-season following the burn; indirect effect	Maternity roosting areas	Vegetation near roost trees	Beneficial through maintenance or improvement of habitat	Beneficial through increased solar radiation on roosts; improved access to roosts however, we are unable to quantify the degree of benefit in terms of increased survival or reproductive success.
Forest Management	Prescribed Burning	Destroying existing snags and other trees suitable for roosting	Year-round; indirect effect	All occupied areas except hibernacula	Trees	Reduced fitness	Loss of suitable roosts decreases opportunities for successful reproduction, more efficient use of forest habitat
Forest Management	Prescribed Burning	Heat and smoke	Active season, day time; direct effect	Roosting areas (maternity and non-maternity)	Individuals; adults and volant juveniles	Disturbance (fleeing); harass	Fleeing the line of fire of a prescribed burn during daylight hours increases the likelihood of predation
Forest Management	Prescribed Burning	Heat and smoke	Active season, night time; direct effect	Foraging areas	Individuals; adults and volant juveniles	Disturbance (fleeing)	Fleeing the line of fire of a prescribed burn during night-time foraging is unlikely to cause injury
Forest Management	Prescribed Burning	Heat and smoke	Winter; direct effect	Near hibernacula	Individuals	Arousal from hibernation; reduced fitness, mortality; take in the form of harm	Response depends on proximity of fire to hibernacula entrances and airflow patterns. Sufficient smoke entering hibernacula may cause injury or mortality.
Forest Management	Prescribed Burning	Heat and smoke	Non-volant season; direct effect	Maternity roosting areas	Individuals; non-volant juveniles	Injury, mortality; harm	Response varies with fire intensity and roost height; a combination of high-intensity burns and/or low roosts is likely to cause injury or mortality
Wind Energy	Operation	Sound from Operating Turbines	Active season, day and night; direct effect	Active season; direct effect	Individuals	Disturbance (fleeing)	Studies (Szewczak and Arnett 2006, Horn et al. 2008) have found evidence to suggest that bats are not likely to be negatively affected by sound from operating turbines.
Wind Energy	Operation	Collision with Operating Turbines	Active season, direct effect	All occupied areas except hibernacula	Individuals	Mortality; harm	Collision with wind wind turbines is likely to kill bats
Other	Most subactivities	Lighting	Active season, night; direct effect	All occupied areas except hibernacula	Individuals	Disturbance (fleeing), increased risk of predation; increase energy expenditure; harass	Foraging in lighted areas may increase risk of predation (leading to death) or it may deter bats from flying in those areas. Bats that significantly alter their foraging patterns may increase their energy expenditures resulting in reduced reproductive rates. This depends on the context (e.g., duration, location, extent, type) of the lighting. Some studies also show a beneficial effect of concentrating prey.
Other	Most subactivities	Use of pesticides and herbicides for pest and vegetation control	Active season, direct and indirect effect	All occupied areas except hibernacula	Individuals; insect prey	lethal or sublethal exposure to toxins; reduction in prey availability; harm/harass	Bats may drink contaminated water or forage in affected areas with the potential to eat insects exposed to chemicals. Bats may also be directly exposed to herbicides sprayed in roosting areas. Effects are reduced because all herbidices and pesticides must be used in accordance with their label.
Other	Most subactivities	Chemical contamination from use or spills in/around bat habitat	Active season, direct and indirect effect	All occupied areas except hibernacula	Individuals; insect prey	lethal or sublethal exposure to toxins; reduction in prey availability; harm/harass	Bats may drink contaminated water or forage in affected areas with the potential to eat insects exposed to chemicals.
Other	Most subactivities	Water Quality Alteration; sedimentation	Active season, indirect effect	All occupied areas except hibernacula	Insect prey	Reduced fitness	Temporary effects on water quality could occur during construction, which could reduce local insect populations. Standard construction BMPs (e.g., silt fencing) will minimize erosion and subsequent sedimentation, thus reducing potential impacts on aquatic ecosystems.

Table 4.1. Continued.

Activity	Subactivity	Stressor	Exposure (time)	Exposure (space)	Resource Affected	Individual Response	Interpretation
Other	Military Operations	Noise from munitions, detonations, and training vehicles, including aircraft	Active season, direct effect	All occupied areas except hibernacula	Individuals	Disturbance (fleeing)	Fleeing disturbance increases the likelihood of predation. However, studies indicate bats do not avoid active ranges or alter foraging behavior during night-time maneuvers, and NLEBs are expected to become habituated to noise disturbance.
Other	Military Operations	Use of Military Training Smoke and Obscurants	Active season, direct effect	All occupied areas except hibernacula	Individuals	Injury, mortality; harm	Research indicates that prolonged dermal and respiratory exposures smokes and obsurants could have adverse effects on roosting and foraging bats.
Other	Bridge maintenance, repair, or replacement	Bridge work activities affect roosting bats	Active season, direct effect	Roosting areas (maternity and non-maternity)	Individuals	injury, mortality; harm	Bats may be injured or killed if they do not exit the bridge before it is either removed or the action results in effects to portion of the bridge where the bats are roosting.
Other	Bridge maintenance, repair, or replacement	Bridge work makes it unsuitable for roosting.	Inactive season, indirect effect	Roosting areas (maternity and non-maternity)	Individuals	Increased energy exposure; reduced fitness	Removal of bridges where bat colonies have demonstrated repeated could reduce fitness through additional energy expenditure while searching for a new roost site.
Other	Drilling	Subsurface drilling utility line and road installation	Winter (direct effect) and active season (indirect effect)	Near hibernacula	Individuals	Arousal from hibernation; reduced fitness, mortality; take in the form of harm.	Response depends on proximity of harvest to hibernacula entrances, airflow patterns, and local hydrology. Sufficient modification may cause injury or mortality (take in the form of harm).
Other	Blasting	Use of explosives to remove rocks for utility line and road installation	Winter (direct effect) and active season (indirect effect)	Near hibernacula	Individuals	Arousal from hibernation; reduced fitness, mortality; take in the form of harm.	Response depends on proximity of harvest to hibernacula entrances, airflow patterns, and local hydrology. Sufficient modification may cause injury or mortality (take in the form of harm).
Other	Storage Pits for oil and gas waste	Bats can become trapped in waste pits or drink contaminated water	Active season, direct effect	All occupied areas except hibernacula	Individuals	Injury, mortality; harm	Bats may drink contaminated water or become trapped in waste pits and die.

Table 4.2. Mean annual harvest (acres) for each state included in the analysis (Source: U.S. Forest Service's Forest Inventory EVALIDator web-application Version 1.6.0.03; Available only on internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp).

					Harvest (acres)							Percent of Annual Average
Region	State	Acres of Forested Land	Years	N (years)	National Forest	Other Federal	State & Local	Private	Total	Average (acre/year)	Acres Harvested
Midwest	Iowa	3,013,759	2009-2014	6	0	0	6,290	118,105	124,395	20,733	0.7%
Midwest	Illinois	4,847,480	2009-2014	6	0	7,392	0	220,038	227,430	37,905	0.8%
Midwest	Indiana	4,830,395	2009-2014	6	2,924	3,500	12,114	292,650	311,189	51,865	1.1%
Midwest	Michigan	20,127,048	2009-2014	6	79,571	0	340,950	1,189,042	1,609,563	268,261	1.3%
Midwest	Minnesota	17,370,394	2010-2014	5	43,708	2,977	391,433	360,229	798,346	159,669	0.9%
Midwest	Missouri	15,471,982	2009-2014	6	66,135	0	45,879	933,470	1,045,484	174,247	1.1%
Midwest	Ohio	8,088,277	2009-2014	6	1,945	0	15,572	467,607	485,124	80,854	1.0%
Midwest	Wisconsin	16,980,084	2009-2014	6	75,449	4,738	390,366	1,144,172	1,614,726	269,121	1.6%
Eastern	Connecticut	1,711,749	2009-2014	6	0	0	14,622	44,924	59,546	9,924	0.6%
Eastern	Delaware	339,520	2009-2014	6	0	0	2,540	13,625	16,164	2,694	0.8%
Eastern	Maine	17,660,246	2010-2014	5	0	0	86,952	2,285,161	2,372,113	474,423	2.7%
Eastern	Maryland	2,460,652	2009-2014	6	0	0	11,192	76,740	87,931	14,655	0.6%
Eastern	Massachusetts	3,024,092	2009-2014	6	0	0	16,196	66,640	82,837	13,806	0.5%
Eastern	New Hampshire	4,832,408	2009-2014	6	14,502	7,118	35,153	355,549	412,332	68,722	1.4%
Eastern	New Jersey	1,963,561	2009-2014	6	0	0	0	21,442	21,442	3,574	0.2%
Eastern	New York	18,966,416	2009-2014	6	0	0	62,807	1,002,449	1,065,256	177,543	0.9%
Eastern	Pennsylvania	16,781,960	2009-2014	6	10,966	8,625	128,668	1,026,196	1,174,456	195,743	1.2%
Eastern	Rhode Island	359,519	2009-2014	6	0	0	0	0	0	0	0.0%
Eastern	Vermont	4,591,280	2010-2014	5	4,858	0	5,596	245,487	259,941	51,988	1.1%
Eastern	Virginia	15,907,041	2008-2013	6	2,606	9,518	20,195	1,125,092	1,157,410	192,902	1.2%
Eastern	West Virginia	12,154,471	2009-2014	6	0	0	0	463,133	463,133	77,189	0.6%
Southern	Arkansas	18,754,916	2009-2014	6	193,868	11,975	43,919	2,411,963	2,661,725	443,621	2.4%
Southern	Kentucky	12,471,762	2006-2013	8	17,706	8,644	4,873	847,274	878,496	109,812	0.9%
Southern	Mississippi	19,541,284	2006-2014	9	68,994	21,053	60,562	3,273,286	3,423,895	380,433	1.9%
Southern	North Carolina	18,587,540	2003-2014	12	0	29,351	60,638	2,276,778	2,366,767	197,231	1.1%
Southern	Tennessee	13,941,333	2005-2013	9	0	12,837	3,028	1,151,325	1,167,190	129,688	0.9%
Western	Kansas	2,502,434	2009-2014	6	0	6,205	0	57,781	63,985	10,664	0.4%
Western	Nebraska	1,576,174	2009-2014	6	0	0	1,221	91,823	93,044	15,507	1.0%
Western	North Dakota	759,998	2009-2014	6	0	0	0	0	0	0	0.0%
Western	South Dakota	1,910,934	2009-2014	6	163,971	0	1,489	52,375	217,834	36,306	1.9%
	Total	281,528,709			747,203	133,933	1,762,255	21,614,356	24,261,754	3,669,077	1.3%

Table 4.3. Estimated numbers of NLEB affected (disturbed) annually by human activity from active-season harvest in maternity roosting areas.

Region	State	A. Harvest, Bat Active Season (acres)[1]	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Bats Affected (FxE)
Midwest	Iowa	12,149	3,013,759	0.403%	6.3%	765	0.808	619
Midwest	Illinois	22,212	4,847,480	0.458%	9.4%	2,097	0.701	1,469
Midwest	Indiana	30,393	4,830,395	0.629%	5.7%	1,722	0.701	1,207
Midwest	Michigan	157,201	20,127,048	0.781%	4.8%	7,479	0.701	5,240
Midwest	Minnesota	93,566	17,370,394	0.539%	8.9%	8,295	0.808	6,706
Midwest	Missouri	102,109	15,471,982	0.660%	4.0%	4,040	0.701	2,831
Midwest	Ohio	47,380	8,088,277	0.586%	6.4%	3,013	0.701	2,111
Midwest	Wisconsin	157,705	16,980,084	0.929%	6.8%	10,694	0.701	7,493
Eastern	Connecticut	5,816	1,711,749	0.340%	1.4%	83	0.359	30
Eastern	Delaware	1,579	339,520	0.465%	0.8%	12	0.359	5
Eastern	Maine	278,012	17,660,246	1.574%	1.4%	3,949	0.701	2,767
Eastern	Maryland	8,588	2,460,652	0.349%	0.8%	65	0.359	24
Eastern	Massachusetts	8,090	3,024,092	0.268%	1.0%	83	0.359	30
Eastern	New Hampshire	40,271	4,832,408	0.833%	1.5%	597	0.359	215
Eastern	New Jersey	2,094	1,963,561	0.107%	4.8%	101	0.359	37
Eastern	New York	104,040	18,966,416	0.549%	5.0%	5,233	0.359	1,880
Eastern	Pennsylvania	114,705	16,781,960	0.684%	5.1%	5,856	0.359	2,104
Eastern	Rhode Island	0	359,519	0.000%	1.4%	0	0.359	0
Eastern	Vermont	30,465	4,591,280	0.664%	1.5%	451	0.359	163
Eastern	Virginia	113,040	15,907,041	0.711%	7.3%	8,246	0.359	2,963
Eastern	West Virginia	45,233	12,154,471	0.372%	8.1%	3,662	0.359	1,316
Southern	Arkansas	259,962	18,754,916	1.386%	9.9%	25,636	0.701	17,961
Southern	Kentucky	64,350	12,471,762	0.516%	6.1%	3,956	0.701	2,772
Southern	Mississippi	222,934	19,541,284	1.141%	5.2%	11,515	0.808	9,309
Southern	North Carolina	115,577	18,587,540	0.622%	6.0%	6,982	0.701	4,892
Southern	Tennessee	75,997	13,941,333	0.545%	6.2%	4,717	0.359	1,695
Western	Kansas	6,249	2,502,434	0.250%	3.4%	213	0.808	172
Western	Nebraska	9,087	1,576,174	0.577%	3.4%	309	0.808	250
Western	North Dakota	0	759,998	0.000%	3.4%	0	0.808	0
Western	South Dakota	21,275	1,910,934	1.113%	3.4%	723	0.808	585
	Total	2,150,079	281,528,709	0.764%		120,495		76,846

[1] We prorated the total annual harvest for activities occuring during the active season by using the annual percent of the active season (58.6%).

[2] From Table 2.5

Table 4.4. Estimated numbers of NLEB pups affected (harmed) annually by non-volant season harvest in maternity roosting areas.

Region	State	A. Havest, Non-Volant Season[1] (acres)	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Maternity Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Pups Affected (FxE)
Midwest	Iowa	3,462	3,013,759	0.115%	6.3%	218	0.269	9
Midwest	Illinois	6,330	4,847,480	0.131%	9.4%	598	0.234	21
Midwest	Indiana	8,661	4,830,395	0.179%	5.7%	491	0.234	18
Midwest	Michigan	44,800	20,127,048	0.223%	4.8%	2,131	0.234	75
Midwest	Minnesota	26,665	17,370,394	0.154%	8.9%	2,364	0.269	96
Midwest	Missouri	29,099	15,471,982	0.188%	4.0%	1,151	0.234	41
Midwest	Ohio	13,503	8,088,277	0.167%	6.4%	859	0.234	31
Midwest	Wisconsin	44,943	16,980,084	0.265%	6.8%	3,048	0.234	107
Eastern	Connecticut	1,657	1,711,749	0.097%	1.4%	24	0.120	1
Eastern	Delaware	450	339,520	0.133%	0.8%	4	0.120	1
Eastern	Maine	79,229	17,660,246	0.449%	1.4%	1,125	0.234	40
Eastern	Maryland	2,447	2,460,652	0.099%	0.8%	19	0.120	1
Eastern	Massachusetts	2,306	3,024,092	0.076%	1.0%	24	0.120	1
Eastern	New Hampshire	11,477	4,832,408	0.237%	1.5%	170	0.120	4
Eastern	New Jersey	597	1,963,561	0.030%	4.8%	29	0.120	1
Eastern	New York	29,650	18,966,416	0.156%	5.0%	1,491	0.120	27
Eastern	Pennsylvania	32,689	16,781,960	0.195%	5.1%	1,669	0.120	30
Eastern	Rhode Island	0	359,519	0.000%	1.4%	0	0.120	0
Eastern	Vermont	8,682	4,591,280	0.189%	1.5%	129	0.120	3
Eastern	Virginia	32,215	15,907,041	0.203%	7.3%	2,350	0.120	43
Eastern	West Virginia	12,891	12,154,471	0.106%	8.1%	1,044	0.120	19
Southern	Arkansas	74,085	18,754,916	0.395%	9.9%	7,306	0.234	256
Southern	Kentucky	18,339	12,471,762	0.147%	6.1%	1,127	0.234	40
Southern	Mississippi	63,532	19,541,284	0.325%	5.2%	3,282	0.269	133
Southern	North Carolina	32,938	18,587,540	0.177%	6.0%	1,990	0.234	70
Southern	Tennessee	21,658	13,941,333	0.155%	6.2%	1,344	0.120	25
Western	Kansas	1,781	2,502,434	0.071%	3.4%	61	0.269	3
Western	Nebraska	2,590	1,576,174	0.164%	3.4%	88	0.269	4
Western	North Dakota	0	759,998	0.000%	3.4%	0	0.269	0
Western	South Dakota	6,063	1,910,934	0.317%	3.4%	206	0.269	9
	Total	612,736	281,528,709	0.218%		34,339		1,109

[1] We prorated the total annual harvest for activities occuring during the non-volant season by using the annual percent of the non-volant season (16.7%).

[2] From Table 2.5

Table 4.5. Estimated numbers of NLEB adults affected (harmed) annually by active season harvest in maternity roosting areas.

Region	State	A. Havest, Active Season[1] (acres)	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Maternity Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Adults Affected (FxE)
Midwest	Iowa	12,149	3,013,759	0.403%	6.3%	765	0.081	2
Midwest	Illinois	22,212	4,847,480	0.458%	9.4%	2,097	0.071	5
Midwest	Indiana	30,393	4,830,395	0.629%	5.7%	1,722	0.071	4
Midwest	Michigan	157,201	20,127,048	0.781%	4.8%	7,479	0.071	16
Midwest	Minnesota	93,566	17,370,394	0.539%	8.9%	8,295	0.081	21
Midwest	Missouri	102,109	15,471,982	0.660%	4.0%	4,040	0.071	9
Midwest	Ohio	47,380	8,088,277	0.586%	6.4%	3,013	0.071	7
Midwest	Wisconsin	157,705	16,980,084	0.929%	6.8%	10,694	0.071	23
Eastern	Connecticut	5,816	1,711,749	0.340%	1.4%	83	0.036	1
Eastern	Delaware	1,579	339,520	0.465%	0.8%	12	0.036	1
Eastern	Maine	278,012	17,660,246	1.574%	1.4%	3,949	0.071	9
Eastern	Maryland	8,588	2,460,652	0.349%	0.8%	65	0.036	1
Eastern	Massachusetts	8,090	3,024,092	0.268%	1.0%	83	0.036	1
Eastern	New Hampshire	40,271	4,832,408	0.833%	1.5%	597	0.036	1
Eastern	New Jersey	2,094	1,963,561	0.107%	4.8%	101	0.036	1
Eastern	New York	104,040	18,966,416	0.549%	5.0%	5,233	0.036	6
Eastern	Pennsylvania	114,705	16,781,960	0.684%	5.1%	5,856	0.036	7
Eastern	Rhode Island	0	359,519	0.000%	1.4%	0	0.036	0
Eastern	Vermont	30,465	4,591,280	0.664%	1.5%	451	0.036	1
Eastern	Virginia	113,040	15,907,041	0.711%	7.3%	8,246	0.036	9
Eastern	West Virginia	45,233	12,154,471	0.372%	8.1%	3,662	0.036	4
Southern	Arkansas	259,962	18,754,916	1.386%	9.9%	25,636	0.071	55
Southern	Kentucky	64,350	12,471,762	0.516%	6.1%	3,956	0.071	9
Southern	Mississippi	222,934	19,541,284	1.141%	5.2%	11,515	0.081	29
Southern	North Carolina	115,577	18,587,540	0.622%	6.0%	6,982	0.071	15
Southern	Tennessee	75,997	13,941,333	0.545%	6.2%	4,717	0.036	6
Western	Kansas	6,249	2,502,434	0.250%	3.4%	213	0.081	1
Western	Nebraska	9,087	1,576,174	0.577%	3.4%	309	0.081	1
Western	North Dakota	0	759,998	0.000%	3.4%	0	0.081	0
Western	South Dakota	21,275	1,910,934	1.113%	3.4%	723	0.081	2
	Total	2,150,079	281,528,709	0.764%		120,495		247

[1] We prorated the total annual harvest for activities occuring during the active season by using the annual percent of the active season (58.6%).

[2] From Table 2.5

Table 4.6. Prescribed fire (acres) within forested lands from 2002-2014 for each state included in the analysis (Source: National Interagency Fire Center, modified using the percent of prescribed fire within forested lands in each state from the 2012 National Prescribed Fire Use Survey Report).

Region	State	Acres of Forested Land	Average Annual Acres of Forest Land Burned	Minimum Annual Acres of Forest Land Burned	Maximum Annual Acres of Forest Land Burned	Percent of Average Available Habitat Burned
Midwest	Iowa	3,013,759	10,365	251	26,741	0.3%
Midwest	Illinois	4,847,480	8,102	626	21,890	0.2%
Midwest	Indiana	4,830,395	6,385	1,962	12,600	0.1%
Midwest	Michigan	20,127,048	9,325	1,669	16,652	0.0%
Midwest	Minnesota	17,370,394	102,512	48,837	158,160	0.6%
Midwest	Missouri	15,471,982	35,419	-	95,268	0.2%
Midwest	Ohio	8,088,277	2,781	259	6,767	0.0%
Midwest	Wisconsin	16,980,084	15,831	2,836	25,495	0.1%
Eastern	Connecticut	1,711,749	53	-	113	0.0%
Eastern	Delaware	339,520	50	-	161	0.0%
Eastern	Maine	17,660,246	3	2	5	0.0%
Eastern	Maryland	2,460,652	2,631	524	11,823	0.1%
Eastern	Massachusetts	3,024,092	272	2	815	0.0%
Eastern	New Hampshire	4,832,408	103	35	209	0.0%
Eastern	New Jersey	1,963,561	7,115	-	14,549	0.4%
Eastern	New York	18,966,416	189	39	918	0.0%
Eastern	Pennsylvania	16,781,960	1,795	-	7,013	0.0%
Eastern	Rhode Island	359,519	19	-	97	0.0%
Eastern	Vermont	4,591,280	323	46	902	0.0%
Eastern	Virginia	15,907,041	13,570	5,768	20,546	0.1%
Eastern	West Virginia	12,154,471	718	87	2,950	0.0%
Southern	Arkansas	18,754,916	153,639	100,108	200,998	0.8%
Southern	Kentucky	12,471,762	8,207	3,495	12,097	0.1%
Southern	Mississippi	19,541,284	126,297	1,818	253,860	0.6%
Southern	North Carolina	18,587,540	109,273	38,869	170,668	0.6%
Southern	Tennessee	13,941,333	14,959	1,856	23,085	0.1%
Western	Kansas	2,502,434	77	7	134	0.0%
Western	Nebraska	1,576,174	7,432	2,883	17,339	0.5%
Western	North Dakota	759,998	6,291	1,413	8,464	0.8%
Western	South Dakota	1,910,934	5,171	383	9,291	0.3%
		281,528,709	648,908	213,775	1,119,611	0.2%

Table 4.7. Estimated numbers of NLEB affected (disturbed) annually by heat and smoke from active-season prescribed burning in maternity roosting areas.

Region	State	A. Active Season Burning (acres)[1]	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Bats Affected (FxE)
Midwest	Iowa	6,074	3,013,759	0.2%	6.3%	383	0.808	310
Midwest	Illinois	4,748	4,847,480	0.1%	9.4%	448	0.701	314
Midwest	Indiana	3,742	4,830,395	0.1%	5.7%	212	0.701	149
Midwest	Michigan	5,464	20,127,048	0.0%	4.8%	260	0.701	183
Midwest	Minnesota	60,072	17,370,394	0.3%	8.9%	5,325	0.808	4,306
Midwest	Missouri	20,755	15,471,982	0.1%	4.0%	821	0.701	576
Midwest	Ohio	1,630	8,088,277	0.0%	6.4%	104	0.701	73
Midwest	Wisconsin	9,277	16,980,084	0.1%	6.8%	629	0.701	441
Eastern	Connecticut	31	1,711,749	0.0%	1.4%	0	0.359	1
Eastern	Delaware	29	339,520	0.0%	0.8%	0	0.359	1
Eastern	Maine	2	17,660,246	0.0%	1.4%	0	0.701	1
Eastern	Maryland	1,542	2,460,652	0.1%	0.8%	12	0.359	5
Eastern	Massachusetts	159	3,024,092	0.0%	1.0%	2	0.359	1
Eastern	New Hampshire	60	4,832,408	0.0%	1.5%	1	0.359	1
Eastern	New Jersey	4,170	1,963,561	0.2%	4.8%	202	0.359	73
Eastern	New York	111	18,966,416	0.0%	5.0%	6	0.359	2
Eastern	Pennsylvania	1,052	16,781,960	0.0%	5.1%	54	0.359	20
Eastern	Rhode Island	11	359,519	0.0%	1.4%	0	0.359	1
Eastern	Vermont	189	4,591,280	0.0%	1.5%	3	0.359	2
Eastern	Virginia	7,952	15,907,041	0.0%	7.3%	580	0.359	209
Eastern	West Virginia	421	12,154,471	0.0%	8.1%	34	0.359	13
Southern	Arkansas	90,032	18,754,916	0.5%	9.9%	8,879	0.701	6,221
Southern	Kentucky	4,809	12,471,762	0.0%	6.1%	296	0.701	208
Southern	Mississippi	74,010	19,541,284	0.4%	5.2%	3,823	0.808	3,091
Southern	North Carolina	64,034	18,587,540	0.3%	6.0%	3,868	0.701	2,711
Southern	Tennessee	8,766	13,941,333	0.1%	6.2%	544	0.359	196
Western	Kansas	45	2,502,434	0.0%	3.4%	2	0.808	2
Western	Nebraska	4,355	1,576,174	0.3%	3.4%	148	0.808	120
Western	North Dakota	3,687	759,998	0.5%	3.4%	126	0.808	102
Western	South Dakota	3,030	1,910,934	0.2%	3.4%	103	0.808	84
	Total	380,260	281,528,709	0.1%		26,863		19,417

[1] We prorated the total annual burning for activities occuring during the active season by using the annual percent of the active season (58.6%).

[2] From Table 2.5

Table 4.8. Estimated numbers of NLEB pups affected (harmed) annually by heat and smoke from non-volant season prescribed burning in maternity roosting areas.

Region	State	A. Non-Volant Season[1] Burning (acres)	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Pups Affected (FxE)
Midwest	Iowa	1,731	3,013,759	0.1%	6.3%	109	0.269	30
Midwest	Illinois	1,353	4,847,480	0.0%	9.4%	128	0.234	30
Midwest	Indiana	1,066	4,830,395	0.0%	5.7%	60	0.234	15
Midwest	Michigan	1,557	20,127,048	0.0%	4.8%	74	0.234	18
Midwest	Minnesota	17,119	17,370,394	0.1%	8.9%	1,518	0.269	409
Midwest	Missouri	5,915	15,471,982	0.0%	4.0%	234	0.234	55
Midwest	Ohio	464	8,088,277	0.0%	6.4%	30	0.234	7
Midwest	Wisconsin	2,644	16,980,084	0.0%	6.8%	179	0.234	42
Eastern	Connecticut	9	1,711,749	0.0%	1.4%	0	0.120	1
Eastern	Delaware	8	339,520	0.0%	0.8%	0	0.120	1
Eastern	Maine	1	17,660,246	0.0%	1.4%	0	0.234	1
Eastern	Maryland	439	2,460,652	0.0%	0.8%	3	0.120	1
Eastern	Massachusetts	45	3,024,092	0.0%	1.0%	0	0.120	1
Eastern	New Hampshire	17	4,832,408	0.0%	1.5%	0	0.120	1
Eastern	New Jersey	1,188	1,963,561	0.1%	4.8%	58	0.120	7
Eastern	New York	32	18,966,416	0.0%	5.0%	2	0.120	1
Eastern	Pennsylvania	300	16,781,960	0.0%	5.1%	15	0.120	2
Eastern	Rhode Island	3	359,519	0.0%	1.4%	0	0.120	1
Eastern	Vermont	54	4,591,280	0.0%	1.5%	1	0.120	1
Eastern	Virginia	2,266	15,907,041	0.0%	7.3%	165	0.120	20
Eastern	West Virginia	120	12,154,471	0.0%	8.1%	10	0.120	2
Southern	Arkansas	25,658	18,754,916	0.1%	9.9%	2,530	0.234	591
Southern	Kentucky	1,371	12,471,762	0.0%	6.1%	84	0.234	20
Southern	Mississippi	21,092	19,541,284	0.1%	5.2%	1,089	0.269	294
Southern	North Carolina	18,249	18,587,540	0.1%	6.0%	1,102	0.234	258
Southern	Tennessee	2,498	13,941,333	0.0%	6.2%	155	0.120	19
Western	Kansas	13	2,502,434	0.0%	3.4%	0	0.269	1
Western	Nebraska	1,241	1,576,174	0.1%	3.4%	42	0.269	12
Western	North Dakota	1,051	759,998	0.1%	3.4%	36	0.269	10
Western	South Dakota	864	1,910,934	0.0%	3.4%	29	0.269	8
	Total	108,368	281,528,709	0.038%		7,656		1,859

[1] We prorated the total annual burning for activities occuring during the non-volant season by using the annual percent of the non-volant season (16.7%).

[2] From Table 2.5

Table 4.9. Mean annual acres of forest conversion harvest for each state included in the analysis.

REGION	STATE	Acres of Forested Land	Approximate Acres of Forest Lost per Year (NLCD change 2001 to 2011)	Percent of Habitat Lost Annually	Approximate Acres of Forest Lost by 2022	Percent of Habitat Lost by 2022
Midwest	Iowa	3,013,759	2,520	0.1%	17,641	0.6%
Midwest	Illinois	4,847,480	6,156	0.1%	43,092	0.9%
Midwest	Indiana	4,830,395	4,002	0.1%	28,011	0.6%
Midwest	Michigan	20,127,048	44,704	0.2%	312,930	1.6%
Midwest	Minnesota	17,370,394	52,135	0.3%	364,942	2.1%
Midwest	Missouri	15,471,982	16,968	0.1%	118,775	0.8%
Midwest	Ohio	8,088,277	13,522	0.2%	94,655	1.2%
Midwest	Wisconsin	16,980,084	30,191	0.2%	211,334	1.2%
Eastern	Connecticut	1,711,749	2,940	0.2%	20,577	1.2%
Eastern	Delaware	339,520	1,492	0.4%	10,444	3.1%
Eastern	Maine	17,660,246	52,154	0.3%	365,076	2.1%
Eastern	Maryland	2,460,652	6,286	0.3%	43,999	1.8%
Eastern	Massachusetts	3,024,092	7,075	0.2%	49,526	1.6%
Eastern	New Hampshire	4,832,408	12,002	0.2%	84,016	1.7%
Eastern	New Jersey	1,963,561	6,045	0.3%	42,318	2.2%
Eastern	New York	18,966,416	14,117	0.1%	98,822	0.5%
Eastern	Pennsylvania	16,781,960	22,638	0.1%	158,468	0.9%
Eastern	Rhode Island	359,519	715	0.2%	5,003	1.4%
Eastern	Vermont	4,591,280	3,858	0.1%	27,008	0.6%
Eastern	Virginia	15,907,041	95,261	0.6%	666,824	4.2%
Eastern	West Virginia	12,154,471	12,700	0.1%	88,899	0.7%
Southern	Arkansas	18,754,916	115,372	0.6%	807,604	4.3%
Southern	Kentucky	12,471,762	23,167	0.2%	162,169	1.3%
Southern	Mississippi	19,541,284	162,759	0.8%	1,139,312	5.8%
Southern	North Carolina	18,587,540	130,835	0.7%	915,845	4.9%
Southern	Tennessee	13,941,333	54,006	0.4%	378,039	2.7%
Western	Kansas	2,502,434	4,224	0.2%	29,567	1.2%
Western	Nebraska	1,576,174	4,036	0.3%	28,252	1.8%
Western	North Dakota	759,998	1,826	0.2%	12,785	1.7%
Western	South Dakota	1,910,934	10,532	0.6%	73,725	3.9%
	TOTALS	281,528,709	914,237	0.3%	6,399,657	2.3%

Table 4.10. Estimated numbers of NLEB affected (disturbed) annually by human activity from active-season forest conversion in maternity roosting areas.

Region	State	A. Forest Conversion, Bat Active Season (acres)[1]	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Bats Affected (FxE)
Midwest	Iowa	1,477	3,013,759	0.049%	6.3%	93	0.808	76
Midwest	Illinois	3,607	4,847,480	0.074%	9.4%	341	0.701	239
Midwest	Indiana	2,345	4,830,395	0.049%	5.7%	133	0.701	94
Midwest	Michigan	26,197	20,127,048	0.130%	4.8%	1,246	0.701	874
Midwest	Minnesota	30,551	17,370,394	0.176%	8.9%	2,708	0.808	2,190
Midwest	Missouri	9,943	15,471,982	0.064%	4.0%	393	0.701	276
Midwest	Ohio	7,924	8,088,277	0.098%	6.4%	504	0.701	354
Midwest	Wisconsin	17,692	16,980,084	0.104%	6.8%	1,200	0.701	841
Eastern	Connecticut	1,723	1,711,749	0.101%	1.4%	25	0.359	9
Eastern	Delaware	874	339,520	0.258%	0.8%	7	0.359	3
Eastern	Maine	30,562	17,660,246	0.173%	1.4%	434	0.701	305
Eastern	Maryland	3,683	2,460,652	0.150%	0.8%	28	0.359	11
Eastern	Massachusetts	4,146	3,024,092	0.137%	1.0%	43	0.359	16
Eastern	New Hampshire	7,033	4,832,408	0.146%	1.5%	104	0.359	38
Eastern	New Jersey	3,543	1,963,561	0.180%	4.8%	171	0.359	62
Eastern	New York	8,273	18,966,416	0.044%	5.0%	416	0.359	150
Eastern	Pennsylvania	13,266	16,781,960	0.079%	5.1%	677	0.359	244
Eastern	Rhode Island	419	359,519	0.116%	1.4%	6	0.359	3
Eastern	Vermont	2,261	4,591,280	0.049%	1.5%	33	0.359	13
Eastern	Virginia	55,823	15,907,041	0.351%	7.3%	4,072	0.359	1,463
Eastern	West Virginia	7,442	12,154,471	0.061%	8.1%	602	0.359	217
Southern	Arkansas	67,608	18,754,916	0.360%	9.9%	6,667	0.701	4,672
Southern	Kentucky	13,576	12,471,762	0.109%	6.1%	835	0.701	585
Southern	Mississippi	95,377	19,541,284	0.488%	5.2%	4,926	0.808	3,983
Southern	North Carolina	76,669	18,587,540	0.412%	6.0%	4,632	0.701	3,245
Southern	Tennessee	31,647	13,941,333	0.227%	6.2%	1,964	0.359	706
Western	Kansas	2,475	2,502,434	0.099%	3.4%	84	0.808	69
Western	Nebraska	2,365	1,576,174	0.150%	3.4%	80	0.808	66
Western	North Dakota	1,070	759,998	0.141%	3.4%	36	0.808	30
Western	South Dakota	6,172	1,910,934	0.323%	3.4%	210	0.808	170
	Total	535,743	281,528,709	0.190%		32,673		21,004

[1] We prorated the total annual conversion for activities occuring during the active season by using the annual percent of the active season (58.6%).

[2] From Table 2.5

Table 4.11. Estimated numbers of NLEB pups affected (harmed) annually by non-volant-season forest conversion in maternity roosting areas.

Region	State	A. Forest Conversion, Non-Volant Season[1] (acres)	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Maternity Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Pups Affected (FxE)
Midwest	Iowa	421	3,013,759	0.014%	6.3%	27	0.269	2
Midwest	Illinois	1,028	4,847,480	0.021%	9.4%	97	0.234	4
Midwest	Indiana	668	4,830,395	0.014%	5.7%	38	0.234	2
Midwest	Michigan	7,466	20,127,048	0.037%	4.8%	355	0.234	13
Midwest	Minnesota	8,706	17,370,394	0.050%	8.9%	772	0.269	32
Midwest	Missouri	2,834	15,471,982	0.018%	4.0%	112	0.234	4
Midwest	Ohio	2,258	8,088,277	0.028%	6.4%	144	0.234	6
Midwest	Wisconsin	5,042	16,980,084	0.030%	6.8%	342	0.234	12
Eastern	Connecticut	491	1,711,749	0.029%	1.4%	7	0.120	1
Eastern	Delaware	249	339,520	0.073%	0.8%	2	0.120	1
Eastern	Maine	8,710	17,660,246	0.049%	1.4%	124	0.234	5
Eastern	Maryland	1,050	2,460,652	0.043%	0.8%	8	0.120	1
Eastern	Massachusetts	1,182	3,024,092	0.039%	1.0%	12	0.120	1
Eastern	New Hampshire	2,004	4,832,408	0.041%	1.5%	30	0.120	1
Eastern	New Jersey	1,010	1,963,561	0.051%	4.8%	49	0.120	1
Eastern	New York	2,358	18,966,416	0.012%	5.0%	119	0.120	3
Eastern	Pennsylvania	3,781	16,781,960	0.023%	5.1%	193	0.120	4
Eastern	Rhode Island	119	359,519	0.033%	1.4%	2	0.120	1
Eastern	Vermont	644	4,591,280	0.014%	1.5%	10	0.120	1
Eastern	Virginia	15,909	15,907,041	0.100%	7.3%	1,160	0.120	21
Eastern	West Virginia	2,121	12,154,471	0.017%	8.1%	172	0.120	4
Southern	Arkansas	19,267	18,754,916	0.103%	9.9%	1,900	0.234	67
Southern	Kentucky	3,869	12,471,762	0.031%	6.1%	238	0.234	9
Southern	Mississippi	27,181	19,541,284	0.139%	5.2%	1,404	0.269	57
Southern	North Carolina	21,849	18,587,540	0.118%	6.0%	1,320	0.234	47
Southern	Tennessee	9,019	13,941,333	0.065%	6.2%	560	0.120	11
Western	Kansas	705	2,502,434	0.028%	3.4%	24	0.269	1
Western	Nebraska	674	1,576,174	0.043%	3.4%	23	0.269	1
Western	North Dakota	305	759,998	0.040%	3.4%	10	0.269	1
Western	South Dakota	1,759	1,910,934	0.092%	3.4%	60	0.269	3
	Total	152,678	281,528,709	0.054%		9,311		317

[1] We prorated the total annual conversion for activities occuring during the non-volant season by using the annual percent of the non-volant season (16.7%).

[2] From Table 2.5

Table 4.12. Estimated numbers of NLEB adults affected (harmed) annually by active-season forest conversion in maternity roosting areas.

Region	State	A. Forest Conversion, Active Season[1] (acres)	B. Forest Habitat (acres)	C. Percent of Forest Affected (A/B)	D. Percent of Forest Used as Maternity Roost Areas[2]	E. Expected Overlap (acres) (BxCxD)	F. Density	G. Number of Adults Affected (FxE)
Midwest	Iowa	1,477	3,013,759	0.049%	6.3%	93	0.081	1
Midwest	Illinois	3,607	4,847,480	0.074%	9.4%	341	0.071	1
Midwest	Indiana	2,345	4,830,395	0.049%	5.7%	133	0.071	1
Midwest	Michigan	26,197	20,127,048	0.130%	4.8%	1,246	0.071	3
Midwest	Minnesota	30,551	17,370,394	0.176%	8.9%	2,708	0.081	7
Midwest	Missouri	9,943	15,471,982	0.064%	4.0%	393	0.071	1
Midwest	Ohio	7,924	8,088,277	0.098%	6.4%	504	0.071	2
Midwest	Wisconsin	17,692	16,980,084	0.104%	6.8%	1,200	0.071	3
Eastern	Connecticut	1,723	1,711,749	0.101%	1.4%	25	0.036	1
Eastern	Delaware	874	339,520	0.258%	0.8%	7	0.036	1
Eastern	Maine	30,562	17,660,246	0.173%	1.4%	434	0.071	1
Eastern	Maryland	3,683	2,460,652	0.150%	0.8%	28	0.036	1
Eastern	Massachusetts	4,146	3,024,092	0.137%	1.0%	43	0.036	1
Eastern	New Hampshire	7,033	4,832,408	0.146%	1.5%	104	0.036	1
Eastern	New Jersey	3,543	1,963,561	0.180%	4.8%	171	0.036	1
Eastern	New York	8,273	18,966,416	0.044%	5.0%	416	0.036	1
Eastern	Pennsylvania	13,266	16,781,960	0.079%	5.1%	677	0.036	1
Eastern	Rhode Island	419	359,519	0.116%	1.4%	6	0.036	1
Eastern	Vermont	2,261	4,591,280	0.049%	1.5%	33	0.036	1
Eastern	Virginia	55,823	15,907,041	0.351%	7.3%	4,072	0.036	5
Eastern	West Virginia	7,442	12,154,471	0.061%	8.1%	602	0.036	1
Southern	Arkansas	67,608	18,754,916	0.360%	9.9%	6,667	0.071	15
Southern	Kentucky	13,576	12,471,762	0.109%	6.1%	835	0.071	2
Southern	Mississippi	95,377	19,541,284	0.488%	5.2%	4,926	0.081	13
Southern	North Carolina	76,669	18,587,540	0.412%	6.0%	4,632	0.071	10
Southern	Tennessee	31,647	13,941,333	0.227%	6.2%	1,964	0.036	3
Western	Kansas	2,475	2,502,434	0.099%	3.4%	84	0.081	1
Western	Nebraska	2,365	1,576,174	0.150%	3.4%	80	0.081	1
Western	North Dakota	1,070	759,998	0.141%	3.4%	36	0.081	1
Western	South Dakota	6,172	1,910,934	0.323%	3.4%	210	0.081	1
	Total	535,743	281,528,709	0.190%		32,673		83

[1] We prorated the total annual harvest for activities occuring during the active season by using the annual percent of the active season (58.6%).

[2] From Table 2.5

Table 4.13. Estimated NLEB fatalities from wind energy operation created using current and projected wind capacity through 2022.

REGION	STATE	Installed Wind Capacity in 2014 (MW)	Projected Wind Capacity in 2020 (MW)	Projected Wind Capacity in 2030 (MW)	Mean Annual Build-out 2014-2020 (MW)	Mean Annual Build-out 2021-2022 (MW)	Current Fatality through 2014	Annual Fatality 2015	Annual Fatality 2016	Annual Fatality 2017	Annual Fatality 2018	Annual Fatality 2019	Annual Fatality 2020	Annual Fatality 2021	Annual Fatality 2022	Total Fatality All Years
Midwest	Iowa	5688	6200	17300	85	1110	90	91	93	94	95	97	98	115	133	906
Midwest	Illinois	3568	3980	19490	69	1551	56	57	59	60	61	62	63	87	112	616
Midwest	Indiana	1745	2610	13500	144	1089	28	30	32	34	37	39	41	58	76	375
Midwest	Michigan[1]	1531	1531	1850	0	32	24	24	24	24	24	24	24	25	25	219
Midwest	Minnesota	3035	3470	3990	73	52	48	49	50	51	53	54	55	56	56	472
Midwest	Missouri	459	1280	4350	137	307	7	9	12	14	16	18	20	25	30	151
Midwest	Ohio	435	2990	5320	426	233	7	14	20	27	34	41	47	51	55	295
Midwest	Wisconsin	648	1320	1640	112	32	10	12	14	16	17	19	21	21	22	152
Eastern	Connecticut	0	130	130	22	0	0	0	1	1	1	2	2	2	2	11
Eastern	Delaware[2]	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastern	Maine	440	950	950	85	0	7	8	10	11	12	14	15	15	15	107
Eastern	Maryland	160	820	820	110	0	3	4	6	8	9	11	13	13	13	80
Eastern	Massachusetts	107	270	270	27	0	2	2	3	3	3	4	4	4	4	29
Eastern	New Hampshire	171	470	470	50	0	3	3	4	5	6	7	7	7	7	50
Eastern	New Jersey[2]	9	9	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern	New York	1748	1750	3860	0	0	28	28	28	28	28	28	28	28	28	249
Eastern	Pennsylvania[2]	1340	5580	5400	707	0	21	32	43	55	66	77	88	88	88	559
Eastern	Rhode Island[2]	9	9	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern	Vermont[2]	119	440	430	54	0	2	3	4	4	5	6	7	7	7	45
Eastern	Virginia	0	100	830	17	73	0	0	1	1	1	1	2	3	4	12
Eastern	West Virginia	583	600	2030	3	143	9	9	9	9	9	9	9	12	14	91
Southern	Arkansas	0	0	2550	0	255	0	0	0	0	0	0	0	4	8	12
Southern	Kentucky	0	0	950	0	95	0	0	0	0	0	0	0	2	3	5
Southern	Mississippi	0	0	450	0	45	0	0	0	0	0	0	0	1	1	2
Southern	North Carolina	0	750	750	125	0	0	2	4	6	8	10	12	12	12	65
Southern	Tennessee	29	29	1310	0	128	0	0	0	0	0	0	0	2	5	10
Western	Kansas[2]	2967	3420	3270	76	0	47	48	49	50	52	53	54	54	54	461
Western	Nebraska	812	1260	1360	75	10	13	14	15	16	18	19	20	20	20	155
Western	North Dakota	1886	2870	4710	164	184	30	32	35	38	40	43	45	48	51	362
Western	South Dakota	803	1260	2400	76	114	13	14	15	16	17	19	20	22	24	159
Totals		**28294**	**44100**	**100380**	**2634**	**5453**	**447**	**489**	**530**	**572**	**613**	**655**	**697**	**783**	**869**	**5654**

[1]Projections were held constant for Michigan between 2014 and 2020 because 2020 projections were already exceeded.

[2]Projections are expected to decline slightly between 2020-2030; however, we did not reduce capacity because we assume constructed facilities will continue to operate.

Table 4.14. Influence of conservation measures for tree removal activities included in the final 4(d) rule for the NLEB.

Range	State	Known Hibernacula	Known Occupied Maternity Roost Trees	Acres Covered by Hibernacula Conservation Measure[1]	Acres Covered by Maternity Roost Tree Conservation Measure[2]	Acres of Forested Land	Percent of Total Available Habitat Covered by Measures
Midwest	Iowa	2	14	251	22	3,013,759	0.01%
Midwest	Illinois	44	39	5,531	62	4,847,480	0.12%
Midwest	Indiana	69	193	8,673	309	4,830,395	0.19%
Midwest	Michigan	77	25	9,679	40	20,127,048	0.05%
Midwest	Minnesota	15	102	1,886	163	17,370,394	0.01%
Midwest	Missouri	269	58	33,813	93	15,471,982	0.22%
Midwest	Ohio	32	4	4,022	6	8,088,277	0.05%
Midwest	Wisconsin	67	84	8,422	134	16,980,084	0.05%
Eastern	Connecticut	8	0	1,006	0	1,711,749	0.06%
Eastern	Delaware	2	0	251	0	339,520	0.07%
Eastern	Maine	3	0	377	0	17,660,246	0.00%
Eastern	Maryland	8	0	1,006	0	2,460,652	0.04%
Eastern	Massachusetts	7	16	880	26	3,024,092	0.03%
Eastern	New Hampshire	11	0	1,383	0	4,832,408	0.03%
Eastern	New Jersey	9	47	1,131	75	1,963,561	0.06%
Eastern	New York	90	27	11,313	43	18,966,416	0.06%
Eastern	Pennsylvania	322	157	40,475	251	16,781,960	0.24%
Eastern	Rhode Island	0	0	0	0	359,519	0.00%
Eastern	Vermont	16	0	2,011	0	4,591,280	0.04%
Eastern	Virginia	11	12	1,383	19	15,907,041	0.01%
Eastern	West Virginia	104	231	13,073	370	12,154,471	0.11%
Southern	Alabama	11	0	1,383	0	22,876,792	0.01%
Southern	Arkansas	77	310	9,679	496	18,754,916	0.05%
Southern	Georgia	6	20	754	32	24,768,236	0.00%
Southern	Kentucky	122	254	15,335	406	12,471,762	0.13%
Southern	Louisiana	0	0	0	0	14,540,135	0.00%
Southern	Mississippi	0	0	0	0	19,541,284	0.00%
Southern	North Carolina	29	101	3,645	162	18,587,540	0.02%
Southern	Oklahoma	9	0	1,131	0	12,646,138	0.01%
Southern	South Carolina	3	0	377	0	13,120,509	0.00%
Southern	Tennessee	61	50	7,668	80	13,941,333	0.06%
Western	Kansas	1	0	126	0	2,502,434	0.01%
Western	Montana	0	0	0	0	25,573,200	0.00%
Western	Nebraska	2	0	251	0	759,998	0.03%
Western	North Dakota	0	0	0	0	1,576,174	0.00%
Western	South Dakota	21	0	2,640	0	1,910,934	0.14%
Western	Wyoming	0	0	0	0	11,448,541	0.00%
	Total	1,508	1,744	189,556	2,790	406,502,260	0.05%

[1]Hibernacula buffer circles have a radius of 0.25 mi, which is 125.7 acres

[2]Maternity roost trees have a temporary buffer circle with a 150 ft radius, which is 1.6 acres

Table 4.15. Summary of annual disturbance and harm estimates from timber harvest, prescribed fire, forest conversion, and wind[4].

Region	State	Harass Timber Harvest	Harass Prescribed Fire	Harass Forest Conversion	Harm (pups) Timber Harvest	Harm (pups) Prescribed Fire	Harm (pups) Forest Conversion	Harm (adults) Timber Harvest	Harm (adults) Forest Conversion	Harm (adults) Average Wind	Total Annual Harassment	Total Annual Harm (pups)	Total Annual Harm (adults)
Midwest	Iowa	619	310	76	9	30	2	2	1	102	1,005	41	105
Midwest	Illinois	1,469	314	239	21	30	4	5	1	70	2,022	55	76
Midwest	Indiana	1,207	149	94	18	15	2	4	1	43	1,450	35	48
Midwest	Michigan	5,240	183	874	75	18	13	16	3	24	6,297	106	43
Midwest	Minnesota	6,706	4,306	2,190	96	409	32	21	7	53	13,202	537	81
Midwest	Missouri	2,831	576	276	41	55	4	9	1	18	3,683	100	28
Midwest	Ohio	2,111	73	354	31	7	6	7	2	36	2,538	44	45
Midwest	Wisconsin	7,493	441	841	107	42	12	23	3	18	8,775	161	44
Eastern	Connecticut	30	1	9	1	1	1	1	1	1	40	3	3
Eastern	Delaware	5	1	3	1	1	1	1	1	0	9	3	2
Eastern	Maine	2,767	1	305	40	1	5	9	1	13	3,073	46	23
Eastern	Maryland	24	5	11	1	1	1	1	1	10	40	3	12
Eastern	Massachusetts	30	1	16	1	1	1	1	1	3	47	3	5
Eastern	New Hampshire	215	1	38	4	1	1	1	1	6	254	6	8
Eastern	New Jersey	37	73	62	1	7	1	1	1	0	172	9	2
Eastern	New York	1,880	2	150	27	1	3	6	1	28	2,032	31	35
Eastern	Pennsylvania	2,104	20	244	30	2	4	7	1	67	2,368	36	75
Eastern	Rhode Island	0	1	3	0	1	1	0	1	0	4	2	1
Eastern	Vermont	163	2	13	3	1	1	1	1	5	178	5	7
Eastern	Virginia	2,963	209	1,463	43	20	21	9	5	2	4,635	84	16
Eastern	West Virginia	1,316	13	217	19	2	4	4	1	10	1,546	25	15
Southern	Arkansas	17,961	6,221	4,672	256	591	67	55	15	2	28,854	914	72
Southern	Kentucky	2,772	208	585	40	20	9	9	2	1	3,565	69	12
Southern	Mississippi	9,309	3,091	3,983	133	294	57	29	13	0	16,383	484	42
Southern	North Carolina	4,892	2,711	3,245	70	258	47	15	10	8	10,848	375	33
Southern	Tennessee	1,695	196	706	25	19	11	6	3	1	2,597	55	10
Western	Kansas	172	2	69	3	1	1	1	1	52	243	5	54
Western	Nebraska	250	120	66	4	12	1	1	1	18	436	17	20
Western	North Dakota	0	102	30	0	10	1	0	1	42	132	11	43
Western	South Dakota	585	84	170	9	8	3	2	1	18	839	20	21
	Total	76,846	19,417	21,004	1,109	1,859	317	247	83	650	117,267	3,285	980

[4] Wind is the mean annual estimate from 2015 to 2022 reported in Table 4.13.

Table 4.16. Summary of the activities expected to disturb NLEB annually. The total number of bats per state includes adults and pups.

Region	State	Total # Bats Harassed per year	Percent Harass from Burning	Percent Harass from Harvest	Percent Harass from Conversion	Total # Bats per State	Percent Total Bats Affected
Midwest	Iowa	1,005	30.8%	61.6%	7.6%	153,495	0.7%
Midwest	Illinois	2,022	15.5%	72.7%	11.8%	320,580	0.6%
Midwest	Indiana	1,450	10.3%	83.2%	6.5%	191,763	0.8%
Midwest	Michigan	6,297	2.9%	83.2%	13.9%	670,878	0.9%
Midwest	Minnesota	13,202	32.6%	50.8%	16.6%	1,244,835	1.1%
Midwest	Missouri	3,683	15.6%	76.9%	7.5%	428,922	0.9%
Midwest	Ohio	2,538	2.9%	83.2%	13.9%	360,360	0.7%
Midwest	Wisconsin	8,775	5.0%	85.4%	9.6%	806,715	1.1%
Eastern	Connecticut	40	2.5%	75.0%	22.5%	8,760	0.5%
Eastern	Delaware	9	11.1%	55.6%	33.3%	960	0.9%
Eastern	Maine	3,073	0.0%	90.0%	9.9%	175,734	1.7%
Eastern	Maryland	40	12.5%	60.0%	27.5%	6,720	0.6%
Eastern	Massachusetts	47	2.1%	63.8%	34.0%	11,160	0.4%
Eastern	New Hampshire	254	0.4%	84.6%	15.0%	25,740	1.0%
Eastern	New Jersey	172	42.4%	21.5%	36.0%	34,140	0.5%
Eastern	New York	2,032	0.1%	92.5%	7.4%	342,720	0.6%
Eastern	Pennsylvania	2,368	0.8%	88.9%	10.3%	307,800	0.8%
Eastern	Rhode Island	4	25.0%	0.0%	75.0%	1,860	0.2%
Eastern	Vermont	178	1.1%	91.6%	7.3%	24,420	0.7%
Eastern	Virginia	4,635	4.5%	63.9%	31.6%	416,880	1.1%
Eastern	West Virginia	1,546	0.8%	85.1%	14.0%	353,520	0.4%
Southern	Arkansas	28,854	21.6%	62.2%	16.2%	1,295,775	2.2%
Southern	Kentucky	3,565	5.8%	77.8%	16.4%	537,147	0.7%
Southern	Mississippi	16,383	18.9%	56.8%	24.3%	815,940	2.0%
Southern	North Carolina	10,848	25.0%	45.1%	29.9%	786,708	1.4%
Southern	Tennessee	2,597	7.5%	65.3%	27.2%	310,920	0.8%
Western	Kansas	243	0.8%	70.8%	28.4%	68,850	0.4%
Western	Nebraska	436	27.5%	57.3%	15.1%	43,335	1.0%
Western	North Dakota	132	77.3%	0.0%	22.7%	20,925	0.6%
Western	South Dakota	839	10.0%	69.7%	20.3%	52,515	1.6%
	Total	117,267	16.6%	65.5%	17.9%	9,820,077	1.2%

Table 4.17. Summary of the activities expected to harm NLEB pups annually.

Region	State	Total # Pups Harmed per year	Percent Harm from Burning	Percent Harm from Harvest	Percent Harm from Conversion	Total # Pups per State	Percent Total Pups Affected
Midwest	Iowa	41	73.2%	22.0%	4.9%	51,165	0.1%
Midwest	Illinois	55	54.5%	38.2%	7.3%	106,860	0.1%
Midwest	Indiana	35	42.9%	51.4%	5.7%	63,921	0.1%
Midwest	Michigan	106	17.0%	70.8%	12.3%	223,626	0.0%
Midwest	Minnesota	537	76.2%	17.9%	6.0%	414,945	0.1%
Midwest	Missouri	100	55.0%	41.0%	4.0%	142,974	0.1%
Midwest	Ohio	44	15.9%	70.5%	13.6%	120,120	0.0%
Midwest	Wisconsin	161	26.1%	66.5%	7.5%	268,905	0.1%
Eastern	Connecticut	3	33.3%	33.3%	33.3%	2,920	0.1%
Eastern	Delaware	3	33.3%	33.3%	33.3%	320	0.9%
Eastern	Maine	46	2.2%	87.0%	10.9%	58,578	0.1%
Eastern	Maryland	3	33.3%	33.3%	33.3%	2,240	0.1%
Eastern	Massachusetts	3	33.3%	33.3%	33.3%	3,720	0.1%
Eastern	New Hampshire	6	16.7%	66.7%	16.7%	8,580	0.1%
Eastern	New Jersey	9	77.8%	11.1%	11.1%	11,380	0.1%
Eastern	New York	31	3.2%	87.1%	9.7%	114,240	0.0%
Eastern	Pennsylvania	36	5.6%	83.3%	11.1%	102,600	0.0%
Eastern	Rhode Island	2	50.0%	0.0%	50.0%	620	0.3%
Eastern	Vermont	5	20.0%	60.0%	20.0%	8,140	0.1%
Eastern	Virginia	84	23.8%	51.2%	25.0%	138,960	0.1%
Eastern	West Virginia	25	8.0%	76.0%	16.0%	117,840	0.0%
Southern	Arkansas	914	64.7%	28.0%	7.3%	431,925	0.2%
Southern	Kentucky	69	29.0%	58.0%	13.0%	179,049	0.0%
Southern	Mississippi	484	60.7%	27.5%	11.8%	271,980	0.2%
Southern	North Carolina	375	68.8%	18.7%	12.5%	262,236	0.1%
Southern	Tennessee	55	34.5%	45.5%	20.0%	103,640	0.1%
Western	Kansas	5	20.0%	60.0%	20.0%	22,950	0.0%
Western	Nebraska	17	70.6%	23.5%	5.9%	14,445	0.1%
Western	North Dakota	11	90.9%	0.0%	9.1%	6,975	0.2%
Western	South Dakota	20	40.0%	45.0%	15.0%	17,505	0.1%
	Total	3,285	56.6%	33.8%	9.6%	3,273,359	0.1%

Table 4.18. Summary of the activities expected to harm NLEB adults annually.

Region	State	Total # Adults Harmed per year	Percent Harm from Harvest	Percent Harm from Conversion	Percent Harm from Wind	Total # Adults per State	Percent Total Adults Affected
Midwest	Iowa	105	1.9%	1.0%	97.1%	102,330	0.10%
Midwest	Illinois	76	6.6%	1.3%	92.1%	213,720	0.04%
Midwest	Indiana	48	8.3%	2.1%	89.7%	127,842	0.04%
Midwest	Michigan	43	37.0%	6.9%	56.1%	447,252	0.01%
Midwest	Minnesota	81	25.9%	8.6%	65.4%	829,890	0.01%
Midwest	Missouri	28	32.1%	3.6%	64.3%	285,948	0.01%
Midwest	Ohio	45	15.5%	4.4%	80.1%	240,240	0.02%
Midwest	Wisconsin	44	52.6%	6.9%	40.6%	537,810	0.01%
Eastern	Connecticut	3	29.6%	29.6%	40.7%	5,840	0.06%
Eastern	Delaware	2	50.0%	50.0%	0.0%	640	0.31%
Eastern	Maine	23	40.0%	4.4%	55.6%	117,156	0.02%
Eastern	Maryland	12	8.6%	8.6%	82.8%	4,480	0.26%
Eastern	Massachusetts	5	18.6%	18.6%	62.8%	7,440	0.07%
Eastern	New Hampshire	8	12.9%	12.9%	74.2%	17,160	0.05%
Eastern	New Jersey	2	50.0%	50.0%	0.0%	22,760	0.01%
Eastern	New York	35	17.1%	2.9%	80.0%	228,480	0.02%
Eastern	Pennsylvania	75	9.3%	1.3%	89.4%	205,200	0.04%
Eastern	Rhode Island	1	0.0%	100.0%	0.0%	1,240	0.08%
Eastern	Vermont	7	13.6%	13.6%	72.9%	16,280	0.05%
Eastern	Virginia	16	57.6%	32.0%	10.4%	277,920	0.01%
Eastern	West Virginia	15	26.7%	6.7%	66.7%	235,680	0.01%
Southern	Arkansas	72	76.9%	21.0%	2.1%	863,850	0.01%
Southern	Kentucky	12	77.4%	17.2%	5.4%	358,098	0.00%
Southern	Mississippi	42	68.6%	30.8%	0.6%	543,960	0.01%
Southern	North Carolina	33	45.1%	30.1%	24.8%	524,472	0.01%
Southern	Tennessee	10	60.8%	30.4%	8.9%	207,280	0.00%
Western	Kansas	54	1.9%	1.9%	96.3%	45,900	0.12%
Western	Nebraska	20	5.1%	5.1%	89.9%	28,890	0.07%
Western	North Dakota	43	0.0%	2.4%	97.6%	13,950	0.30%
Western	South Dakota	21	9.4%	4.7%	86.0%	35,010	0.06%
	Total	980	25.2%	8.5%	66.3%	6,546,718	0.01%

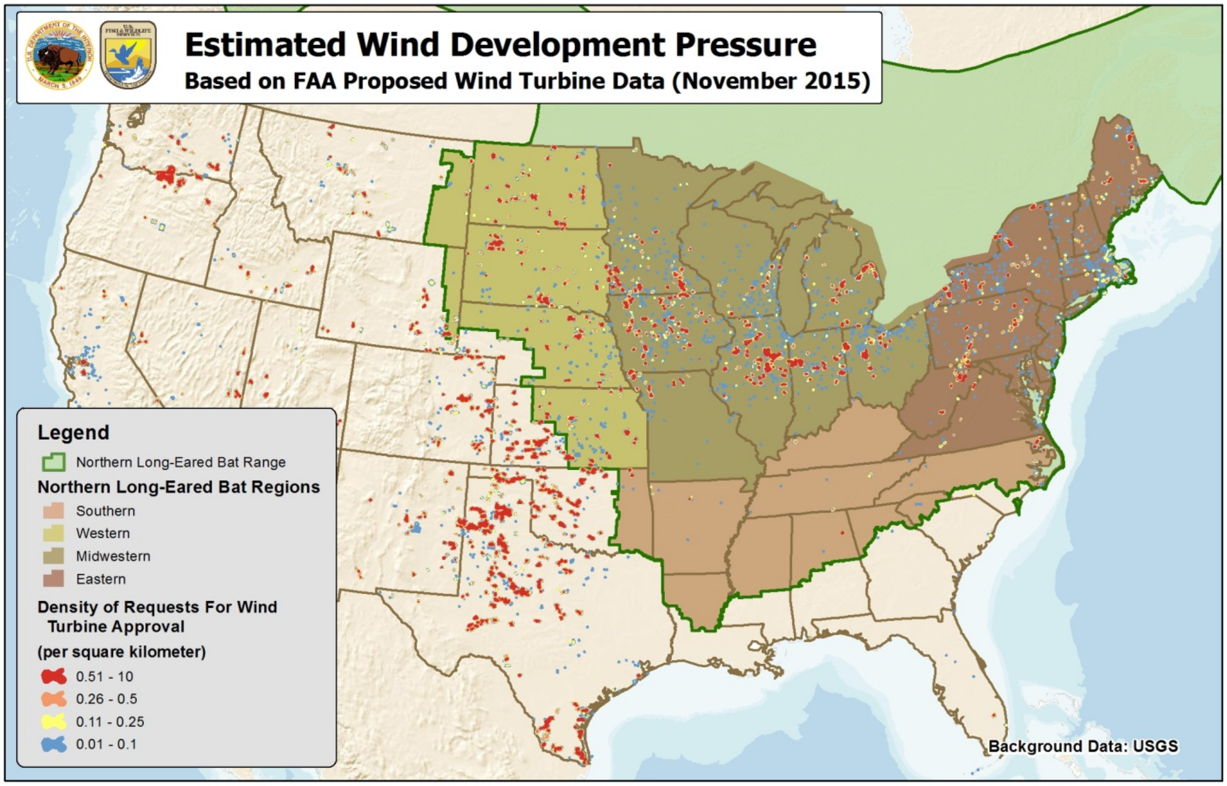

Figure 4.1. Estimated wind development pressure based on the Federal Aviation Administration's proposed wind turbine data.

5 CUMULATIVE EFFECTS

In the context of a consultation, cumulative effects are the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under section 7 of the ESA.

Section 4 of this BO discusses all actions that may affect the NLEB associated with the implementation of the final 4(d) rule. These include effects of state, tribal, local and private actions. These actions are typically included in this section; however, the action evaluated in this BO is the finalization and implementation of the final 4(d) rule, which includes state, tribal, local, and private actions. We acknowledge that some of the activities included in the effects of the action are cumulative effects, but we do not separate them in this BO.

6 CONCLUSION

WNS is the primary factor affecting the status of the NLEB, which has caused dramatic and rapid declines in abundance, resulting in the local extirpation of the species in some areas. Although other factors, individually or in combination, are likely insignificant at the range-wide scale, they may exacerbate the effects of WNS at the local population scale, thereby accelerating declines and the likelihood of local extirpation due to the disease or reducing the population's ability to survive and potentially rebound. Our analysis of the effects of activities that may affect the NLEB, but do not cause prohibited take, indicates that the additional loss of individual NLEB resulting from these activities would not exacerbate the effects of WNS at the scale of states within its range. Even if all anthropogenic activities that might adversely affect NLEB ceased, we do not believe that the resulting reduction in adverse effects would materially change the devastating impact WNS has had, and will continue to have, on NLEB at the local population level or at larger scales.

The species' foremost conservation need is to reduce or eliminate the threat of WNS. In areas impacted by WNS, the next priorities are to protect NLEB in hibernacula and maternity roost trees, and to continue to monitor populations in summer habitats (e.g., identify where the species continues to survive after the detection of Pd or WNS and determine the factors influencing its resilience).

From our assessment of the species' status/environmental baseline, we have observed NLEB population declines within a few years following the arrival of WNS, and can expect further declines as the disease moves through the Action Area. Based on post-WNS occupancy rates inferred from summer survey data and assumptions about colony size and distribution in forested habitats, we estimate that the population of NLEB is currently about 6,546,700 adult NLEB.

Activities that may affect the NLEB, but will not cause prohibited take under the final 4(d) rule, primarily include timber harvest, prescribed fire, forest conversion, and wind turbine operation. We estimate that these activities will disturb up to 117,267 volant NLEB (both adults and juveniles) each year, all within roosting areas (both maternity and non-maternity), and mostly (65.5 percent) resulting from timber harvest. The Action is expected to harm up to 3,285 non-volant juvenile NLEB annually, all within maternity roosting areas, and mostly resulting from prescribed burning and tree clearing activities conducted during the active season. The Action is also expected to harm up to 980 adults annually, mostly from wind turbine operation and removal of undocumented occupied roosts.

The disturbance estimate amounts to 1.2 percent of the total NLEB population, including young-of-the-year (1 per adult female following parturition), and less than 2.3% of the total number of NLEBs in each individual state. We do not expect disturbance of less than 2.3% of a state's population to significantly affect the numbers or reproduction of the species in the states, as only a small fraction of those fleeing roosts due to disturbance are likely to suffer injury from day-time predators or other hazards encountered before roosting elsewhere. Further, we do not expect disturbance to significantly affect the distribution of the species on the Forests, as the disturbances causing it are temporary, ceasing when project-level activity ceases.

The harm estimate of 3,285 NLEB pups amounts to less than 0.1 percent of the total population of non-volant pups. Less than 1% of the total number of NLEB pups may be harmed in individual states. However, these numbers are overestimates. As noted above, most of this harm is caused by prescribed burning and tree clearing activities, where the potential for death or injury depends largely on site-specific circumstances, e.g., the likelihood of felling a tree containing a maternity colony. Not all tree clearing activities through maternity roosting areas will kill or injure all pups present, but our methodology in this BO estimates that all potentially vulnerable individuals within the expected area of activity/occupancy overlap are affected. The same is true for prescribed fire. We also estimated that 980 adults (less than 0.02% of the total population) may be affected by wind turbine operation and tree clearing activities. Less than 1% of the total number of NLEB adults may be affected in all individual states. These numbers are more realistic estimations because we did not assume that all potentially vulnerable individuals would be affected – we assumed that only 3% of adults would be impacted.

There are no additional interrelated and interdependent actions to the proposed Action or cumulative effects that are not included in the analysis of the proposed Action.

The final 4(d) rule determined that the conservation of the NLEB as a threatened species is best served by limiting the full suite of prohibitions applicable to endangered species under section 9 of the Act to its most vulnerable life stages, i.e., while in hibernacula or in maternity roost trees within the WNS zone, and to activities, tree removal in particular, that are most likely to affect the species. Activities excepted from the requirements to obtain incidental take statements or incidental take permits will affect relatively small numbers of individuals, which is not anticipated to impair conservation efforts or the recovery potential of the species. The vast majority of individuals and populations that survive WNS are unaffected by these activities. It is likely that the species will persist in the individual states based on the number of maternity colonies and widely-dispersed nature of the activities. Based on the relatively small numbers affected annually compared to the state population sizes, we conclude that adverse effects from timber harvest, prescribed fire, forest conversion, wind energy, and other activities will not cause population-level declines in this species.

The Service defines "to jeopardize the continued existence of a listed species" as to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species. After reviewing the current status of the NLEB, environmental baseline, effects of the Action, and cumulative effects, it is the Service's biological opinion that the Action, as proposed, is not likely to jeopardize the continued existence of the NLEB. The Service has not proposed or designated critical habitat for this species; therefore, none is affected.

Incidental take that is not expressly prohibited under the final 4(d) rule does not require exception in an Incidental Take Statement. This BO has evaluated major categories of actions that may affect the NLEB, but for which incidental take is not prohibited. Accordingly, there are no reasonable and prudent measures or terms and conditions that are necessary and appropriate for these actions. Federal agencies may rely on this BO to fulfill their project-specific section 7(a)(2) responsibilities under the framework specified in section 1.3 of this BO, which provides a process by which agencies may verify that their proposed actions do not include activities that would cause prohibited incidental take. Prohibited incidental take requires either a separate consultation (federal actions) or an incidental take permit (non-federal actions).

7 REINITIATION NOTICE

Reinitiation of formal consultation is required and shall be requested by the Service, where discretionary federal involvement or control over the action has been retained or is authorized by law and: (a) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (b) If the identified action is subsequently modified in a manner that has an effect to the listed species or critical habitat that was not considered in the biological opinion; or (c) If a new species is listed or critical habitat designated that may be affected by the identified action. The section 7 regulations also require that consultation be reinitiated if the amount or extent of taking specified in the incidental take statement is exceeded (50 CFR 402.16); however, this condition does not apply to this consultation because all incidental take resulting from actions carried out in compliance with the final 4(d) rule is not prohibited.

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UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

CENTER FOR BIOLOGICAL DIVERSITY, *et al.*, Plaintiffs, v. MARGARET EVERSON, *et al.*, Defendants and AMERICAN FOREST & PAPER ASSOCIATION, *et al.*, Defendant-Intervenors.	Civil Action No. 15-477 (EGS)
DEFENDERS OF WILDLIFE, Plaintiff, v. MARGARET EVERSON, *et al.*, Defendants and AMERICAN FOREST & PAPER ASSOCIATION, *et al.*, Defendant-Intervenors.	Civil Action No. 16-910 (EGS) (Consolidated with 15-cv-477)

MEMORANDUM OPINION

In April 2015, the United States Fish and Wildlife Service ("FWS" or "the Service") issued its final rule listing the northern long-eared bat ("Bat") as a "threatened" species under the Endangered Species Act of 1973. *See* Threatened Species Status for the Northern Long-Eared Bat With 4(d) Rule, 80 Fed. Reg. 17,974 (Apr. 2, 2015) ("Listing Rule"). FWS found that while the Bat "resides firmly in th[e] category where no distinct determination exists to differentiate between endangered and threatened," the Bat "is appropriately categorized as a threatened species" as the Bat "is likely to become an endangered species in the foreseeable future." *Id.* at 18,020-21.

Plaintiffs—the Center for Biological Diversity, Ohio Valley Environmental Coalition, Coal River Mountain Watch, Sierra Club, and Defenders of Wildlife—challenge two separate decisions by FWS pertaining to the Bat that they claim fail to comply with mandates for the Endangered Species Act ("ESA"), 16 U.S.C. §§ 1531-1544, the Administrative Procedure Act ("APA"), 5 U.S.C. §§ 551 *et seq.*, and the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4321-4347. These decisions are: (1) the decision to list the Bat as threatened rather than endangered, with an interim final species-specific 4(d) rule, Listing Rule, 80 Fed. Reg. 17,974; and (2) the final species-specific section 4(d) rule, 81 Fed. Reg. 1900 (Jan. 14, 2016). The Court bifurcated briefing on these two challenges, Min. Order of Jan.

13, 2017, and pending before the Court are the parties' cross-motions for summary judgment on plaintiffs' Listing Rule claim.

Upon careful consideration of the plaintiffs' motion, the Federal defendants' and defendant-intervenors' cross-motions, the oppositions and replies thereto, the arguments of amicus curiae,[1] the relevant law, the full administrative record, and for the reasons set forth below, the Court finds that FWS's decision to list the Bat as threatened under the ESA was arbitrary and capricious. Accordingly, the Court **GRANTS IN PART AND DENIES IN PART** plaintiffs' motion for summary judgment and **GRANTS IN PART AND DENIES IN PART** Federal defendants' and the defendant-intervenors' motions for summary judgment.

I. Background

A. Statutory and Regulatory Background

The ESA has been described as "the most comprehensive legislation for the preservation of endangered species ever enacted by any nation." *Tennessee Valley Auth. v. Hill,* 437 U.S. 153, 180 (1978). Congress enacted the ESA "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species." 16 U.S.C. § 1531(b). "The plain intent of

[1] The Court appreciates the analysis provided by amicus curiae.

Congress in enacting this statute was to halt and reverse the trend toward species extinction, whatever the cost." *Tennessee Valley Auth.*, 437 U.S. at 184.

The ESA's protections are triggered when a species is designated as either "threatened" or "endangered." A designation of "endangered" triggers a broad scope of protections, including a prohibition on "taking" individual members of the species. *See* 16 U.S.C. § 1538(a)(1)(B); *see also id.* § 1532(19) ("The term take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."). A designation of "threatened" requires the Secretary to "issue such regulations as he deems necessary and advisable to provide for the conservation of such species." *Id.* § 1533(d).

An "endangered species" is "any species which is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). A "threatened species" is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." *Id.* § 1532(20). The term "species" is defined in the Act to include species, subspecies, and "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." *Id.* § 1532(16).

The ESA requires the Secretary of the Interior to publish and maintain a list of all species that have been designated as threatened or endangered. *Id.* § 1533(c). Species are added to and removed from this list after notice and an opportunity for public comment, either on the initiative of the Secretary or as a result of a petition submitted by an "interested person." *Id.* § 1533(b)(1), (3), (5). The Secretary of the Interior and the Secretary of Commerce are responsible for making listing decisions. *Id.* §§ 1532(15), 1533(a)(2). The Secretary of the Interior is responsible for making listing determinations for the Bat. *See* 50 C.F.R. § 402.01(b).

A listing determination is made on the basis of one or more of five statutorily prescribed factors: "(A) the present or threatened destruction, modification, or curtailment of a species' habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or manmade factors affecting a species' continued existence." 16 U.S.C § 1533(a)(1)(A)-(E); *see also* 50 C.F.R. § 424.11(c). The agency must list a species as long as "any one or a combination" of these factors demonstrates that the species is threatened or endangered. 50 C.F.R. § 424.11(c).

The decision to list a species must be made

> solely on the basis of the best scientific and commercial data available ... after conducting a review of the status of the species and after

> taking into account those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species . . . .

16 U.S.C. § 1533(b)(1)(A).

B. Factual and Procedural Background

The Bat is a medium-sized bat species with relatively long ears whose range extends "across much of the eastern and north-central United States . . . [including] 37 states, the District of Columbia," and "all Canadian Provinces." 80 Fed. Reg. at 17,975. The Bat has different winter and summer habitats. In winter, the Bat hibernates in hibernacula, typically caves and abandoned mines. *Id.* at 17,984. In summer, the Bat typically roosts alone or in colonies "underneath bark or in cavities or crevices of both live trees and snags," with no apparent preference for tree species. *Id.* The maximum lifespan of the Bat is estimated at 18.5 years, and adult females give birth to a single pup each year. *Id.* at 17,988.

A number of bat species are susceptible to White-nose syndrome ("WNS"), caused by a fungus known as "Pd," which has been "responsible for unprecedented mortality of insectivorous bats in eastern North America." *Id.* at 17,993–94. First documented in 2006, it "has spread rapidly." *Id.* at 17,994. The Bat has been found to be highly-susceptible to WNS. *Id.* at 17,998. As stated in the Listing Rule,

> A recent study revealed that the northern long-eared bat has experienced a precipitous population decline, estimated at approximately 96 percent (from hibernacula data) in the northeastern portion of its range, due to the emergence of WNS. WNS has spread to approximately 60 percent of the northern long-eared bat's range in the United States, and if the observed average rate of spread of Pd continues, the fungus will be found in hibernacula throughout the entire species' range within 8 to 13 years based on the calculated rate of spread observed to date (by both the Service and COSEWIC[[2]]). We expect that similar declines as seen in the East and portions of the Midwest will be experienced in the future throughout the rest of the species' range.

Id. at 18,000. Once a bat becomes infected with WNS, there is no cure. *Id.* at 18,021.

In 2010, the Center for Biological Diversity petitioned FWS to list the Bat as endangered or threatened and to designate critical habitat for the species, and in October 2013, FWS proposed to list the Bat as an endangered species. *See* 12-Month Finding on a Petition to List the Eastern Small-Footed Bat and the Northern Long-eared Bat as Endangered or Threatened Species; Listing the Northern Long-Eared Bat as an Endangered Species, 78 Fed. Reg. 61,046 (Oct. 23, 2013) ("Proposed Rule"). Thereafter, in April 2015, FWS issued its final rule listing the Bat as a

[2] COSEWIC stands for Committee on the Status of Endangered Wildlife in Canada.

threatened rather than an endangered species. *See generally* 80 Fed. Reg. 17,974.

In describing the Bat's range, FWS divided the range into four geographical sections, and explained that WNS has affected three of the four sections, with WNS being undetected in the section where the Bat is generally "uncommon" or "rare." The eastern section of the range includes the District of Columbia, Delaware, Connecticut, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Pennsylvania, Vermont, Virginia, West Virginia, New York, and Rhode Island. *Id.* at 17,976. As explained by FWS,

> Historically, the [Bat] was widely distributed in the eastern part of its range," but due to the arrival of WNS, while the Bat "continue[s] to be distributed across much of the historical range, . . . there are many gaps within the range where bats are no longer detected or captured, and in other areas, their occurrence is sparse. . . . Since WNS has been documented, multiple hibernacula now have zero reported northern long-eared bats. Frick et al. (2015, p. 6) documented the local extinction of northern long-eared bats from 69 percent of sites included in their analyses (468 sites where WNS has been present for at least 4 years in Vermont, New York, Pennsylvania, Maryland, West Virginia, and Virginia).

Id. at 17,976-77. The midwestern section includes Missouri, Illinois, Iowa, Indiana, Ohio, Michigan, Wisconsin, and Minnesota, with WNS documented in all but Iowa and Minnesota, where the fungus that causes WNS has been confirmed. *Id.* at 17,979. "[H]istorically, [the Bat] was considered one of the more frequently encountered bat species in the region," *id.*, and "clear declines in winter populations of [the Bat] have been observed in Ohio and Illinois," *id.* The southern section includes Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, and Tennessee. *Id.* at 17,980. The Bat is considered more common in Kentucky and Tennessee and less common in the other states. *Id.* The only state in this section with survey data is Kentucky, and in Kentucky, WNS has been documented "with mortality confirmed at many sites." *Id.* The western portion includes South Dakota, North Dakota, Nebraska, Wyoming, Montana, and Kansas. *Id.* at 17,983. Historically, the Bat is less common in this portion than in the northern portion of its range. *Id.* In particular, the Bat "is considered common in only small portions of the western part of its range (e.g., Black Hills of South Dakota) and uncommon or rare in the western extremes of the range (e.g., Wyoming, Kansas, Nebraska)" although "there has been limited survey effort throughout much of this part of the [Bat's] range." *Id.* As of the publication of the Listing Rule, WNS had not been detected in the western portion of the range. *Id.*

FWS considers the portions of the range affected by WNS likely to be the core of the Bat's range:

> Information provided to the Service by a number of State agencies demonstrates that the area currently (as of 2015) affected by WNS likely constitutes the core of the species' range, where densities of northern long-eared bats were highest prior to WNS. Further, it has been suggested that the species was considered less common or rare in the extreme southern, western, and northwestern parts of its range (Caceres and Barclay 2000, p. 2; Harvey 1992, p. 35), areas where WNS has not yet been detected. The northern long-eared bat has been extirpated from hibernacula where WNS, has been present for a significant number of years (e.g., 5 years), and has declined significantly in other hibernacula where WNS has been present for only a few years. A corresponding decline on the summer landscape has also been witnessed. As WNS expands to currently uninfected areas within the range of northern long-eared bat, there is the expectation that the disease, wherever found, will continue to negatively affect the species. WNS is the predominant threat to the northern long-eared bat rangewide, and it is likely to spread to the entirety of the species' range.

Id. at 17,998.

FWS noted that "[t]he Act defines an endangered species as any species that is 'in danger of extinction throughout all or a significant portion of its range' and a threatened species as any species 'that is likely to become endangered throughout all or a significant portion of its range within the foreseeable future.'" *Id.* at 18,020. FWS explained "that the phrase 'in danger of extinction' can be most simply expressed as meaning that a species is 'on the brink of extinction in the wild.'" *Id.* (quoting Dec. 21, 2011, Memorandum from Acting FWS Director Dan

Ashe Re: Determination of Threatened Status for Polar Bears [hereinafter the "Polar Bear Memo."]. FWS explained:

> In at least one type of situation, where a species still has relatively widespread distribution, but has nevertheless suffered ongoing major reductions in numbers, range or both as a result of factors that have not been abated, the Service acknowledges that no distinct determination exists between "endangered" and "threatened." In such cases: "Whether a species . . . is ultimately an endangered species or a threatened species depends on the specific lift history and ecology of the species, the nature of the threats, and population numbers and trends. Even species that have suffered fairly substantial declines in numbers or range are sometimes listed as threatened rather than endangered. (Polar Bear Memo, p. 6)."

Id. FWS stated that the Bat "resides firmly in this category where no distinct determination exists to differentiate between endangered and threatened. Therefore, our determination that this species is threatened is guided by the best available data on the biology of the species, and the threat posed by [WNS]." *Id.*

FWS stated that "[n]o one factor alone conclusively establishes whether the species is 'on the brink' of extinction. Taken together, however, the data indicate a current condition where the species, while likely to become in danger of extinction at some point in the foreseeable future, is not on the brink of extinction at this time." *Id.* In explaining why the

Bat is appropriately categorized as a threatened species, FWS stated that

> WNS has impacted the species throughout much of its range, and can be expected to . . . within 8 to 13 years . . . spread and impact the species throughout its entire range. Once WNS becomes established in new areas, we can expect similar, substantial losses of bats beginning in the first few years following infection (Factor C). There is currently no effective means to stop the spread of the disease, or to minimize bat mortalities associated with the disease. The spread of WNS and its expected impact on the [Bat] are reasonably foreseeable, and thus the species is likely to become an endangered species within the foreseeable future.

Id. at 18,021.

Nonetheless, FWS concluded "that while the species is likely to become an endangered species within the foreseeable future, it is not . . . currently 'on the brink' of extinction" based on several factors taken together. *Id.* The four factors which, in the aggregate, led FWS to this conclusion are:

> 1. "WNS has not yet been detected throughout the entire range of the species, and will not likely affect the entire range for . . . most likely 8 to 13 years."
>
> 2. "[I]n the area not yet affected by WNS (about 40 percent of the species' total geographic range), the species has not yet suffered declines and appears stable."
>
> 3. "[T]he species still persists in some areas impacted by WNS, thus creating at least some uncertainty as to the timing of the extinction risk posed by WNS. Even in New York, where WNS was first detected in 2007,

> small numbers of [Bats] persist . . . despite the passage of approximately 8 years."
>
> 4. "[C]oarse population estimates where they exist for this species indicate a population of potentially several million [Bats] still on the landscape across the range of the species."

Id. Because FWS determined that the Bat was threatened throughout all of its range, it did not consider whether the Bat was endangered in a significant portion of its range. *Id.* at 18,022 (citing Final Policy on Interpretation of the Phrase "Significant Portion of Its Range" in the Endangered Species Act's Definitions of "Endangered Species" and "Threatened Species," 79 FR 37,577 (July 1, 2014) ("Final SPR Policy")).

II. Standard of Review

A. Review of FWS's Listing Decisions

FWS's listing decisions are subject to review under the APA. *See, e.g., Am. Wildlands v. Kempthorne*, 530 F.3d 991, 997 (D.C. Cir. 2008). Under APA review, federal agency actions are to be held unlawful and set aside where they are "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." 5 U.S.C. § 706(2)(A). To make this finding, a court must determine whether the agency "considered the factors relevant to its decision and articulated a rational connection between the facts found and the choice made." *Keating v. FERC*, 569 F.3d 427, 433 (D.C. Cir. 2009) (citing

Elec. Co. v. Natural Res. Def. Council, Inc., 462 U.S. 87, 105, (1983)).

The standard of review under the APA is a narrow one. *Citizens to Pres. Overton Park v. Volpe*, 401 U.S. 402, 416, (1971). The court is not empowered to substitute its judgment for that of the agency. *Id.* Deference to the agency's judgment is particularly appropriate where the decision at issue "requires a high level of technical expertise." *Marsh v. Or. Natural Res. Council*, 490 U.S. 360, 375–77 (1989); *Ethyl Corp. v. EPA*, 541 F.2d 1, 36 (D.C. Cir. 1976) ("[The court] must look at the decision not as the chemist, biologist or statistician that [it is] qualified neither by training nor experience to be, but as a reviewing court exercising [its] narrowly defined duty of holding agencies to certain minimal standards of rationality."). Specifically, with regard to FWS decisions, this Court has previously recognized that "[g]iven the expertise of the [FWS] in the area of wildlife conservation and management and the deferential standard of review, the Court begins with a strong presumption in favor of upholding decisions of the [FWS]." *Am. Wildlands*, 478 F. Supp. 2d at 96 (citing *Carlton v. Babbitt*, 900 F. Supp. 526, 530 (D.D.C. 1995)).

"If an agency fails to articulate a rational basis for its decision, it is appropriate for a court to remand for reasoned decision-making." *Defenders of Wildlife v. Babbitt*, 958 F. Supp

670, 679 (D.D.C. 1997) (citing *Carlton*, 900 F. Supp. at 533 ("remanding FWS'[s] 12-month finding that the grizzly bear should not be reclassified because the FWS 'failed to sufficiently explain how it exercised its discretion with respect to certain of the statutory listing factors'").

B. Review of FWS's Statutory Interpretations

Here, in addition to challenging FWS's listing decision, plaintiffs also challenge FWS's interpretation of the ESA's statutory language. The framework for reviewing an agency's interpretation of a statute that the agency is charged with administering is set forth in *Chevron, U.S.A., Inc. v. Natural Res. Def. Council, Inc.*, 467 U.S. 837 (1984). The first step in this review process is for the court to determine "whether Congress has directly spoken to the precise question at issue." *Id.* at 842. "If the intent of Congress is clear, that is the end of the matter; for the court, as well as the agency, must give effect to the unambiguously expressed intent of Congress." *Id.* at 842–43. In determining whether the statute unambiguously expresses the intent of Congress, the court should use all the "traditional tools of statutory construction," including looking to the text and structure of the statute, as well as its legislative history, if appropriate. *See id.* at 843 n.9; *see also Bell Atlantic Tel. Co. v. FCC*, 131 F.3d 1044, 1047 (D.C. Cir. 1997). If the court concludes that the statute is either silent or ambiguous with respect to the precise question at issue, the second step of the court's review process is to determine whether the interpretation proffered by the agency is "based on a permissible construction of the statute." *Chevron*, 467 U.S. at 843. The court must defer to agency interpretations that are not "arbitrary, capricious, or manifestly contrary to the statute." *Id.* at 844.

"If the agency enunciates its interpretation through notice-and-comment rule-making or formal adjudication, [courts] give the agency's interpretation *Chevron* deference." *Mount Royal Joint Venture v. Kempthorne*, 477 F.3d 745, 754 (D.C. Cir. 2007). "On the other hand, if the agency enunciates its interpretation through informal action that lacks the force of law, [courts] accept the agency's interpretation only if it is persuasive." *Id.* at 754 (citing *United States v. Mead Corp.*, 533 U.S. 218, 235 (2001); *see also Christensen v. Harris County*, 529 U.S. 576, 587 (2000) (explaining that if *Chevron* deference is not appropriate, courts may still accord an informal agency determination some deference under *Skidmore v. Swift & Co.*, 323 U.S. 134 (1944) and noting that *Skidmore* deference, however, is appropriate "only to the extent that those interpretations have the 'power to persuade'" (quoting *Skidmore*, 323 U.S. at 140)); *Power v. Barnhart*, 292 F.3d 781, 786 (D.C. Cir. 2002). The "power to persuade" is determined by "the thoroughness evident in [the agency's] consideration, the validity of its reasoning, [and] its consistency with earlier pronouncements." *Skidmore*, 323 U.S. at 140. An agency's interpretation "may merit some deference whatever its form, given the specialized experience and broader investigations and information available to the agency, and given the value of uniformity in its administrative and judicial understandings of what a national law requires[.]" *Mead*, 533 U.S. at 234 (internal quotation marks and citations omitted).

III. Analysis

A. The Threatened Determination is Arbitrary and Capricious

1. The "40% of Total Geographic Range" Rationale is not Supported by the Best Available Scientific Data

Plaintiffs ask the Court to remand the threatened listing decision, arguing that the rationales FWS relied on are contradicted by the best available scientific data because: (1) the timeframe for the rangewide spread of WNS does not justify the threatened determination; (2) the "40% of the total geographic range" rationale ignores the fact that the Bat is uncommon to rare in the periphery of its range; (3) to the extent "potentially millions of bats" existed, they were in areas already affected by WNS by April 2015; and (4) there is no credible evidence that "some bats persist" in WNS-infected areas. The Court agrees that the second rationale invoked by FWS is contradicted by the best available scientific data. Since these four rationales are interdependent, 80 Fed. Reg. at 18,021, the Court will remand the listing decision to FWS "for reasoned decision-making." *Defenders of Wildlife*, 958 F. Supp. at 679. The Court does not consider and expresses no opinion regarding plaintiffs' challenges to the other three rationales. *Cf. Friends of Animals v. Ross*, 396 F. Supp. 3d 1, *9 (D.D.C. 2019) (accepting one of six challenges to a listing determination and not considering or expressing a view about the five remaining challenges).

FWS's second rationale for listing the Bat as threatened rather than endangered based on the species' current status is that "in the area not yet affected by WNS (about 40 percent of the species' total geographic range), the species has not yet suffered declines and appears stable." 80 Fed. Reg. at 18,021.

Plaintiffs argue that this characterization is misleading because "the Bat's abundance is not equal over all of its range . . . [and] the more distant portions of the range, where WNS has not yet spread, have *always* had low bat density," Pls.' Partial Mot. for Summ. J. on their Listing Claims ("Pls.' Mot."), ECF No. 52 at 41; and that "[a]t the time of the final rule, those portions of the Bat's range where the species had previously been most abundant had already experienced massive mortality or were on the brink of imminent declines from WNS," *id*. Thus, according to plaintiffs, "the '40 percent of total geographic range' metric is not based on the best available scientific data on the Bat's varying distribution within its range." *Id*. Plaintiffs point out that the proposed and final rules are consistent in that they both state that the pre-WNS populations were concentrated in the northeastern and midwestern ranges, and less dense in the northwestern, western, and midwestern ranges. *Id*. at 42. Plaintiffs conclude that FWS did not make the listing determination based on the best available scientific data, the record does not support this rationale, and therefore FWS arbitrarily and unlawfully relied on this rationale to justify the threatened determination. *Id*. at 44.

Federal defendants respond that its characterization is not misleading because as Plaintiffs acknowledge, "'[t]he proposed and final rules are consistent in stating that the species' pre-WNS populations were concentrated in its northeastern and Midwestern ranges, with much lower population densities in the northwestern, western and extreme southern range.'" Fed. Defs.' Opp'n and Partial Mot. for Summ. J. on the Listing Claims ("Fed. Defs.' Opp'n"), ECF No. 53 at 36 (quoting Pls.' Mot., ECF No. 52 at 42 (comparing 78 Fed. Reg. at 61,051-54 with 80 Fed. Reg. at 17,976)).

Plaintiffs respond that "[i]n relying on this rationale to support [] its threatened determination, FWS arbitrarily ignored": (1) "the explicit findings stated in the final rule that the Bat has always been uncommon to rare in the as-yet-infected areas"; and (2) "evidence . . . that Bats in the far-flung parts of the range might primarily be summer residents, with the core of the species' hibernating entirely in the WNS-infected range." Pls.' Reply, ECF No. 59 at 26. Plaintiffs dispute that the threatened determination was "guided by the best available biology of this species," 80 Fed. Reg. 18,020, because there is no discussion of how the high population densities in the WNS-infected areas and low population the uninfected areas support the determination, Pls.' Reply, ECF No. 59 at 26-27. Plaintiffs conclude that FWS "should provide a rational explanation for why the same data can support two opposing conclusions"—the proposed endangered determination and the final threatened determination. *Id.* at 27.

Plaintiffs also argue that Federal defendants do not explain why FWS disregarded the expert advice "that any Bats in the westward and southern periphery of the species' range are likely primarily summer residents only, and that the core of the species' hibernating distribution was in areas already infected or imminently facing WNS infection." *Id.* at 27-28. On this point, Federal defendants respond that since "Bats are not long-distance migrants," the spread of WNS to currently uninfected areas was unlikely to be hastened by any migratory behavior. Fed. Defs.' Reply, ECF No. 63 at 20-21.

The Court is not persuaded that, as stated by FWS, it "reasonably concluded at the time of the listing determination—when 40 percent of the species' range was WNS-free—that Bats are a threatened species as defined by the ESA." Fed. Defs.' Reply, ECF No. 63 at 18. FWS did acknowledge the disparate population densities between the WNS-infected range and the 40 percent of the range that is WNS-free in its determination. *See supra* Section I.B. In making the threatened determination, FWS specifically relied on the rationale that "in the area not yet affected by WNS (about 40 percent of the species' total geographic range), the species has not yet suffered declines and appears stable." 80 Fed. Reg. at 18,021. But FWS does not provide a rational explanation for why the significant disparity in population density between the 60 percent of the range that is WNS-infected and the 40 percent that is not supports a threatened rather than endangered determination. Such an explanation is necessary in view of the significant population disparities between the WNS-infected areas and those areas not yet infected, *id.* at 17,976-83; the evidence that WNS "is responsible for unprecedented mortality" and "has spread rapidly," resulting in population declines of the Bat of 96 to 99%," *id.* at 17,994, 18,012; and that there are "no known examples of [Bats] that have survived" a WNS infection, NLEB Listing 03573. Accordingly, FWS failed to "articulate a rational connection between the facts found and the choice made." *Keating*, 569 F.3d at 433.

2. FWS Did Not Consider the Cumulative Effects of Threats in Explaining the Basis for the Listing Determination

A listing determination is made on the basis of one or more of five statutorily prescribed factors: "(A) the present or threatened destruction, modification, or curtailment of a species' habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or manmade factors affecting a species' continued existence." 16 U.S.C § 1533(a)(1)(A)-(E); *see also* 50 C.F.R. § 424.11(c). The agency must list a species as long as "any one or a combination" of these factors demonstrates that the species is threatened or endangered. 50 C.F.R. § 424.11(c). Accordingly, in making the listing determination, the ESA requires FWS to consider each of the listing factors both individually and in combination.

FWS focused on Factors A, C, and E. With regard to Factor A, FWS concluded that "[c]urrent and future forest conversion may have negative additive impacts where the species has been impacted by WNS." 80 Fed. Reg. at 17,991. FWS also stated that "in areas with WNS, we believe [the Bats] are likely less resilient to stressors and maternity colonies are smaller. Given the low inherent reproductive potential of [the Bat] (max of one pup per female), death of adult females or pups or both during tree felling reduces the long-term viability of those colonies." *Id.* at 17,993. FWS concluded that "[w]hile, these activities alone were unlikely to have significant, population-level effects, there is now likely a cumulative effect on the species in portions of range that have been impacted by WNS." *Id.*

With regard to Factor E, FWS concluded that "[t]here is currently no evidence that these natural or manmade factors would have significant population-level effects on the northern long-eared bat when considered alone. However, these factors may have a cumulative effect on this species when considered in concert with WNS, as this disease has led to dramatic northern long-eared bat population declines." *Id.* at 18,005-06.

FWS analyzed the cumulative effects as follows: "although the effects on the northern long-eared bat from Factors A, [D], and E, individually or in combination, do not have significant effects on the species, when combined with the significant population reductions due to white-nose syndrome (Factor C), they may have a cumulative effect on this species at a local population scale." *Id.* at 18,006.

Plaintiffs argue—and the Court agrees—that despite this analysis, FWS disregarded the cumulative effects that factors other than WNS may have on the species when explaining the rationale for the threatened determination. The Court does not dispute that, as Federal defendants point out, "FWS considered the impacts of the threats to the species in almost 20 pages of analysis." Fed. Defs.' Reply, ECF No. 63 at 28; *see also* Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 30. However, in explaining the rationale for the listing determination, FWS relied solely on WNS, and failed to take into consideration the other factors and the cumulative effect of the other factors that FWS itself analyzed. The listing determination states:

> There are several factors that affect the northern long-eared bat; however, no other threat is as severe and immediate to the species persistence as WNS (Factor C). This disease is the prevailing threat to the species, and there is currently no known cure. While we have received some information concerning localized impacts or concerns (unrelated to WNS) regarding the status of the northern long-eared bat, it is likely true that many North American wildlife species have suffered some localized, isolated impacts in the face of human population growth and the continuing development of the continent. Despite this, based upon available evidence, the species as a whole appears to have been doing well prior to WNS.

Id. at 18,021.

With this rationale, however, FWS ignored its own analysis. Specifically, with regard to Factor A, FWS concluded that "[w]hile, these activities alone were unlikely to have significant, population-level effects, there is now likely a cumulative effect on the species in portions of range that have been impacted by WNS." *Id.* at 17,993. And with regard to Factor E, FWS concluded that "[t]here is currently no evidence that these natural or manmade factors would have significant population-level effects on the northern long-eared bat when considered alone. However, these factors may have a cumulative effect on this species when considered in concert with WNS, as this disease has led to dramatic northern long-eared bat population declines." *Id.* at 18,005-06. Defendant-Intervenors argue that FWS's analysis is adequate because the "observed population trends" necessarily include any cumulative impacts. Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 30. But as plaintiffs point out, Pls.' Reply, ECF No. 59 at 32, this explanation was not relied on by FWS and so is irrelevant. *Camp v. Pitts*, 411 U.S. 138, 142 (1973) ("the focal point for judicial review [of agency action] should be the administrative record already in existence, not some new record made initially in the reviewing court").

Because FWS disregarded the cumulative effects that factors other than WNS may have on the species when explaining the rationale for the threatened determination, it failed to articulate a rational connection between its own analysis and its determination. Accordingly, the listing determination is arbitrary and capricious. *WildEarth Guardians v. Salazar,* 741 F. Supp. 2d 89, 103 (D.D.C. 2010) (finding that the Service's failure to consider cumulative impact of listing factors rendered the agency's decision not to reclassify the Utah prairie dog arbitrary and capricious).

B. FWS's Interpretation of "In Danger of Extinction" Articulated in the Polar Bear Memo is Persuasive

Plaintiffs argue that the threatened determination "is arbitrary and capricious because it improperly pairs an unreasonably narrow interpretation of 'in danger of extinction' and an amorphous, overly broad conception of the 'foreseeable future' that fails to articulate any coherent rationale on the Bat's 'future conservation status' in the face of WNS' inexorable spread." Pls.' Mot., ECF No. 52 at 35. Federal defendants respond that its interpretation of "in danger of extinction" is entitled to deference. Fed. Defs.' Opp'n, ECF No. 53 at 30-31. Defendant-Intervenors argue that FWS's interpretation of "in danger of extinction" cannot be "[a] one-size-fits-all interpretation," noting that nonetheless, FWS "has identified four typical fact patterns meeting the 'endangered' standard of a species 'on the brink of extinction in the wild.'" Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 14.

As discussed *supra* Section I.B., the listing determination relied on FWS's interpretation of "in danger of extinction" to be "on the brink of extinction in the wild" as articulated in the Polar Bear Memo. 80 Fed. Reg. at 18,020. As an initial matter, the parties dispute whether this interpretation is entitled to *Chevron* deference. To analyze this issue, it is necessary to explain the genesis and purpose of the Polar Bear Memo. The Polar Bear Memo was drafted in response to this Court's Memorandum Opinion in *In re Polar Bear Endangered Species Act Listing and 4(d) Rule Litigation ("Polar Bear I")*, 748 F. Supp. 2d 19 (D.D.C. 2010) (Sullivan, J.), in which this Court found that the term "endangered species" is ambiguous and "remand[ed] the [Polar Bear] Listing Rule to the agency for the limited purpose of providing additional explanation for the legal basis of its listing determination, and for such further action as it may wish to take in light of the Court's finding that the definition of an 'endangered species' under the ESA is ambiguous." *Polar Bear I* at 29-30.

In response, the Federal defendants submitted FWS's Polar Bear Memo to the Court. The agency stated that its submission was a "supplemental explanation of the meaning of the statutory phrase 'in danger of extinction' as applied in the Polar Bear Listing Rule," and explained the scope of the memo:

> As a supplemental explanation of the listing decision that was made previously for the Court to consider along with the administrative record in evaluating the Listing Rule, this explanation does not set forth a new statement of agency policy, nor is it a "rule" as defined in the Administrative Procedure Act. Indeed, given the narrow scope of the remand, the Court determined that notice-and-comment procedures were not required. As the Court explained in ordering this remand, it was not "require[ing] the agency to adopt independent, broad-based criteria for defining the statutory term "in danger of extinction." Mem. Op. at 24 n.18. Thus, the explanation set forth in this memorandum does not represent a new interpretation of the statute and is not a prospective statement of agency policy. Furthermore, consistent with the Court's remand order, the Service did not conduct additional fact-finding in the development of this supplemental explanation. The interpretation used in the Listing Rule is supported by the administrative record already lodged with the Court, as demonstrated more fully in this memorandum.

NLEB Listing 23,067-68.

Plaintiffs argue that FWS's "interpretation of 'in danger of extinction' to mean 'currently on the brink of extinction in the wild' deserves no deference because it . . . has never been appropriately promulgated through the rulemaking requirements of section 4(h) of the ESA." Pls.' Mot., ECF No. 52 at 35.[3] Federal

[3] Plaintiffs also argue that the Service's interpretation of 'in danger of extinction' deserves no deference because it represents a litigation position. Pls.' Mot., ECF No. 52 at 35. Federal defendants respond—and the Court agrees—that just because the memo was created in response to the Court's order, that does not make the long-standing interpretations explained

defendants respond that the ESA "does not require FWS to provide the public with notice and an opportunity to comment on FWS's synthesis of how the agency has historically interpreted 'in danger of extinction' that is reflected in the Polar Bear Memo," Fed. Defs.' Opp'n, ECF No. 53 at 29-30, and that "because FWS applies its interpretation of 'in danger of extinction' on a species-by-species basis, the public has in fact had notice and numerous opportunities to comment on FWS's application of its interpretation," *id.* at 30. Federal defendants further argue that the agency's definition of "in danger of extinction" as articulated in the Polar Bear Memo is entitled to deference under *Chevron* for two reasons: (1) because FWS is charged with administering the ESA, the Court must apply the *Chevron* framework to FWS's interpretation of the phrase "in danger of extinction";[4] and (2) this Court has already determined that the phrase "in danger of extinction" is ambiguous and upheld the agency's interpretation of the phrase at *Chevron* step two in *In re Polar Bear Endangered Species Act Listing and 4(d) Rule*

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in the memo to be a litigation position. Fed. Defs.' Opp'n, ECF No. 53 at 28-29. The agency clearly states that the memo explains the consistent application of the phrase over the agency's 37-plus years of administering the ESA rather than being a "litigation position." NLEB Listing 23,084.

[4] In the alternative, Federal defendants argue that FWS's interpretation of "in danger of extinction" is entitled to *Skidmore* deference. Fed. Defs.' Reply, ECF No. 63 at 13 n.1.

Litigation ("Polar Bear II"), 794 F. Supp. 2d 65, 90 (D.D.C. 2010) (Sullivan, J.). *Id.* at 30-31.

The Court disagrees with Federal defendants that *Chevron* is the appropriate standard for determining the level of deference to accord FWS's interpretation of "in danger of extinction" as articulated in the Polar Bear Memo. Rather, given the context, *Skidmore* is the appropriate standard. There is no dispute that FWS's interpretation of "in danger of extinction" set forth in the Polar Bear Memo did not undergo notice and comment. Furthermore, in the Polar Bear Memo, the agency specifically stated that the Memo "does not set forth a new statement of agency policy, nor is it a 'rule' as defined in the Administrative Procedure Act." NLEB Listing 23,067. The agency also stated that "the explanation set forth in this memorandum does not represent a new interpretation of the statute and is not a prospective statement of agency policy." *Id.* at 23,068. Because "the agency [has] enunciate[d] its interpretation through informal action that lacks the force of law, [the Court will] accept the agency's interpretation only if it is persuasive." *Mount Royal Joint Venture*, 477 F.3d at 754. In making this determination, "[t]he weight of [an agency interpretation] will depend upon the thoroughness evident in its consideration, the validity of its reasoning, its consistency with earlier and later pronouncements, and all those factors which give it power to persuade, if lacking power to control." *Skidmore*, 323 U.S. at 140.

Plaintiffs argue that FWS's interpretation of "in danger of extinction" set forth in the Polar Bear Memo is "unlawfully stringent." The Court disagrees and finds FWS's interpretation of "in danger of extinction," as a general matter, to mean "on the brink of extinction in the wild" to be persuasive. As explained in the Polar Bear Memo, the agency considered the legislative history of the ESA in articulating its "general understanding" of the phrase "in danger of extinction." NLEB Listing 23,069. Senator Tunney, as designee of the majority leader, explained that "[t]he goal of the [ESA] is to conserve, protect, restore, and propagate species of fish and wildlife, that are in imminent danger of extinction or are likely to become endangered within the foreseeable future." 119 CONG. REC. 25,668 (daily ed. July 24, 1973) (statement of Sen. Tunney). He went on to state that the ESA provides a basis for listing species which "are likely in the foreseeable future to become extinct, as well as those which are presently threatened with extinction." *Id.* He also stated that Congress intended "maximum protection" for endangered species, which are those that are "on the brink of extinction." *Id.* at 25,669. FWS's interpretation of the phrase, as a general matter, is therefore consistent with congressional intent. Accordingly, FWS's interpretation of "in danger of extinction" to mean "on the brink of extinction in the wild" is persuasive. *Skidmore*, 323 U.S. at 140.

The Court, however, rejects Federal defendants' argument that because this Court has already upheld FWS's interpretation of "in danger of extinction" as articulated in the Polar Bear Memo—as a general matter—at *Chevron* step two in *Polar Bear II*, it must do so here as well. The Court's ruling in *Polar Bear II* was limited to the application of the interpretation of the phrase to the polar bear: "the Court concludes that the [Polar Bear Memo] sufficiently demonstrates that the Service's definition of an endangered species, *as applied to the polar bear*, represents a permissible construction of the ESA and must be upheld under step two of the *Chevron* framework." 794 F. Supp. 2d at 90 (emphasis added).

Plaintiffs also argue that the Listing Rule's reliance on the Polar Bear Memo was unjustified because that memo did not go through notice and comment as required by 16 U.S.C. § 1533(h) (providing that the "Secretary shall establish, and publish in the Federal Register, agency guidelines to insure that the purposes of this section are achieved efficiently and effectively."). Pls.' Mot., ECF No. 52 at 35 n.10. The Court is persuaded by Federal defendants' argument that 16 U.S.C. § 1533(h) does not require FWS "to provide the public with notice and an opportunity to comment on FWS's synthesis of how the agency has historically interpreted 'in danger of extinction' that is reflected in the Polar Bear Memo." Fed. Defs.' Opp'n, ECF No. 53 at 29. But Federal defendants concede—as they must—that each time FWS applies its interpretation of 'in danger of extinction' to a specific listing determination, it must provide notice and opportunity to comment. As stated by Federal defendants, "because FWS applies its interpretation of 'in danger of extinction' on a species-by-species basis, the public has in fact notice and opportunities to comment on FWS's application of its interpretation." *Id.* at 30. Here, however, and as explained *infra* Section III.C., FWS failed to provide public notice and an opportunity to comment on its interpretation of "in danger of extinction" as applied to the Bat.

Plaintiffs point out in their reply brief that Federal defendants do not respond to plaintiffs' argument "that the determination also unlawfully failed to define rationally the Bat's 'foreseeable future,'" Pls.' Reply, ECF No. 59 at 18, and Federal defendants do not dispute this in their own reply brief, *See generally* Fed. Defs.' Reply, ECF No. 63. Accordingly, Federal defendants have conceded this argument. *See Hopkins v. Women's Div., Gen. Bd. of Global Ministries*, 284 F. Supp. 2d 15, 25 (D.D.C. 2003) ("It is well understood in this Circuit that when a plaintiff files an opposition to a dispositive motion and addresses only certain arguments raised by the defendant, a court may treat those arguments that the plaintiff failed to address as conceded.”), *aff’d*, 98 Fed. App’x 8 (D.C. Cir. 2004). Defendant-Intervenors do respond, arguing that FWS “appropriately focused its foreseeability analysis on the impact of [WNS]—how quickly it would spread, the rate of impact within an affected community, and the susceptibility and potential for resistance to the disease within the population,” Def.-Intervenors’ Br. in Opp’n, ECF No. 56 at 24 (internal citations omitted), as well as the Bat’s life cycle relevant to the impact of WNS, *id*. Plaintiffs argue—and the Court agrees—that FWS policy requires FWS to “look not only at the foreseeability of threats, but also at the foreseeability of the impact of the threats on the species,” Pls.’ Reply, ECF No. 59 at 18 (quoting M-Opinion at 10).

C. The Threatened Determination Violated ESA and APA Notice and Comment Requirements

Plaintiffs also challenge the threatened determination on procedural grounds, arguing that it was “the product of a procedurally flawed process that violated the ESA’s and the APA’s requirements.” Pls.’ Mot., ECF No. 52 at 53. Plaintiffs first argue that the record demonstrates that FWS decided to list the Bat as threatened rather than endangered before the close of the November 18, 2014 to December 18, 2014 comment period.[5] *Id.* In support of this argument, plaintiffs point to the two-day "NLEB Decision Maker Meeting," which began on December 16, 2014, and at which they claim the decision to list the Bat as threatened was made. LAR 58,577-93; NLEB Listing 03571-80. Plaintiffs also point to an October 6, 2014 email in which FWS staff raised a concern regarding how to "balance . . . being predecisional vs the appearance of a forgone decision," NLEB Listing 30,409; and to a January 5, 2015 email stating "We'd like to make sure everyone knows about the preliminary decision to list as threatened," NLEB Listing 43,029. Finally, plaintiffs note that FWS staff was in the process of reviewing existing comments and gathering more comments following the December 16, 2014 "NLEB Decision Maker Meeting." Pls.' Mot., ECF No. 52 at 54 (citing LAR 43080) (January 2015 spreadsheet addressing comments from the comment period Nov. 18-Dec. 18, 2014). Plaintiffs point out in their reply brief that Federal defendants do not respond to plaintiffs' characterization of these procedural failures. Pls.' Reply, ECF No. 59 at 33-34; *see also* Fed. Defs.' Opp'n, ECF No. 53 at 67-69. Nor do Federal defendants, in their own

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[5] Following the publication of the proposed rule on October 2, 2013, FWS extended the public comment period on the proposed endangered determination four times. *See* 78 Fed. Reg. 72,058-01 (Dec. 2, 2013) (comment period to close January 2, 2014); 79 Fed. Reg. 36,698-01 (June 30, 2014) (comment period to close August 29, 2014); 79 Fed. Reg. 68,657-02 (Nov. 18, 2014) (comment period to close December 18, 2014); 80 Fed. Reg. 2371-01 (Jan. 16, 2015) (comment period to close March 17, 2015).

reply brief, respond to plaintiffs having pointed out this failure to respond. *See* Fed. Defs.' Reply, ECF No. 63 at 47-49. Since Federal defendants did not respond to this argument, they have conceded it. *See Hopkins*, 284 F. Supp. 2d at 25 ("It is well understood in this Circuit that when a plaintiff files an opposition to a dispositive motion and addresses only certain arguments raised by the defendant, a court may treat those arguments that the plaintiff failed to address as conceded."), *aff'd*, 98 Fed. App'x 8 (D.C. Cir. 2004).[6]

"An agency is required to provide a meaningful opportunity for comments, which means that the agency's mind must be open to considering them." *Grand Canyon Air Tour Coal. v. FAA*, 154 F.3d 455, 467-68 (D.C. Cir. 1998). "Consideration of comments as a matter of grace is not enough" where the record "suggest[s] too closed a mind" on the part of the agency. *McLouth Steel Products Corp. v. Thomas*, 838 F.2d 1317, 1323 (D.C. Cir. 1988). Here, Federal defendants have conceded that the decision to list the Bat as threatened was made prior to the close of the comment period ending December 18, 2014, and prior to the opening of the final comment period on January 16, 2015. Despite this, in the January 16, 2015 proposed rule and reopening of the comment

[6] Defendant-intervenors do dispute plaintiffs' characterization, Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 9-13, but the Court finds it to be significant that Federal defendants, those with first-hand knowledge of the process, do not.

period, FWS stated that "[it] has not yet made a final listing decision regarding the status of the northern long-eared bat (e.g., not warranted, threatened, or endangered); however, in our review of public comments we did determine that if threatened status is warranted, a species-specific rule under section 4(d) of the Act rule may be advisable." 80 Fed. Reg. 2372. Accordingly, the record here "suggest[s] too closed a mind" on the part of the agency, *McLouth Steel Products Corp.*, 838 F.2d at 1323, to provide plaintiffs a "meaningful opportunity [to] comment[]," *Grand Canyon Air Tour Coal.*, 154 F.3d at 467-68.

Plaintiffs next argue that because FWS relied on the Polar Bear Memo in the Listing Rule, but not in the Proposed Rule, the Listing Rule was not a logical outgrowth of the Proposed Rule. Pls.' Mot., ECF No. 52 at 55-56. Federal defendants and defendant-intervenors respond that the decision in the Listing Rule was a logical outgrowth because it is one of "the three possible scenarios for a species' categorization at any given time" and point out that plaintiffs had numerous opportunities to comment on the Proposed Rule. Fed. Defs.' Opp'n, ECF No. 53 at 67-69; Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 13-15; Fed. Defs.' Reply, ECF No. 63 at 46-49. Federal defendants also respond that, as discussed above, FWS is not required to provide notice and opportunity to comment on the Polar Bear Memo and that because it applies its interpretation of "in danger of extinction" as articulated in the Polar Bear Memo on a species-by-species basis, there have been "numerous opportunities to comment on FWS'[s] application of its interpretation, including as to the Bat." Fed. Defs.' Reply, ECF No. 63 at 47; *see also* Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 13-15.

The Court of Appeals for the District of Columbia Circuit ("D.C. Circuit") has established the following test to determine whether a final rule is a "logical outgrowth" of a proposed rule:

> To satisfy the APA's notice requirement, the NPRM and the final rule need not be identical: "[a]n agency's final rule need only be a 'logical outgrowth' of its notice." *Covad Commc'ns Co. v. FCC,* 450 F.3d 528, 548 (D.C. Cir. 2006). A final rule qualifies as a logical outgrowth "if interested parties 'should have anticipated' that the change was possible, and thus reasonably should have filed their comments on the subject during the notice-and-comment period." *Ne. Md. Waste Disposal Auth. v. EPA,* 358 F.3d 936, 952 (D.C. Cir. 2004) (citations omitted). By contrast, a final rule fails the logical outgrowth test and thus violates the APA's notice requirement where "interested parties would have had to 'divine [the agency's] unspoken thoughts,' because the final rule was surprisingly distant from the proposed rule." *Int'l Union, United Mine Workers of Am. v. Mine Safety & Health Admin.,* 407 F.3d 1250, 1259–60 (D.C. Cir. 2005) (internal citations omitted).

CSX Transp., Inc. v. Surface Transp. Bd., 584 F.3d 1076, 1079-80 (D.C. Cir. 2009).

Although Federal defendants assert that plaintiffs and the public had the opportunity to comment on FWS's application of its interpretation of "in danger of extinction" articulated in the Polar Bear Memo as applied to the Bat, the record does not support that assertion. As an initial matter, Federal defendants provide no citation to the record to support this statement, instead citing their own opposition and partial motion for summary judgment's discussion of the deference due the Polar Bear Memo. Fed. Defs.' Reply, ECF No. 63 at 47 (citing Fed. Defs.' Opp'n, ECF No. 53 at 30). Furthermore, the proposed rule contains no reference to the Polar Bear Memo, nor does it state that the agency intends to apply its interpretation of "in danger of extinction" to be "on the brink of extinction in the wild" to the Bat. *See generally* 78 Fed. Reg. 61,046-01. Neither do any of the four extensions of comment period or reopening of the comment period for the proposed rule provide such notice. *See generally* 78 Fed. Reg. 72,058-01 (Dec. 2, 2013); 79 Fed. Reg. 36,698-01 (June 30, 2014); 79 Fed. Reg. 68,657-02 (Nov. 18, 2014); 80 Fed. Reg. 2371-01 (Jan. 16, 2015). Rather, the first and only time FWS applied its interpretation of "in danger of extinction" as articulated in the Polar Bear Memo to the Bat was in the Listing Rule. 80 Fed. Reg. 17,974-01, 18,020-21 (Apr. 2, 2015). Federal defendants represented to this Court that the public has had opportunities to comment both specifically as to the Bat, Fed. Defs.' Reply, ECF No. 63 at 47 ("because FWS applies its interpretation of 'in danger of extinction' on a species-by-species basis, the public has in fact had notice and numerous opportunities to comment on FWS's application of its interpretation, including as to the Bat."), and as a general matter, Fed. Defs.' Opp'n, ECF No. 53 at 30 ("because FWS applies its interpretation of 'in danger of extinction' on a species-by-species basis, the public has in fact had notice and numerous opportunities to comment on FWS's application of its interpretation"). However, the record here demonstrates that FWS did not provide plaintiffs nor the public with an opportunity to comment on FWS's application of its interpretation of "in danger of extinction" as applied to the Bat. For this reason alone, the final rule is not a logical outgrowth of the notice in the proposed rule. The Court also notes that in none of the four extensions and reopenings of the comment period over more than a year, did FWS put the public on notice of how it was applying is interpretation of "in danger of extinction" specifically to the Bat.

Because the Court agrees that the threatened determination was procedurally flawed on these two grounds, the Court need not reach plaintiffs' argument that the four rationales supporting the threatened determination were "entirely new" and consequently, they did not have the opportunity to make the arguments to FWS that they have made to this Court. Pls.' Mot., ECF No. 52 at 55. As to plaintiffs' argument that "FWS relied on a key change to the Final SPR Policy to justify its decision not to analyze whether the Bat is endangered in a significant portion of its range," a change that plaintiffs and the public have never had the opportunity to comment on, Pls.' Mot., ECF No. 52 at 56, as explained below, the Court agrees that the Final SPR Policy was procedurally flawed. *See infra* Section III.B.4.d.

D. The Challenged Aspect of the Manner in Which the Final SPR Policy is Applied is Unlawful[7]

The ESA defines an "endangered species" in relevant part as "any species which is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). The phrase "significant portion of its range" is not defined in the ESA, and courts faced with the question have concluded that the phrase is ambiguous for *Chevron* purposes. *Humane Soc'y of the United States v. Jewell*, 76 F. Supp. 3d 69, 128 (D.D.C. 2014).

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[7] Plaintiffs allege a number of procedural irregularities regarding the decision-making process that resulted in the Listing Rule. Pls.' Mot., ECF No. 52 at 54. Defendant-Intervenors respond that the agency's decision-making process is "entitled to a presumption of regularity and good faith." Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 15-16 (internal quotations and citation omitted). Given that the Court has determined that the Listing Rule is unlawful on various grounds, the Court need not reach whether or not there were procedural irregularities.

Accordingly, FWS "has a wide degree of discretion in determining whether the [species] is in danger 'throughout a significant portion of its range.'" *W. Watersheds Project v. Ashe*, 948 F. Supp. 2d. 1166, 1184 (D. Idaho 2013) (citation omitted).

In 2014, FWS and the National Marine Fisheries Service (collectively, "the Services") promulgated the Final SPR Policy, which both interprets the phrase "significant portion of its range" and explains how the Services will implement their interpretation of the phrase. *See* 79 Fed. Reg. 37,578; 37,579. The Final SPR Policy defines "significant portion of its range" as follows: "a portion of the range of a species is 'significant' if the species is not currently endangered or threatened throughout all of its range, but the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range." *Id.* at 37,579. The Services explained that the following procedure would be used to implement the policy:

> The first step in our analysis of the status of a species is to determine its status throughout all of its range. If we determine that the species is in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range, we will list the species as endangered (or threatened) and no SPR analysis will be required. If the species is neither endangered nor threatened

> throughout all of its range, we will determine whether the species is endangered or threatened throughout a significant portion of its range. If it is, we will list the species as endangered or threatened, respectively; if it is not, we will conclude that listing the species is not warranted.

Id. at 37,585. Plaintiffs challenge one aspect of this procedure: that the Services will not analyze whether a species is endangered in a significant portion of its range if the Services have determined that the species is threatened throughout all of its range. Plaintiffs argue that this procedure is "facially irreconcilable with the ESA's unambiguous command to list any species as endangered if it is 'in danger of extinction . . . [in] a significant portion of its range.'" Pls.' Reply, ECF No. 59 at 36-37.

1. Plaintiffs' Challenges to the Final SPR Policy are Properly Analyzed Under the *Chevron* Standard

Plaintiffs challenge this aspect of the policy as "facially unlawful. . . contrary to the ESA's language and goals and fails at [*Chevron*] step one." Pls.' Mot., ECF No. 52 at 57. As an initial matter, the parties dispute the appropriate test for plaintiffs' facial challenge to the Final SPR Policy. Federal defendants argue that since plaintiffs have brought a facial challenge, they have the burden of establishing that "no set of circumstances exists" under which the policy would be valid. Fed. Defs.' Opp'n, ECF No. 53 at 42 (citing *United States v.*

Salerno, 481 U.S. 739, 745 (1987); *Reno v. Flores*, 507 U.S. 292, 301 (1993)). The Court is not persuaded that the "no set of circumstances" test applies to plaintiffs' challenge, however, because plaintiffs do not bring a pre-application challenge to the policy.[8] Other courts in this District have acknowledged that there is some confusion in this Circuit and others regarding when a court should apply the "no set of circumstances" test articulated in *Salerno* and *Flores* rather than *Chevron. See Chamber of Commerce of the United States of America v. Nat'l Labor Relations Bd.*, 118 F. Supp. 3d, 171, 184-85 & n.8 (D.D.C. 2015) (applying the "no set of circumstances" test to a "'pre-implementation challenge' to the discretionary aspects of [a] Final Rule" based on "an agency's purely legal interpretation of a statute" and acknowledging *Am. Petroleum Inst. v. Johnson*, 541 F. Supp. 2d 165, 188 (D.D.C. 2008) ("noting that the *Chevron* approach 'seem[ed] especially sound,' but deciding case on procedural grounds under the APA") and *Mineral Policy Ctr. v. Norton*, 292 F. Supp. 2d 30, 38–40 (D.D.C. 2003) ("noting that 'confusion in this Circuit remains' regarding the application of the *Flores* test to facial challenges to agency regulations, and analyzing the challenge in that case under *Chevron*")); *see also*

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[8] Because the Court has determined that the "no set of circumstances" test does not apply, the Court need not consider whether or not the Final SPR Policy satisfies the test.

Ctr. for Biological Diversity v. Jewell, 248 F. Supp. 3d 946, 955 n.9 (D. Ariz. 2017) (noting that "[t]he Court is not convinced that the 'no set of circumstances' test is applicable here . . .").

Here, however, the Final SPR Policy has been in effect since 2014, has been applied, and aspects of it have been vacated both with and without geographical limitation. *See infra* Section III.D.2. This situation is therefore distinguishable from that in *Flores* where the Supreme Court applied the "no set of circumstances" test to

> a facial challenge to INS regulation 242.24. Respondents do not challenge its application in a particular instance; it had not yet been applied in a particular instance—because it was not yet in existence—when their suit was brought ... and it had been in effect only a week when the District Court issued the judgment invalidating it. We have before us no findings of fact, indeed no record, concerning the INS's interpretation of the regulation or the history of its enforcement. We have only the regulation itself and the statement of basis and purpose that accompanied its promulgation.

Flores, 507 U.S. at 300-01. Nor is this situation similar to that in *Cellco P'ship v. FCC*, 700 F.3d 534 (D.C. Cir. 2012), where the D.C. Circuit applied the "no set of circumstances" test to decide a facial challenge to an agency rule. Although the court did not explicitly state that it was applying that test because it was considering a pre-implementation challenge to the rule, the context indicates that it was. The challenged rule was adopted on April 7, 2011, *Cellco P'ship*, 700 F.3d at 540, 549; and challenged on May 13, 2011, *see generally* Court of Appeals Docket # 11-1135, a few weeks before the rule became effective on June 6, 2011, 76 Fed. Reg. 26,199.

Furthermore, plaintiffs do not challenge a "discretionary aspect" of the rule, *see Chamber of Commerce*, 118 F. Supp. 3d at 184-85, but rather an aspect of the policy over which it has no discretion, specifically, "[i]f we determine that the species is in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range, we will list the species as endangered (or threatened) and no SPR analysis will be required." 79 Fed. Reg. at 37,585. And as plaintiffs point out, "FWS has already applied the Policy to foreclose all consideration of whether the Bat is endangered in any significant portion of its range after it first determined that the species is threatened throughout its range." Pls.' Reply, ECF No. 59 at 38 (citing 80 Fed. Reg. at 18,022; Pls.' Mot., ECF No. 52 at 67-69). Plaintiffs also note that the Services applied the policy in a similar manner in at least 13 other listing decisions. *Id*. Accordingly, the Court the will analyze plaintiffs' challenge under the *Chevron* standard.

2. The Precise Question at Issue is Whether the Challenged Aspect of the Procedures Implementing the Final SPR Policy Is Consistent With the Plain Language of the ESA

Applying the *Chevron* standard, the parties dispute what exactly is "the precise question at issue." *Chevron*, 467 U.S. at 842. Plaintiffs argue that the Final SPR Policy fails at *Chevron* step one because there is no ambiguity in the ESA regarding the two circumstances under which a species must be listed as endangered. Specifically, a species must be considered endangered (1) when it is "in danger of extinction throughout all . . . of its range"; or (2) when it is "in danger of extinction throughout . . . a significant portion of its range." 16 U.S.C. § 1532(6). Plaintiffs argue that the Final SPR Policy is inconsistent with this statutory language because it "renders the entire clause 'or a significant portion of its range' in the definition of an 'endangered species' completely superfluous." Pls.' Mot., ECF No. 52 at 57, 59.

Federal defendants argue that the Final SPR Policy is properly analyzed under *Chevron* step two rather than step one because "the specific issue addressed by the" policy is how FWS should interpret "significant portion of its range" and there is no dispute that the phrase "significant portion of its range" is ambiguous for *Chevron* purposes. Fed. Defs.' Opp'n, ECF No. 53 at 45-48. Plaintiffs disagree, responding that "[t]he issue presented by [p]laintiffs' claim is not whether the phrase 'significant portion of its range' is ambiguous . . . [but] whether the Service must consider a species' status in a 'significant portion of its range'—however defined—*at all*, in situations where that species is also threatened throughout its range." Pls.' Reply, ECF No. 59 at 43.

The Court is persuaded that the precise question at issue is whether this aspect of the procedures implementing the Final SPR Policy is consistent with the plain language of the ESA. Plaintiffs do not challenge the Services' interpretation of what "significant portion of its range" means. If they had, plaintiffs' challenge would arguably be moot because the Final SPR Policy's definition of "significant" in "significant portion of its range" has been deemed inconsistent with the ESA and has been vacated nationwide. *Friends of Animals*, 396 F. Supp. 3d at *10 (citing *Desert Survivors v. United States Dep't of Interior*, 321 F. Supp. 3d. 1011 (N.D. Cal. 2018) and *Desert Survivors v. United States Dep't of Interior*, 336 F. Supp. 3d 1131 (N.D. Cal. 2018)). Moreover, Federal defendants assert that the fact that its interpretation of "significant portion of its range" has been vacated has no impact on this case. *See* Fed. Defs.' Resp. to Notice of Suppl. Auth., ECF No. 77 at 2. Specifically, Federal defendants state that "[p]laintiffs do not challenge the Final SPR Policy's definition of 'significant' or determinations that relied on that definition. . . . Instead, [p]laintiffs challenge the first part of the Final SPR Policy, which says that if [FWS] has already determined that the species is threatened or endangered throughout all of its range, the agency will not analyze whether the species is also threatened or endangered in a significant portion of its range." *Id.* at 3. Furthermore, the procedures implementing the Final SPR Policy are significantly broader than the meaning of the phrase "significant portion of its range." *See generally* Final SPR Policy. Accordingly, the Court will analyze the challenged procedure implementing the Final SPR Policy at *Chevron* step one.

3. The Challenged Aspect of the Final SPR Policy Fails at *Chevron* Step One

The parties agree that the ESA sets forth four separate bases for listing a species as endangered or threatened: (1) the species is "in danger of extinction throughout all of its range"; (2) the species is "in danger of extinction throughout . . . a significant portion of its range"; (3) the species "is likely to become an endangered species within the foreseeable future throughout all . . . of its range; and (4) the species "is likely to become an endangered species within the foreseeable future throughout . . . a significant portion of its range." 16 U.S.C. § 1532(6), (20). The Final SPR policy acknowledges these four independent bases for listing a species, 79 Fed. Reg. 37,582, but in implementing the policy, FWS states that "[i]f we determine that the species is in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range, we will list the species as endangered (or threatened) and no SPR analysis will be required." 79 Fed. Reg. at 37,585. As a result, if FWS determines that a species is threatened throughout all of its range, it will not determine whether the species is endangered in a significant portion of its range. This is precisely what occurred with the Bat.

"In ascertaining the plain meaning of the statute, the court must look to the particular statutory language at issue, as well as the language and design of the statute as a whole." *K Mart Corp. v. Cartier*, 486 U.S. 281, 291 (1988). The ESA defines an "endangered species," in relevant part, as "any species which is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). The ESA requires FWS to determine whether a species is endangered, and if it is, to list it as such. 16 U.S.C. § 1533(a). And if a species is listed as endangered, it is entitled to greater legal protections than a species that is listed as threatened. 16 U.S.C. § 1538(a)(1); *see also Defenders of Wildlife v. Norton*, 239 F. Supp. 2d 9, 13 (D.D.C. 2001), *vacated in part on other grounds*, 89 F. App'x 273 (D.C. Cir. 2004) ("Endangered species are entitled to greater legal protection under the ESA than threatened species.”).

The plain language of the statute unambiguously requires FWS to determine whether a species should be listed as endangered by determining whether it is: (1) “in danger of extinction throughout all of its range”; or (2) “in danger of extinction throughout . . . a significant portion of its range.” 16 U.S.C. § 1532(6); *see also United States v. Woods*, 571 U.S. 31, 45 (2013) (when Congress uses “or” in a statute, “its ordinary use is almost always disjunctive, that is, the words it connects are to be given separate meanings”) (internal citation omitted)). Federal defendants do not dispute that under the procedures implementing the Final SPR Policy, if the Services determine that a species is threatened throughout all of its range, it will not determine whether the species is endangered in a significant portion of its range. Fed. Defs.’ Opp’n, ECF No. 53 at 55. They argue that the policy “complies with the plain language of the ESA because it does not render any of the bases for listing superfluous.” Fed. Defs.’ Reply, ECF No. 63 at 32. However, FWS acknowledges that in implementing the policy, it will not determine whether a species is endangered in a significant portion of its range if it has determined that a species is threatened throughout all of its range. In so doing, the policy renders the “endangered in a significant portion of its range" basis for listing superfluous when FWS has determined that a species is threatened throughout all of its range. Accordingly, this aspect of the procedures implementing the Final SPR Policy fail to give meaning to one of the two bases for listing a species as endangered—whether the species is endangered in a significant portion of its range. Second, the policy is inconsistent with the design of the statute, pursuant to which endangered species are entitled to more legal protection than threatened species, because the Services will not analyze whether a species that is threatened throughout all of its range is endangered in a significant portion of its range. In so doing, the Services fail to determine whether a species is entitled to the greater legal protection provided for in the ESA. *See Defenders of Wildlife*, 239 F. Supp. 2d at 19 ("[W]hen Congress enacted the ESA in 1973, it expressly extended protection to a species endangered in only a 'significant portion of its range.' The two earlier statutes enacted to protect and preserve endangered species narrowly defined endangered species as including only those species facing total extinction.").

For these reasons, the challenged aspect of the Final SPR Policy fails at *Chevron* step one.

4. Alternatively, the Challenged Aspect of the Final SPR Policy Fails at *Chevron* Step Two

Even if it were appropriate for the Court to consider the Final SPR Policy at *Chevron* step two because "the precise question at issue" is the meaning of the ambiguous phrase "significant portion of its range," it would also fail at that step because, despite the "substantial deference" due to the interpretation of such a provision, the implementation of the Final SPR Policy interprets the statute in a manner "that does not effectuate Congress' intent." *Ctr. for Biological Diversity v. United States Dep't of Interior*, 563 F.3d 466, 484 (D.C. Cir. 2009).

Plaintiffs argue that the policy is an unreasonable interpretation under *Chevron* step two for three reasons: (1) it "directly subverts the ESA's conservation goal by foreclosing any consideration of whether a species threatened throughout its range should be listed as endangered because of the threats it faces in a significant portion of its range"; (2) it impermissibly "relies on its concerns over its heavy workload and limited 'resources' to justify restricting the SPR analysis"; and (3) it is procedurally deficient because the "180 degree course change" in the final policy is not a logical outgrowth of the draft policy. Pls.' Mot., ECF No. 52 at 64-66.

Federal defendants respond that the Final SPR Policy is a reasonable interpretation of "significant portion of its range" because it: (1) does not render any basis for listing superfluous; (2) complies with the ESA principles; (3) is consistent with the ESA's conservation goals; and (4) does not require the Services to consider improper listing factors. Fed. Defs.' Opp'n, ECF No. 53 at 49-62. The Court considers each argument in turn.

a. The Challenged Aspect of the Final SPR Policy Renders the "Endangered in a Significant Portion of its Range" Basis for Listing Superfluous

Federal defendants argue that the policy does not render any basis for listing superfluous because "'there is at least one set of facts that falls uniquely within each of the four bases [] without simultaneously filling the standard of another basis[].'" Fed. Defs.' Opp'n, ECF No. 53 at 49 (quoting 79 Fed. Reg. 37,582). However, as explained above, the policy renders the "endangered in a significant portion of its range" basis for listing superfluous because the Services will not determine whether a species is endangered in a significant portion of its range if it has determined that a species is threatened throughout all of its range.

Federal defendants also assert that "Congress's placement of the 'throughout all' language before the 'significant portion of its range' language in the definitions of endangered species and threatened species indicates that Congress intended the Services to focus their analysis on a species' status throughout all of its range." *Id.* at 54. However, Federal defendants have neither pointed to a canon of statutory construction to support this argument nor provided any legal support for it. *See generally*, Fed. Defs.' Opp'n, ECF No. 53; Fed. Defs.' Reply, ECF No. 63.

Federal defendants argue that "there is no language in the ESA that requires the Services to analyze and make a determination on each of the remaining bases for listing *after* the Services determine that one of the bases for listing is applicable to the species . . . [n]or is there any language in the ESA that dictates in what order the Services should analyze the four bases for listing." Fed. Defs.' Opp'n, ECF No. 53 at 53-54. They also argue that it would "be illogical for the Services to continue analyzing whether a species fits within the three remaining bases for listing after they determine that a particular basis for listing is applicable to a species," stating that "if the Services did perform this analysis, it would lead to confusing results . . ." *Id.* at 54 & n.11.

The Court disagrees. Congress's intent in enacting the ESA and creating the two levels of classification was "to provide incremental protection to species in varying degrees of danger."

Defenders of Wildlife v. Norton, 258 F.3d 1136, 1143 (9th Cir. 2001); *see also* 16 U.S.C. § 1531(b) ("The purposes of this chapter are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered and threatened species."). As explained above, if a species is listed as endangered, it is entitled to greater legal protections than a species that is listed as threatened. In 1973, Congress enacted the ESA to provide "broadened protection for species in danger of extinction throughout 'a significant portion of [their] range' . . . a significant change" from then-existing laws protecting endangered species. *Defenders of Wildlife*, 258 F.3d at 1144. Accordingly, there is nothing illogical or wasteful of agency resources for the Services to analyze whether a species that is threatened throughout all of its range is also endangered in a significant portion of its range. Rather, not to do so is an unreasonable interpretation of the statute and inconsistent with Congress's intent in enacting the ESA. As stated above, Senator Tunney explained that "[t]he goal of the [ESA] is to conserve, protect, restore, and propagate species of fish and wildlife, that are in imminent danger of extinction or are likely to become endangered within the foreseeable future." 119 CONG. REC. 25,668 (daily ed. July 24, 1973) (statement of Sen. Tunney). With regard to whether Congress intended that a species could be listed simultaneously as endangered and threatened, it is clear that Congress intended that a species could:

> Under [the ESA] . . . the Secretary may list an animal as "endangered" throughout all or a portion of its range. An animal might be "endangered" in most States but overpopulated in some. In a State in which a species is overpopulated, the Secretary would have the discretion to list that animal as merely threatened or to remove it from the endangered species listing entirely while still providing protection in areas where it was threatened with extinction.

Id. at 25,669. For these reasons, the challenged aspect of the Final SPR Policy renders the "endangered in a significant portion of its range" basis for listing superfluous.

b. The Challenged Aspect of the Final SPR Policy is Inconsistent with ESA Principles

Federal defendants and defendant-intervenors argue that the policy provides a reasonable interpretation of the "significant portion of its range" phrase because logically, "a species cannot simultaneously meet the definitions of 'endangered species' and 'threatened species.'" Fed. Defs.' Opp'n, ECF No. 53 at 55;[9] Def.-Intervenors' Br. in Opp'n, ECF No. 56 at 26.

[9] The Court is not persuaded by Federal defendants' argument that a simultaneous listing for a species would be inconsistent with two opinions in other district courts because, as explained by plaintiffs, "[t]hese cases stand for the proposition that if a species is (biologically) endangered in a significant portion of its range, it must be protected as (legally) endangered throughout its range" and "say nothing about whether the Service

Federal defendants state that under the Draft SPR Policy, it would have been "possible that a single 'species' could meet the definition of both 'endangered species' and 'threatened species'—it would be threatened throughout all of its range while simultaneously being endangered in a significant portion of its range," which would lead to confusion. Fed. Defs.' Opp'n, ECF No. 53 at 58. FWS also noted that the final policy eliminates the possibility of a species being simultaneously "threatened throughout all of its range and endangered throughout a significant portion of its range" so as to not confuse "the public." 79 Fed. Reg. at 37,581.

As explained above, however, in enacting the ESA, Congress specifically intended that a species could simultaneously meet both definitions. Furthermore, the Services did not rely on this interpretation of the statute as a basis for its Final SPR Policy. *See SEC v. Chenery Corp.*, 332 U.S. 194, 196 (1947) (the propriety of agency action must be judged "solely by the grounds invoked by the agency"). Rather, the Services found that "[t]he Act . . . does not specify the relationship between the two provisions." 79 Fed. Reg. at 37,580. For these reasons, the

may lawfully choose to list a species as 'threatened' when it is 'endangered' in a significant portion of its range." Pls.' Reply, ECF No. 59 at 45-46.

challenged aspect of the Final SPR Policy is inconsistent with ESA principles.

c. The Challenged Aspect of the Final SPR Policy Subverts the Conservation Goals of the ESA

Federal defendants argue that the policy does not subvert the ESA's conservation goals because species receive protection under either status and therefore "[p]laintiffs' argument that a species listed as threatened under the Final SPR policy are somehow not 'conserved' is meritless." Fed. Defs.' Opp'n, ECF No. 53 at 60-61. Federal defendants further argue that "the Final SPR Policy does not mandate or even suggest that the Services should consider factors other than those outlined in 16 U.S.C. § 1533(a)(1) or make decisions that are not based on the best scientific and commercial data available in determining whether or not to list a species." Fed. Defs.' Opp'n, ECF No. 53 at 61. Rather, "the [Final SPR] Policy reflects the Services' 'lawful and completely appropriate' effort of 'resolving ambiguities in the [ESA] and providing guidance for its implementation . . . consider[ing] a wide variety of factors' including 'both textual and practical reasons.'" *Id.* (citing 79 Fed. Reg. at 37,580; 37,591-92). Federal defendants state that in the Final SPR Policy, "the Services noted that there is a '*related benefit* of limiting the applicability of the SPR language" in order to conserve the Services "limited resources." *Id.* (quoting 79 Fed. Reg. at 37,581 (emphasis added)). But Federal defendants argue that "this practical benefit has no bearing on what factors the Services consider when determining" whether to list a species as threatened or endangered. *Id.*

Plaintiffs respond that the ESA mandates that FWS "make listing determinations based solely on the best available scientific data" and that FWS's injection of "economic concerns (i.e. 'limited resources')" as a justification for not considering whether a species is endangered in a significant portion of its range if the Services have determined that it is threatened throughout its range is inconsistent with that mandate. Pls.' Reply, ECF No. 59 at 49.

The Court is not persuaded by Federal defendants' argument because the Services *have* decided, for economic reasons and to avoid confusion, to not reach the question of whether a species should be listed as endangered in a significant portion of its range after determining that it is threatened throughout all of its range. This is contrary to the statutory requirement to list a species as endangered if it is "in danger of extinction" in "a significant portion of its range," 16 U.S.C. § 1532(6), and to make that determination based "solely on the basis of the best scientific and commercial data available," 16 U.S.C. § 1533(b)(1)(A). And this mandate cannot be excused for "budgetary reasons." *Am. Lands All. v. Norton*, 242 F. Supp. 2d 1, 18 (D.D.C. 2003) ("it is beyond th[e] Court's authority to excuse congressional mandates for budgetary reasons”). As plaintiffs point out, the ESA does not require FWS to spend its resources conducting redundant analyses, such as considering whether a species is threatened throughout its range or in a significant portion of its range where it has already determined that the species is endangered throughout its range or in a significant portion of its range. Pls.’ Reply, ECF No. 59 at 50. Defendant-intervenors argue that plaintiffs seek to “strip[] the Service’s discretion to tailor protections for threatened species.” Def.-Intervenors’ Br. in Opp’n, ECF No. 56 at 27. But as plaintiffs point out, requiring FWS to properly determine a species’ listing is separate from FWS’s section 4(d) authority to tailor protections. Pls.’ Reply, ECF No. 59 at 51.

For these reasons, the challenged aspect of the Final SPR Policy subverts the conservation goals of the ESA. Accordingly, the challenged aspect of the Final SPR Policy is an unreasonable interpretation of the ESA under *Chevron* step two.

d. The Challenged Aspect of the Final SPR Policy Violated ESA and APA Notice and Comment Requirements

Plaintiffs also challenge the Final SPR Policy on procedural grounds, arguing that the final policy was not a logical outgrowth of the draft policy due to “the final policy’s 180 degree course change barring consideration of whether a species is endangered in a significant portion of its range when it is threatened throughout its range." Pls.' Mot., ECF No. 52 at 65. "[A]n agency's proposed rule and its final rule may differ only insofar as the latter is a 'logical outgrowth' of the former." *Envtl. Integrity Project v. E.P.A*, 425 F.3d 992, 996 (D.C. Cir. 2005) (citation omitted). The parties do not dispute that the "logical outgrowth" concept properly applies to agency policies. *Methodist Hosp. of Sacramento v. Shalala*, 38 F.3d 1225, 1237-38 (D.C. Cir. 1994). As Federal defendants point out, FWS specifically sought comment on the aspect of the draft policy that could result in a species being threatened throughout all of its range while also being endangered in a significant portion of its range:

> We recognize that under the draft policy, a species can be threatened throughout all of its range while also being endangered in an SPR. For the reasons discussed in this document, in such situations we would list the entire species as endangered throughout all of its range. However, we recognize that this approach may raise concerns that the Services would be applying a higher level of protection where a lesser level of protection may also be appropriate, with the consequences that the Services would have less flexibility to manage the species and that scarce conservation resources would be diverted to species that might arguably better fit a lesser standard if viewed solely across its range. The Services are particularly interested in public comment on this issue.

76 Fed. Reg. at 77,004. The Court is not persuaded, however, by Federal defendants' argument that seeking comment on this aspect

of the draft policy put plaintiffs and the public on notice that FWS would decide to address this concern by deciding that it would not analyze whether a species was endangered in a significant portion of its range after it had determined that the species is threatened throughout all of its range. Although FWS solicited comment on this issue, it gave no indication that this would be the "solution" it would choose, nor were plaintiffs and the public given the opportunity to comment on this solution. The Court's conclusion is bolstered by the fact that FWS acknowledged that the draft policy would result in "partial overlap among categories" which though potentially confusing "in practice will . . . not be a significant hurdle to implementing [the] draft policy because it is consistent with Court decisions and FWS'[s] interpretation of the statutory definitions." *Id.* at 76,996. Accordingly, the draft policy did not provide "public notice of [FWS's] intent to adopt, much less an opportunity to comment on" its decision to not analyze whether a species is endangered in a significant portion of its range after it determined that the species is threatened throughout all of its range. *Envtl. Integrity Project*, 425 F.3d at 997. The Court acknowledges that commenters responded to FWS's solicitation of comments, 79 Fed. Reg. at 37,599, but that does not change the fact that FWS did not provide notice and opportunity to comment on its "solution." For these reasons, this aspect of the Final SPR Policy was not a logical outgrowth of the draft policy.

e. The Application of the Final SPR Policy to the Bat was Unlawful

Plaintiffs' final argument is that when it applied the Final SPR Policy to the Bat, "FWS failed to undertake the necessary analysis of whether the species is in danger of extinction throughout a significant portion of its range" thereby "unlawfully rel[ying] on the SPR Policy to justify ignoring the clear and undisputed fact that the Bat has declined most significantly in the core of its range." Pls.' Mot., ECF No. 52 at 67.[10] Federal defendants respond that the Final SPR Policy is a reasonable interpretation under *Chevron* step two, and that since FWS did not misapply the Final SPR Policy to the Bat, nor do plaintiffs contend otherwise, plaintiffs' argument is without merit. Fed. Defs.' Opp'n, ECF No. 53 at 63.

The Court agrees with Federal defendants that FWS correctly applied the Final SPR Policy as written to the Bat. However, the Court has determined that the challenged aspect of the Final SPR Policy fails at *Chevron* step one, and in the alternative at *Chevron* step two. *See supra* Section III.B.3-4. Consequently,

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[10] As part of this argument, plaintiffs reiterate their arguments that the Final SPR Policy and the final threatened determination violated the procedural requirements of the ESA and APA. Pls.' Mot., ECF No. 52 at 67. The Court has addressed those arguments. *See supra* Sections III.C, III.D.4.d.

since the Final SPR Policy is unlawful, the application of the policy to support the threatened determination as to the Bat was unlawful.

IV. Conclusion

For the reasons set forth above, the Court **GRANTS IN PART AND DENIES IN PART** plaintiffs' motion for summary judgment and **GRANTS IN PART AND DENIES IN PART** Federal defendants' and the defendant-intervenors' motions for summary judgment. The Court **REMANDS**, but does not vacate the "threatened" listing decision, to FWS to make a new listing decision consistent with this Memorandum Opinion. The Court **VACATES** the provision of the Final SPR Policy which provides that if the Services determine that a species is threatened throughout all of its range, the Services will not analyze whether the species is endangered in a significant portion of its range. However, the Court declines to vacate the Polar Bear Memo. An appropriate Order accompanies this Memorandum Opinion.

SO ORDERED.

Signed: Emmet G. Sullivan
United States District Judge
1/28/2020

EFFECTS OF SHELTERWOOD AND PATCH CUT HARVESTS ON A POST WHITE-NOSE SYNDROME BAT COMMUNITY IN THE CUMBERLAND PLATEAU IN EASTERN KENTUCKY

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in Forest and Natural Resource Sciences in the
College of Agriculture, Food, and Environment
at the University of Kentucky

By

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Lexington, Kentucky

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Lexington, Kentucky

2020

Abstract of Thesis

EFFECTS OF SHELTERWOOD AND PATCH CUT HARVESTS ON A POST WHITE-NOSE SYNDROME BAT COMMUNITY IN THE CUMBERLAND PLATEAU IN EASTERN KENTUCKY

The impact of shelterwood and patch cuts harvests on bat communities was tested at three sites in Eastern Kentucky. Shelterwood harvests had 50% of the basal area and understory removed to create a uniform spacing of residual trees. Patch cuts had 1-hectare circular openings created to remove 50% of the basal area creating an aggregated spacing of residual trees. Acoustic detectors were deployed to assess activity levels pre-harvest. Sites were then sampled from 1 – 2 years post-harvest to determine differences. Pre-harvest data revealed little acoustic activity for the *Myotis* spp. at two sites. The remaining site had high activity of *Myotis* pre-harvest. All sites saw a large increase in bat activity post-harvest. Activity of low-frequency and mid-frequency bats increased in response to the harvests. Big brown and red bats were commonly captured within forest harvests. Tri-colored bats also captured, suggesting forest harvests could improve habitat. *Myotis* activity did not increase post-harvest at the site with a known population. Netting efforts revealed a remnant population of northern long-eared bats (*Myotis septentrionalis*). These bats were radio-tagged and tracked to day-roosts. All day roosts were in upslope habitats within 100 m of forest roads created for maintenance and logging operations.

Keywords: Eastern Kentucky, shelterwood, patch cut, timber harvest, northern long-eared bat

Phillip Lee Arant

Signature

August 20, 2020

Date

EFFECTS OF SHELTERWOOD AND PATCH CUT HARVESTS ON A POST WHITE-NOSE SYNDROME BAT COMMUNITY IN THE CUMBERLAND PLATEAU IN EASTERN KENTUCKY

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Introduction

Bats in eastern Kentucky are all insectivorous. Species present in the region include big brown bat (EPFU, *Eptesicus fuscus*), evening bat (NYHU, *Nycticeius humeralis*), eastern red bat (LABO, *Lasiurus borealis*), hoary bat (LACI, *L. cinereus*), silver-haired bat (LANO, *Lasionycteris noctivagans*), tri-colored bat (PESU, *Perimyotis subflavus*), northern long-eared bat (MYSE, *Myotis septentrionalis*), Indiana bat (MYSO, *M. sodalis*), little brown bat (MYLU, *M. lucifugus*), eastern small-footed bat (MYLE, *M. leibii*), Rafinesque big-eared bat (CORA, *Corynorhinus rafinesquii*), and Virginia big-eared bat (COTO, *C. townsendii virginianus*). Bats utilize echolocation in a variety of ways and thus have several different types of calls. Search phase calls are used to navigate on the landscape and members of the same species typically exhibit the same pattern when they navigate. Characteristics such as duration, F_{max}, F_{min}, F_{mean}, and shape of echolocation calls help in determining species identification (Britzke *et al,* 2011). These calls vary across regions and several dialects can occur throughout a species range. However, each species can produce a wide range of calls beyond its typical pattern, confounding call identification among sympatric, non-related bats.

Bats use other types of calls to communicate between individuals. Social calls communicate information such as roost locations and prey sources. Pfalzer and Kusch (2003) found four types of calls. One type of call functions in communicating information between infants and mothers. These calls assisted in tandem flights and might function to communicate feeding site and roost locations. A second type of call is used to attract mates. A third is used by hindered or distressed bats. A final call is used in aggressive interactions. This type of call can be used to inhibit feeding activity of other individuals.

Insectivorous bats reduce the time between calls when approaching prey. This pattern occurs for all species and is called a feeding buzz. Bats capture prey by primarily two approaches. Insects can be captured during flight in the mouth, chiropatagium (wing membrane) or uropatagium (tail membrane). This method is commonly referred to as 'aerial hawking.' Insects can also be captured from vegetative and ground surfaces, a behavior known as gleaning. Although many insectivorous bat species show a preference for one method over the other, most are capable of feeding by both approaches.

Insectivorous bats are often divided into feeding guilds, based on their low, medium, and high call frequencies, especially the F_{max} (i.e., maximum frequency produced) of their calls. Low-frequency bats (open-space foragers) include hoary bat, big brown bat, and silver-haired bat. Low frequency calls travel farther than high frequency calls, permitting these bats to forage effectively within open air space away from forest clutter. Rafinesque's big-eared bat and Virginia big-eared bat also have low frequency calls; however, these species are gleaners that specialize on the capture of insect prey (primarily moths) from the surface of rocks and vegetation. Consequently, the use of low intensity calls by these bats are inaudible to many moth species and are also difficult to detect using acoustic devices. Medium-frequency bats (edge-space foragers) include eastern red bat, evening bat, and tri-colored bat. These species have intermediate call strength and intensity allowing these bats to feed in a variety of habitats, including forest edges. The Myotis species, Indiana bat, little brown bat, northern long-eared bat, and eastern small-footed bat, are high-frequency bats (closed-space foragers) which can successfully feed in micro-habitats with more vegetative clutter. These species are commonly associated with forested habitats. Of these species, the northern long-eared bat and eastern small-footed bat also use gleaning behavior to capture insect prey. As with Corynorhinus species, these bats emit calls of low intensity and use passive listening for insect generated sounds to aid in the capture of prey (Faure *et al.*, 1993).

Flying and maintaining normothermic body temperatures is energetically expensive. The high surface area to volume ratio of bats further increases their energetic demands. Insectivorous bats compensate for their high energy requirements by choosing roosts to passively rewarm, using the microclimate they roost in to influence their return to a normothermic condition. As an additional step bats can use torpor. Torpor allows bats to lower their body temperature to limit energy consumption. Females use and modulate these behaviors to allocate greater energy stores to fetal development and juvenile growth rates (Chruszcz and Barclay, 2002).

During the diurnal period of each day most forest-dwelling insectivorous bats occupy roosts to access predictable temperature regimes, to protect themselves from predators, and for protection from inclement weather. Foliage-roosting species, such as the eastern red bat, hoary bat, and tri-colored bat, typically roost within the canopy of trees, often associated with clusters of dead leaves or needles. Female hoary bats and eastern red bats have between 2 to 4 pups each year and roost solitarily. Tri-colored bats also have 2 pups per year, but are more communal in their roosting behavior, with several reproductive females gathering together to form small maternity colonies. Male silver-haired bats summer in Kentucky and also use trees and stumps for roosting. A majority of these bats, however, do not reside in Kentucky during the winter months and briefly migrate through the state during early-summer and autumn (Perry *et al.,* 2010).

Corynorhinus species roost in caves, bridges, attics, and trees. Females form maternity colonies and males form bachelor colonies that are separate from maternity sites. These bats only have a single pup per year and are more often associated with forests near cliff habitats in eastern Kentucky. Because they are moth specialists, evidence of their feeding habits can easily be discerned as these bats often carry their prey back to roosts to eat where they discard the elytra and other inedible parts to the floor of the roost.

Big brown bats form maternity colonies in trees and a variety of structures including bat boxes and attics. They have one to two pups per year. Females of the species can form large maternity colonies exceeding several hundred individuals. Males often form bachelor colonies but can also be found with females in maternity roosts. The pups take about a month to reach volancy. Evening bats roost in a variety of structures including trees, buildings, and bat boxes, but are most often found in the cavities of trees. They produce twins or triplets.

The Myotis species in eastern Kentucky all give birth to a single pup. Eastern small-footed bats are strongly associated with talus slopes, cliffs and other rock features. Females form small maternity colonies within these structures. Indiana bats roost beneath bark in dead or living trees, but occasionally are found in bat boxes. Extensive research has shown these bats prefer areas of high solar exposure. Maternity colonies can contain up to several hundred individuals, while males roost singly or in small bachelor colonies. Little brown bats roost in anthropogenic structures such as attics and barns. Occasionally they are located in trees under bark or in cavities, and have been found roosting in association with other Myotis species. These bats form small to large maternity colonies of up to several hundred individuals. Northern long-eared bats roost under the bark of dead trees, in bat boxes, and within small tree cavities. These bats form smaller maternity colonies, usually from 25 to 50 females. Landscape-scale studies show these bats are often associated with large tracks of interior forest where minimal edge habitat exists.

Insect prey is less available during winter months. Bats in eastern Kentucky either migrate to areas with weather that is typically above freezing or make shorter movements and hibernate in nearby caves and mines. Hoary bat, silver-haired bat, and some eastern red bats migrate extensive distances during fall to warmer areas. Silver-haired bats hibernate within tree stumps, cliffs, or buildings. Eastern red bats hibernate within the foliage of leaves or on the forest floor within leaf litter. Hoary bats remain active throughout much of the winter after arriving to warmer climates including the southern United States where food supplies remain available during winter months. Little is known about evening bats during winter, other than they do not hibernate in caves, and it is likely that they migrate south only to roost in trees during winter as well.

Indiana bat, little brown bat, northern long-eared bat, eastern small-footed bat, tri-colored bat, big brown bat, Virginia big-eared bat, and Rafinesque big-eared bat typically migrate short distances to caves, mines and rock outcrops to hibernate from November to March. Although migrations can be over 220 km (Roby *et al*., 2019). Rafinesque's big-eared bats arouse during hibernation and are known to frequently switch roost locations throughout winter. Myotis species, big brown bat, and tri-colored bat put on larger amounts of fat reserves prior to hibernation and periodically arouse to drink, void their waste, and recharge their immune system function; although feeding can occur during warm periods.

White-nose syndrome was first discovered in Howe's Caverns in upstate New York in 2006. With a likely origin from Europe, the disease has been spread by both bats and people. People transmit the disease by carrying fungal spores on clothing and gear between caves. Bats carry the spores in their pelage as they move among different cave systems during fall swarming, hibernation, and spring staging. These transmission methods have facilitated the spread of the fungus across North America within the last 14 years. It is likely the disease will eventually spread throughout the continent. Previously common bat species, including little brown bat and northern long-eared bat, have been decimated by the fungus with mortality numbers in the millions.

Psuedogymnoascus destructans is the fungus responsible for white-nose syndrome. The fungus is a saprotroph that opportunistically infects bats (Raudabaugh and Miller, 2013). The disease is named for the white hyphae of the fungus that often occur on the muzzle of bats. The fungus causes flaking of the skin along the forearms of the wings and necrosis of wing tissue in later stages. The fungus optimally grows from 12.5 to 15.8 °C with an upper limit of growth at 20 °C (Verant *et al.,* 2012). Various physiological impacts from the fungus results in more frequent arousal of bats causing them to burn necessary fat reserves, become dehydrated, and exhibit excessive immune response often resulting in death. The fungus can persist and reproduce in caves without bats, and has likely become a permanent resident in North American caves.

Little brown bat, northern long-eared bat, tri-colored bat, and Indiana bat are species severely impacted by the fungus (Thogmartin *et al.,* 2013; Vonhof *et al.,* 2015, 2016; US Department of Interior, 2015; USFWS, 2019). These species often hibernate in micro-sites that possess optimal growth conditions for the fungus, cluster during hibernation facilitating spread of the fungus, and/or have insufficient fat reserves to sustain multiple arousals from the fungus. Death rates have varied throughout ranges and populations, but have been as high as 98% in some hibernacula in eastern U.S. Evidence post-arrival of white nose syndrome suggests the disease has reshaped the bat communities of eastern North America.

Individual bats that have survived the initial impact of the fungus are adopting alternative hibernation strategies including hibernating in alternate roosts (i.e., basements, hollow trees, culverts, railroad tunnels, and bridges), reducing cluster size which minimizes spread of the fungus within hibernacula, and moving to warmer or cooler microclimates within cave systems. Some populations are evolving resistance to the pathogen (Frank *et al.,* 2019), with larger body mass associated with many survivors. Recently, local populations of bat species in infected areas are beginning to increase or stabilize (Reichard *et al*., 2014, Dobony and Johnson, 2018). Regardless, these populations remain vulnerable, are poorly documented, and possess low reproductive rates that will take decades to recover.

Amelon (2007) found that little brown bats were positively associated with bottomland forest, water sources, and negatively associated with heavily trafficked roads and non-forested lands. Starbuck *et al.,* (2015) found northern long-eared bats were associated with pole-stage, closed canopy forests with understory clutter and water. Amelon (2007) found northern long-eared bats were positively associated with dense, cluttered forests, water, and larger mature forests. They were negatively associated with non-forested habitat and young forests. Yates and Muzika (2006) found northern long-eared bats were detected in areas with limited forest edge. Starbuck *et al.,* (2015) found tri-colored bats were found on forest dominated landscapes in areas which were recently burned. Amelon (2007) found tri-colored bats were positively associated with forested habitat with limited clutter and water. They were negatively associated with non-forested habitats and young, cluttered forests. Yates and Muzika (2006) found tri-colored bats were found in areas with scattered large trees, high canopy closure, and substantial understory vegetation at 2-3 m. Womack *et al.,* (2013) found that Indiana bats forage in areas of high canopy cover. These bats preferentially chose to forage in forested areas instead of agricultural areas. Yates and Muzika (2006) determined Indiana bat presence was associated with larger woodlands mixed with open habitats.

Following white-nose syndrome, other trends were also observed. Pauli *et al*. (2015) saw a trade-off between foraging and roosting habitat. Medium to high-intensity removals of single-tree selection harvests maximized both foraging and roosting habitat for northern long-eared bats and Indiana bats by creating openings. Removing all forest harvests would negatively impact bats by minimizing openings within forests. Jachowski *et al.* (2014) concluded competition influenced temporal and spatial activity of bats. The loss of little brown bats and northern long-eared bats appeared to result in a shift in activity of big brown bats.

Brooks *et al.* (2017) found insect prey and bats did not response to different sizes of openings, either small 0.2 - 6 ha, medium 2.1 - 5.6 ha, or large 6.2 - 18.5 ha. Big brown bat, eastern red bat, and tri-colored bat were frequently found within openings.

Myotis made up only 2% of the calls, where previously the little brown bat had comprised 25% of recorded calls.

Northern long-eared bats, in particular, tend to avoid foraging in open spaces. Owen *et al.* (2003) found that northern long-eared bats preferred foraging within diameter limited harvests and road corridors; however, they also made use of the extensively available intact forest. Henderson and Broders (2008) found that northern long-eared bats predominately foraged in riparian areas within dense forests. Their foraging and commuting in agricultural areas were focused on linear features such as tree rows.

This study compares two silvicultural techniques commonly used in regeneration of forests, shelterwood harvests and patch cuts, to assess if commercially viable harvests could benefit bats. Shelterwood harvests are a silvicultural technique used in regeneration. Trees are harvested and the mid-story and clutter are removed. A certain basal area of trees is retained, 50% of the commercial timber volume in this study, in order to shade the forest floor or provide seeds. The cuts are uniform in nature and provide an open environment for bats to feed (Lacki *et al.* 2007). No site preparations occurred.

Patch cuts are another silvicultural technique used in regeneration. In this study, 50% of the commercial timber volume within the treatment area were harvested in small circular groups a hectare in size. All trees within these groups are removed. These gaps mimic natural disturbance and allow shade intolerant species to grow by increasing light exposure. Unlike the uniform shelterwood harvests the disturbance in patch cuts is aggregated in small pockets and surrounded by intact forest. These pockets provide large amounts of edge habitat for bats to feed (Lacki *et al.* 2007). No site preparations occurred.

Although other studies on silviculture practices such as patch cuts and shelterwood harvests have been performed, my study provides replication across multiple study sites across two physiographic regions. For my study, patch cuts and shelterwood harvests were implemented in three field sites. I hypothesized these harvests would cause different responses between feeding guilds of bats. Low frequency echolocators, including big brown bat, hoary bat, and silver-haired bat should be attracted to cuts. The open space presented in both forest harvests should provide enhanced foraging space because it has lower amounts of clutter. Medium frequency echolocators, such as evening bat and eastern red bat, should be attracted to the edges of cuts. Patch cut harvests should be more attractive than shelterwood or unharvested forest to these species. Myotis species should have a negative response to the harvests because the clutter is being removed from the environment. However, in post-WNS communities this could be difficult to test due to the low number of Myotis species present within the region.

These hypotheses were evaluated with a combination of several techniques: acoustic monitoring, light trapping, and mist netting. Acoustic monitoring provided two metrics of data to evaluate activity, calls and pulses. Detectors were placed at ridgetop, mid-slope, and riparian positions to discern any differences in activity levels. Light trapping provided data on the prey base and was performed to offer a possible explanation to account for any difference in bat activity levels demonstrated between the different harvest conditions. Previous experiments have demonstrated prey may aggregate at the edges of harvests which can be attractive to predators (Dodd *et al.* 2012).

Mist netting was performed to confirm acoustic monitoring results and verify species presence. In the event target Myotis species, *Myotis septentrionalis* or *Myotis sodalis*, were captured tracking devices would be attached to collect data on roost locations. Locating roosts would allow population levels to be evaluated and roosts protected. Ideally, roosts would be located within the harvest location and protected during the harvests to evaluate whether bats would roost within the forest harvests.

Study Areas

Three study areas (Figure 1): Robinson Forest (*Big Laurel Ridge and Medicine Hollow tract*), private TIMO property (*Beech tract*), and Kentucky Ridge State Forest (*Kentucky Ridge tract*), were established within the Cumberland Plateau and Cumberland Mountains physiographic regions to study response of insectivorous bats to patch cut harvests and shelterwood harvests. The eastern Kentucky region has elevations ranging from 200 - 500 m (McGrain, 1983). The terrain is rugged and largely covered with mixed mesophytic forests (Braun, 1950). Eastern Kentucky has sandstone cliffs and a variety of caves formed from both the sandstone and limestone that occur throughout the region (McGrain, 1983; Simpson and Florea, 2009).

Robinson Forest (Laurel Ridge tract)

Robinson Forest is located near Clayhole, Kentucky. The forest is situated between the cities of Jackson and Hazard in the southeastern corner of the state. The main block of Robinson Forest is approximately 4,047 ha and, in total, the entire Forest is nearly 6,070 ha. This forested landscape lies within Breathitt, Knott, and Perry counties. Robinson Forest was purchased by E.O. Robinson and Fredrick W. Mowbray in 1908. The forest was then clear cut to extract the timber; harvesting of timber on the forest ended by 1922. The land was donated in 1923 to the University of Kentucky agricultural department to conduct research into improved logging practices, and to help educate the public of eastern Kentucky (Krupa and Lacki, 2002).

The forest has been subjected to many types of disturbance throughout the years including clear cutting, fires, mining, and invasion by exotic plant species (Krupa and Lacki, 2002). Many settlers built homes illegally on the forest, with most evicted in the 1920's and 1930's. Evictions angered many of the settlers and arson, as a form of response, has continued over the last 90 years, resulting in >80% of the forest having been burned at some point in time (Krupa and Lacki, 2002). During the 1970's, and again in the 1990's, mining companies have strip mined sections of the outer blocks of the forest to procure coal (Krupa and Lacki, 2002). Even today the forest is experiencing disturbance. Robinson Forest serves as a working forest used to execute a variety of forestry experiments such as SMZ studies, wildlife clearings, and small harvests aimed at determining best management practices for forestry (Krupa and Lacki, 2002). The forest has a maintained road system which allows researchers to access study areas. A small camp exists near the western end of the main block, with several log cabin buildings that function as housing and dining facilities for research staff and other guests of the University of Kentucky.

Despite the impacts of invasive plants, logging, fires and mining, the forest has developed into a second growth mature forest with diverse plant and animal communities. Forests are mixed mesophytic (Braun, 1950), typical of much of the Cumberland Plateau. At the time of the study, bottomlands were mesic and comprised of maple (*Acer*)-beech (*Fagus*)-poplar (*Liriodendron*) stands, with hemlock (*Tsuga*)-*Rhododendron* communities interspersed. Mid-slopes supported oak-beech-maple forest, and forest habitats on ridge tops, due to the xeric sandy soils, were comprised of oak (*Quercus)*-pines (*Pinus*) or oak-hickory (*Carya*) stands. The different community types and variations in stand age and composition on the forest, the latter as a result of the extensive disturbance history, provided a complex mosaic of habitats for use by forest-dwelling bats.

TIMO Property (Beech tract)

The Beech tract is named for its prominent stands of American beech (*Fagus grandifolia*). The 121-ha study site is located 16 km east of Jackson, Kentucky, in Breathitt County. The property is owned by Forestland Group, LLC. Historically, much of the property was forested. The unharvested ridge tops were dominated by oak -hickory stands, with riparian and mid-slope positions comprised of beech -oak -maple stands. The study site possessed historic skid trails, but these were overgrown with trees and were unlikely to function as flyways for bats. The landscape surrounding the study site was open with sparse tree cover and open fields on all sides. A small farm still operated on the property and had small openings in the previously forested landscape maintained for several decades.

Kentucky Ridge State Forest (Kentucky Ridge tract)

The tract within Kentucky Ridge State Forest is a mixed mesophytic forest situated in the Cumberland Mountains at the edge of the Cumberland Plateau in eastern Kentucky. Located in Bell County, the forest is approximately 22.5 km southwest of Pineville. The forest is managed by the Kentucky Division of Forestry. Kentucky Ridge State Forest is

6,172 ha in size. The forest is managed for sustainable timber production, wildlife habitat, and recreational opportunities (forestry.ky.gov). The study site is 121 ha in size and adjacent to route 190. The landscape surrounding the study site is primarily forested, with small patches of open space containing park facilities and private homes.

The study site had previously been harvested and now supports second growth forest. Several old skid trails still exist throughout the forest. These trails were overgrown by small trees and shrubs and, in some segments, were capable of functioning as flight corridors for bats. The study site is bordered by an active ATV trail which is frequently used by locals.

The study site had several distinct stand types. Bottomland forests were dominated by mesic communities comprised of maple -beech -poplar, with hemlock-*Rhododendron* stands interspersed. Ridge tops supported xeric communities comprised of oak-hickory with an understory of mountain laurel (*Kalmia latifolia*). A nearly pure stand of eastern hemlock (*Tsuga canadensis*) and rosebay rhododendron (*Rhododendron maximum*) covered one of the ridge tops. Mid-slope communities were dominated by bottomland species, with xeric oaks and hickories interspersed.

Figure 1. Map of field sites in Kentucky. Laurel Ridge rests within Robinson Forest near Buckhorn, KY, the Beech site is outside of Jackson, KY, and Kentucky Ridge is outside of Pineville, KY.

Experimental Design

Each study site was approximately 120 ha in size. Within each study site, three ca. 40-ha treatments included unharvested forest, patch cut harvests, and shelterwood harvests. For each 40-ha patch cut harvest, approximately 23, 1-ha patch cuts, were delineated for timber removal. Shelterwood harvests removed 50% of the basal area and cleared the understory of woody vegetation throughout the treatment area.

The pre-treatment transects for acoustic sampling were established by dividing the study area into three approximately equal units; each one to become one of three post-treatments following timber harvesting, including shelterwood harvest, patch cut harvest, and unharvested forest. Based upon the maximum length of each unit, a number was randomly generated to select for the closest point to two predominant slope directions, i.e., north/south or east/west. The closest ridge top to each random point became the starting point of each transect. The riparian point was placed adjacent to the closest stream to the selected ridge top, with mid-slope points placed at an elevation halfway between the riparian and ridge top points. Exact placement of the units was determined from ground surveys. When possible, units were preferably located in the vicinity of closed canopy roads, streams, and canopy gaps.

Pre-treatment acoustic sampling took place in summer 2015 at all three study sites. Activity was monitored using Song Meter 3 units and SMU-1 microphones (Wildlife Acoustics, Maynard, MA). The SM3 units were housed within pelican cases, with microphones placed within PVC pipe and tied to a tree at 1.5-m aboveground (Figure 2). Each location where an acoustic unit was deployed was geolocated with a Garmin GPSMAP 64. These units are accurate within 5 to 15 meters, depending on conditions. In 2015 and 2016, the microphone was housed within PVC pipe for protection from the elements and to prevent damage from wildlife; however, the additional shielding created secondary harmonics, limiting the quality and resolution of call characteristics. Because this study has long-term objectives, a decision was made to remove the shielding for 2017 and 2018.

The samples from all study sites were intended to be analyzed together. An ANOVA was performed on the pre-harvest data. Differences were detected in the activity level of silver-haired bats and Myotis (Table 1). Due to the differences found in activity levels pre-harvest, data from the three sites were analyzed independently.

The original plan was for all study sites to be harvested in the winter of 2015, however, that did not occur (Figure 3). Harvesting of the Beech tract was completed over the winter of 2015 and early spring 2016. Transect points BE1, BE2, and BE3 at the Beech study site were not re-sampled in 2016 and 2017 because they were not located in the shelterwood harvest due to a miscommunication of the harvest location. These locations were replaced with BES1, BES2, and BES3 (Figures 4, 5). Because local markets for timber shifted the original harvest site in the Laurel Ridge tract was no longer a viable option (Figure 6). Two transects from the original study site were lost and two new transects were placed within the new harvest area (Figure 7). This was followed by harvesting of the Kentucky Ridge tract during the winter of 2016 and early spring 2017 (Figure 1). The Laurel Ridge tract at Robinson Forest was harvested over the winter of 2017 and early spring 2018 (Figure 1).

It was decided to modify transect layouts with patch cut harvest treatments. Instead of the original locations, sample points were moved to the closest patch cut from the original transect point to more directly assess bat response to patch cuts. Because the riparian areas of patch cut harvest units were not harvested, the riparian sampling point was moved to a patch cut at the mid-slope position, again, to increase the number of patch openings sampled. This resulted in a ridge top and two mid-slope sampling points along each transect in patch cut harvest treatments following timber removal. This occurred for all patch cut harvests sampled during 2016 to 2017. At Laurel Ridge, I sampled the riparian area of the patch cuts. Patch cut sampling at Robinson Forest followed the pre-harvest transects. Points at the ridge top and mid-slope positions were moved to the closest patch cut available. The riparian point remained in the same position as the pre-harvest surveys. With all sampling of patch cuts, SM3 units were located at the immediate edge of the cut and pointed towards the center of the patch cut opening.

Figure 2. Acoustic set-up. The microphone is tied onto the tree and rests in PCV pipe, while the unit is chained to the tree.

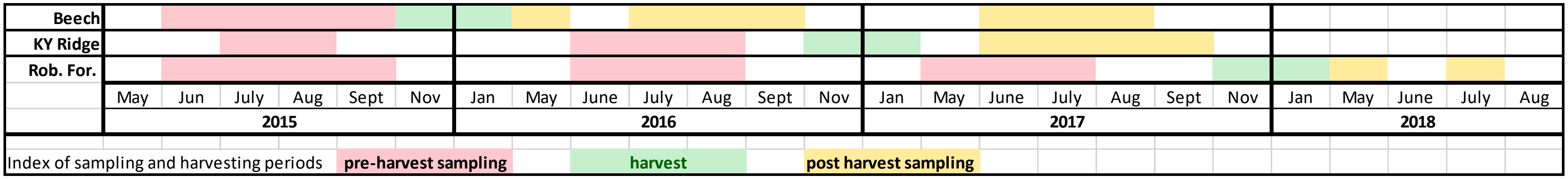


Figure 3. Timeline of forest harvests and acoustic sampling for all study sites.

Table 1. Site differences in estimated species activity based upon Kaleidoscope species assignments in three sites, Laurel Ridge in Robinson Forest, Clayhole, KY, Beech Tract, Oakdale, KY, and Kentucky Ridge State Forest, Chenoa, KY, in Eastern Kentucky.

Parameter	**Beech**	**Kentucky Ridge**	**Laurel Ridge**	**df**		**F-value**	**P-value**
	Mean ± SE	Mean ± SE	Mean ± SE	x	y		
COTO	0.107 ± 0.0347	0.0606 ± 0.0296	0.0517 ± 0.024	2	310	1.01	0.365
EPFU	3.15 ± 0.835	2.21 ± 0.721	1.06 ± 0.393	2	310	2.58	0.0771
LABO	2.47 ± 0.679	1.43 ± 0.387	1.42 ± 0.308	2	310	1.3	0.273
LACI	2.24 ± 0.806	0.545 ± 0.124	1.28 ± 0.299	2	310	1.74	0.177
LANO	3.49 [a] ± 0.779	1 [b] ± 0.318	0.803 [b] ± 0.228	2	310	6.52	0.00169
MYLE	0.0611 ± 0.0210	0.0758 ± 0.0328	0.0345 ± 0.017	2	310	0.794	0.453
MYLU	1.53 ± 0.431	0.258 ± 0.0817	1.06 ± 0.242	2	310	2.76	0.0645
MYSE	2.48 [ab] ± 0.757	0.0455 [b] ± 0.0258	4.41 [a] ± 0.819	2	310	6.7	0.00142
MYSO	0.0534 [b] ± 0.0463	0.0909 [ab] ± 0.0417	0.302 [a] ± 0.0841	2	310	4.61	0.0107
NYHU	0.0763 ± 0.0369	0.0152 ± 0.0152	0.0431 ± 0.0226	2	310	0.881	0.416
PESU	2.02 ± 0.619	1.17 ± 0.418	0.759 ± 0.262	2	310	1.9	0.151

[a,b] Within rows, means without common letters are groups with statistical difference.

Methods and Materials

Acoustic Sampling

Bat activity was assessed during the summers of 2015 to 2018. In 2015, all three tracts were sampled twice from 17 June to 16 September. During 2016, each site was sampled three times from 23 May to 11 September. In 2017, two of the three sites, Beech and Kentucky Ridge, were sampled three times between 7 June and 7 September, with Laurel Ridge sampled twice from 23 May and 20 July. Only Laurel Ridge was sampled in 2018; two times from 22 May to 13 July.

Activity was monitored using Song Meter 3 units and SMU-1 microphones (Wildlife Acoustics, Maynard, MA). The SM3 units were housed within pelican cases, with microphones placed within PVC pipe and tied to a tree at 1.5-m aboveground (Figure 2). Each location an acoustic unit was deployed was geolocated with a Garmin GPSMAP 64. These units are accurate within 5 to 15 m, depending on conditions. During each sampling session, acoustic sampling occurred for a minimum of three consecutive nights to account for random variation in nightly activity patterns. Data were collected from sunset to sunrise each night of sampling. The sunrise and sunset times were determined by a program in the SM3 units.

The pre-treatment transects contained a ridge top, mid-slope, and riparian sampling point (Figure 4, 6, 7, 8). Unharvested treatments and shelterwood harvests largely maintained the same transect layout post-harvesting as during pre-treatment sampling. Ideally, the acoustic units were deployed at the same point pre- and post-harvest. However, points were moved in some instances, typically within a few meters, due to a previous tree used to mount a unit being lost in the harvest. Patch cuts did not have a riparian area sampled, as described in the experimental design section (Figures 5, 9). Units were directed towards the center of the patch cut.

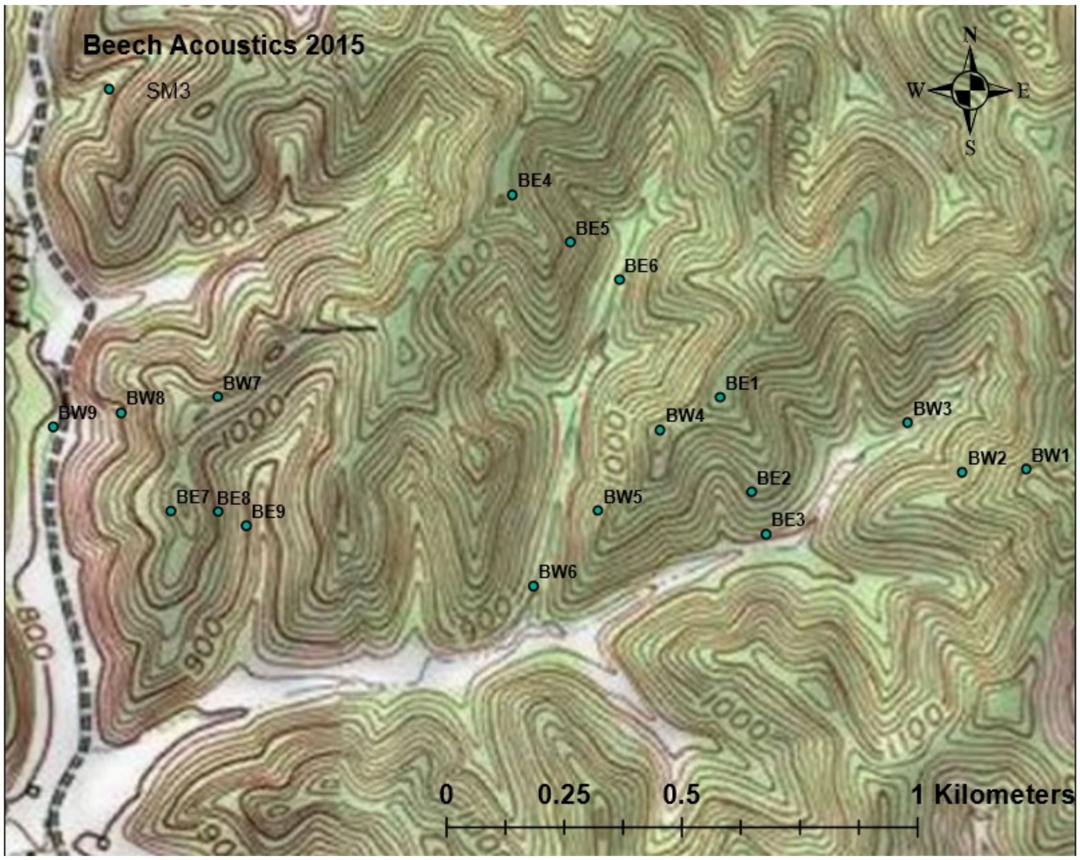


Figure 4. Pre-harvest (2015) acoustic transects at the Beech tract.

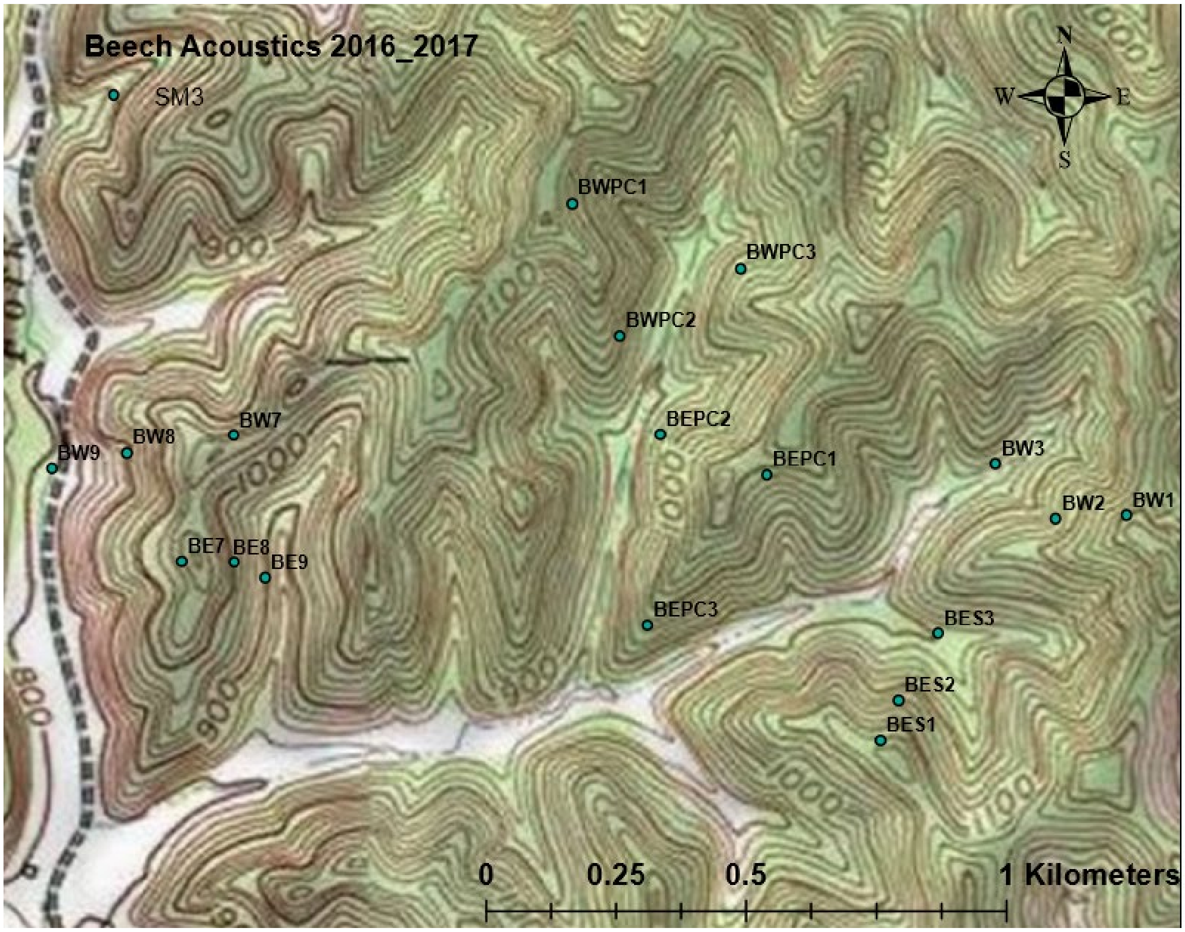


Figure 5. Post-harvest (2016-17) acoustic transects at the Beech tract.

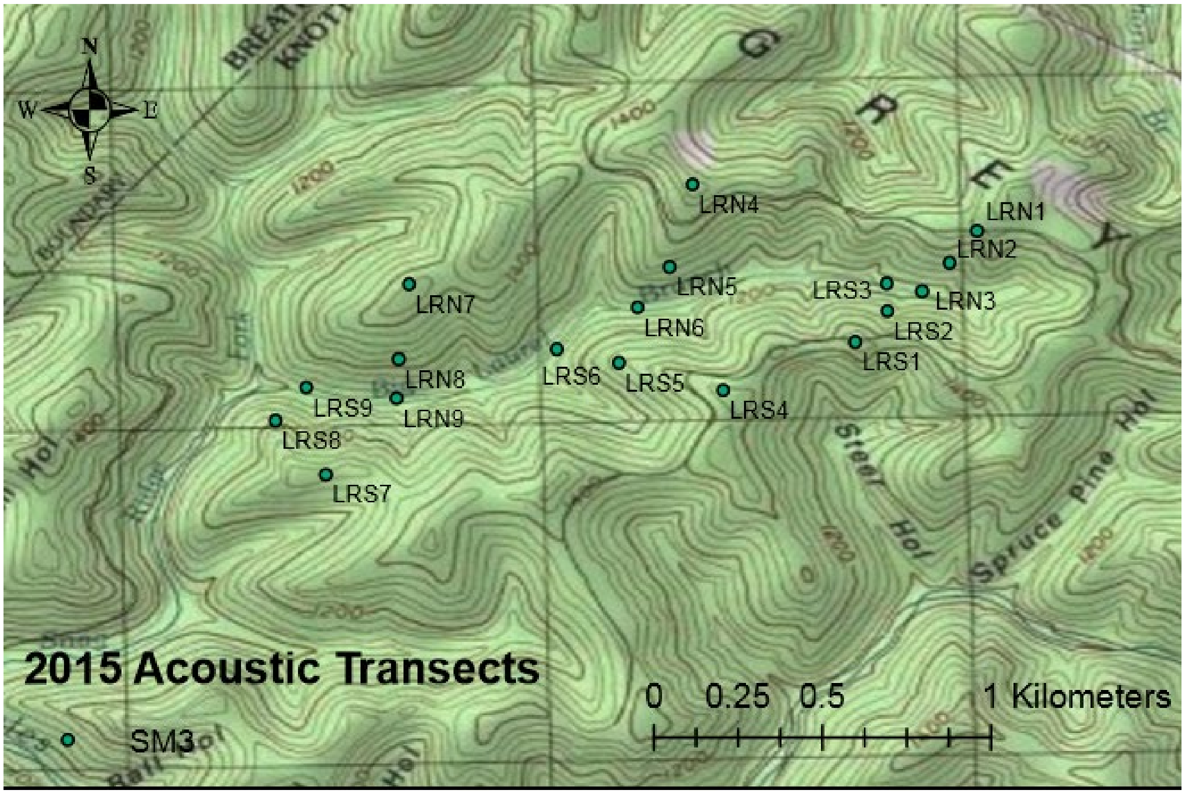


Figure 6. Pre-harvest (2015) acoustic transects at the Laurel Ridge tract, Robinson Forest.

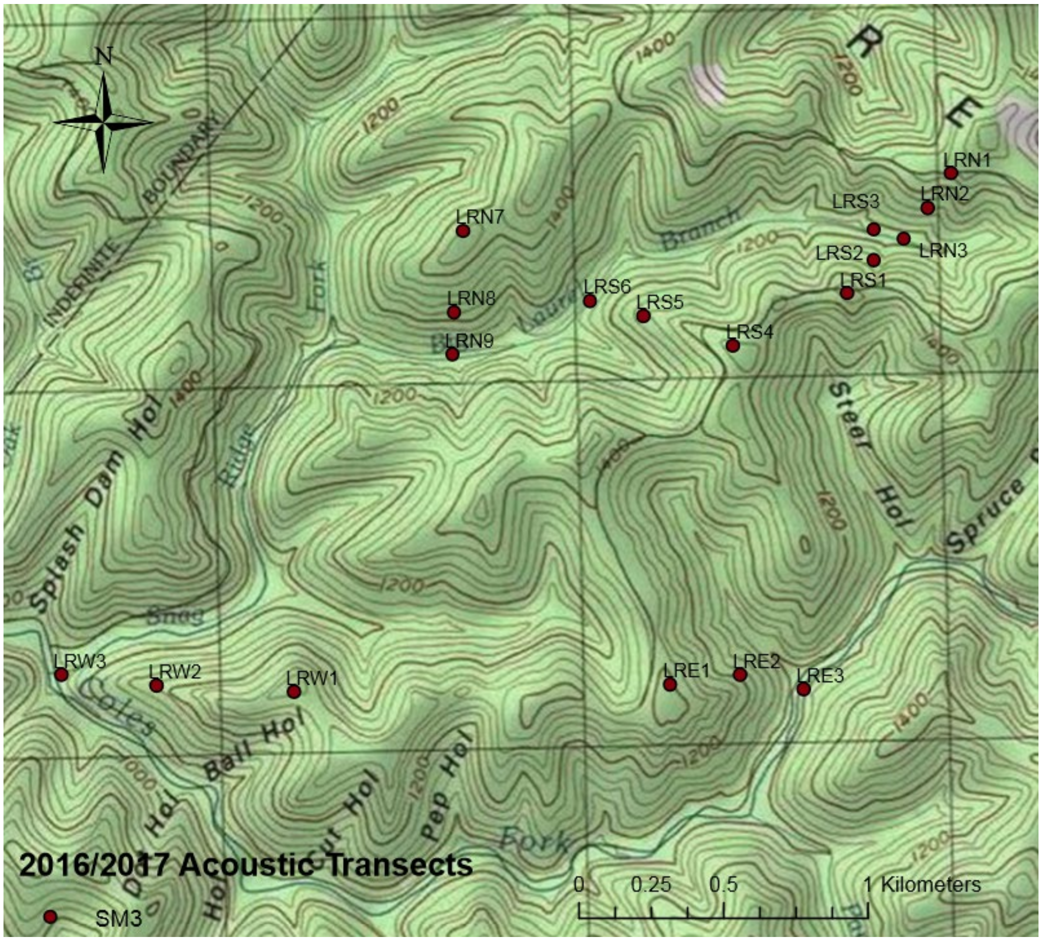


Figure 7. Pre-harvest (2016-17) acoustic transects at the Laurel Ridge tract, Robinson Forest.

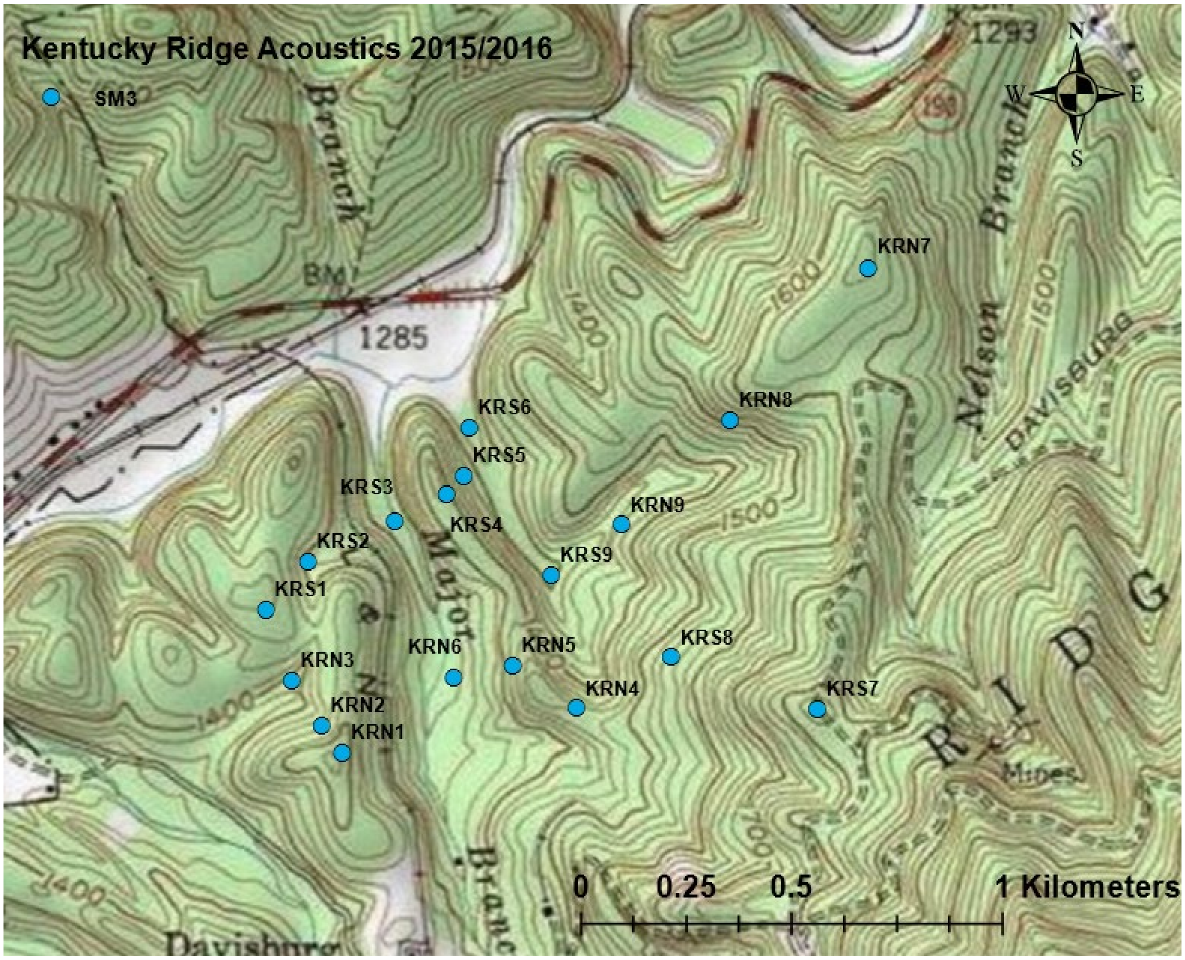


Figure 8. Pre-harvest (2015-16) acoustic transects at the Kentucky Ridge tract.

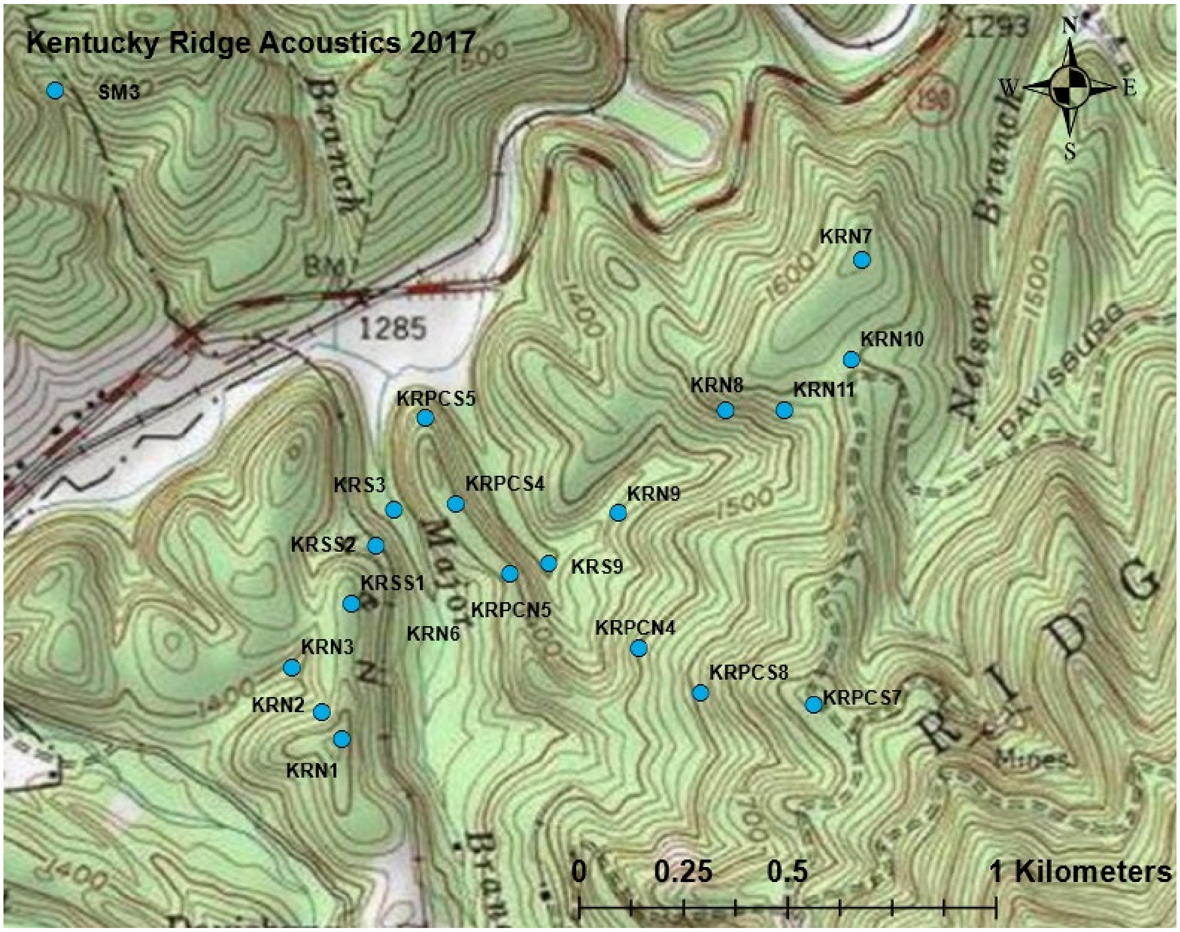


Figure 9. Post-harvest (2017) acoustic transects at the Kentucky Ridge tract.

Analysis of Acoustic Data

Acoustic data were analyzed using Kaleidoscope v. 3.1.8 (Wildlife Acoustics, Maynard, MA). Data were analyzed in two separate forms, number of pulses and number of calls per species. Both species level identifications and number of pulses were determined by Kaleidoscope set to the Kentucky filter to identify species. A few calls assigned to species known to not occur in eastern Kentucky, gray bat (*Myotis grisescens*) and southeastern bat (*M. austroriparius*), were deemed misclassified and not analyzed. Data were compiled, organized, and analyzed using 'R' statistical software 3.5.0 -Joy in

Playing (R Core Team 2013). The packages nlme, agricolae, plyr, magrittr, ggplot2, qcc, multcomp, and dplyr were accessed during data analysis. Data were sorted with a filter function to remove any call with ≤ 4 pulses, a quality less than 10, and a margin greater than 0.3. Count and aggregate were used to summarize the data for statistical tests. Coding is provided (Appendix I).

A quasi-poisson model of pulses was ran to compare activity differences between slope positions within a treatment. A quasi-poisson model was performed for year, as a proxy for pre- and post-harvest data, on the call data to assess how species responded to harvests.

Arthropod Sampling and Analysis

Light trap sampling occurred in pre- and post-harvest sites from late July 2015 thru early September 2017. Each location where a light trap was deployed was geolocated with a Garmin GPSMAP 64. These units are accurate within 5 to 15 m, depending on conditions. Universal backlight traps (Bioquip Products Inc., Rancho Dominguez, CA) were used to sample positively phototactic arthropods active at sampling sites. Arthropods were euthanized by Nuvan Prostrips; active ingredient - DDVP or 2,2-Dichlorovinyl dimethyl phosphate (Amvac, Los Angeles, CA). In 2015, I deployed light traps by hanging them from a tree 50 m from any active acoustic unit at ridge top, mid-slope, and riparian slope positions (Figures 10, 11, 12, 13, 14). During 2016 and 2017, I deployed traps only at mid-slope points due to time and labor constraints (Figures 15, 16). Traps were operated from sunset to sunrise on nights without rain. Specimens were put in plastic containers and placed in a freezer for long-term storage. Captured insects were keyed to taxonomic Order and enumerated.

In total, 109 samples (76 unharvested, 17 shelterwood, and 16 patch cut) were collected from the three field sites (Beech n = 33, Kentucky Ridge n = 43, and Laurel Ridge n = 33) over the course of three summers. Pre-harvest data were collected from all field sites in 2015. During that period, 23 light trap samples from unharvested forests were collected. One transect of light traps was established at the Beech property and resulted in 5 successful samples (2 ridge top, 2 mid-slope, and 1 riparian). One transect of light traps was established at Laurel Ridge resulting in 6 successful samples (2 ridge top, 2 mid-slope, and 2 riparian). Two transects were placed at Kentucky Ridge State Forest and resulted in 12 successful samples (4 ridge top, 4 mid-slope, and 4 riparian).

In late-2015 and early-2016 the Beech tract was harvested. All samples collected from each site during 2016 were at mid-slope positions. Sampling was intended to have an unharvested sample coupled with two harvest treatment samples at the Beech property; however, consistent trap failures resulted in harvest samples not always being paired with an unharvested sample. During 2016, 15 samples (4 unharvested, 4 shelterwood, and 7 patch cut) were collected from the Beech property. Kentucky Ridge had 13 samples collected and Laurel Ridge had 16 samples successfully collected. In total, 44 successful samples were collected in 2016.

In late-2016 and early-2017 the Kentucky Ridge site was harvested. All samples collected from each site in 2017 were at mid-slope positions. Samples were intended to have an unharvested sample coupled with two harvest treatment samples at the two harvested properties (Beech and Kentucky Ridge); however, trap failures resulted in harvest samples not always being paired with unharvested samples. The Beech site had 13 successful samples (4 unharvested, 5 shelterwood, and 4 patch cut). Kentucky Ridge had 18 successful samples (5 unharvested, 5 shelterwood, and 8 patch cut). Laurel Ridge had 11 successful unharvested samples. In total, 42 samples were collected during 2017.

Although light traps are designed to primarily capture Lepidopterans (moths) other orders of insects were commonly found in traps. Analysis was performed on the insect orders which appeared in greater than 60% of my sampling effort. Data for arthropod captures were analyzed using ‘R’ statistical software 3.5.0 -Joy in Playing (**R** Core Development Team, 2013). The packages nlme, agricolae, plyr, magrittr, ggplot2, qcc, multcomp, and dplyr were accessed during data analysis. I used multi-way analysis of variance (ANOVAs) to detect differences in total abundance, order count, and number of individuals for the five dominant orders collected separately, i.e., Lepidoptera, Coleoptera, Diptera, Hemiptera, and Hymenoptera. I examined differences by slope position, tract, year, and treatment. I used slope position and treatment as fixed effects, with tract as the random effect.

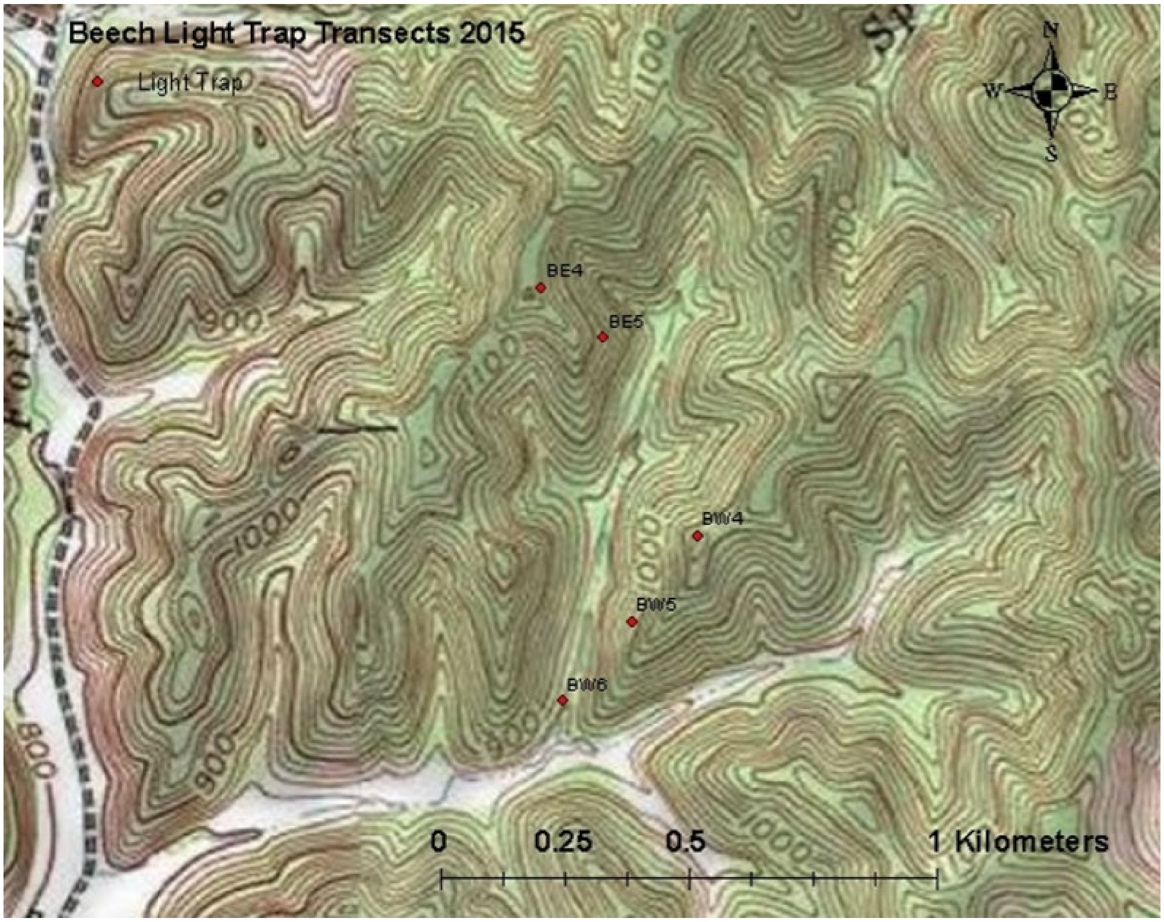


Figure 10. Pre-harvest (2015) light trap transects at the Beech tract.

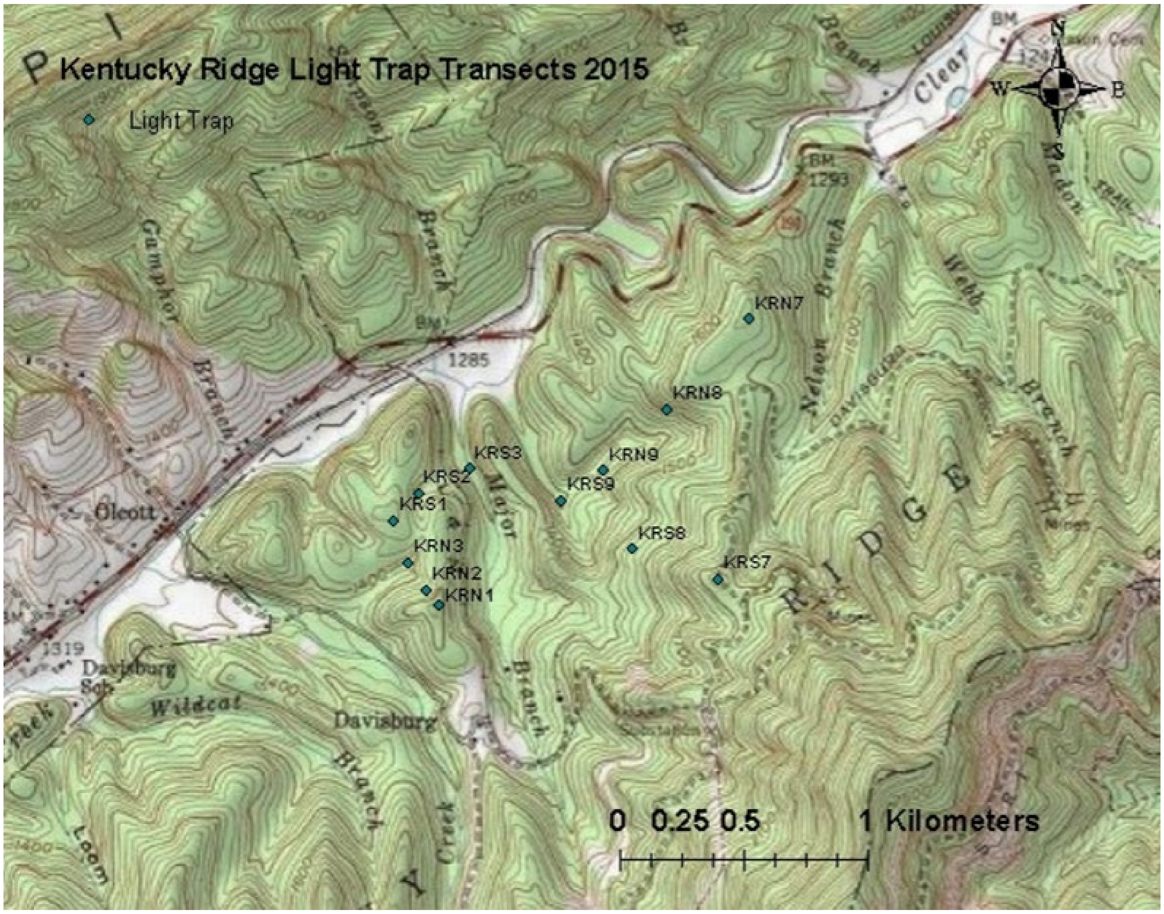


Figure 11. Pre-harvest (2015) light trap transects at the Kentucky Ridge tract.

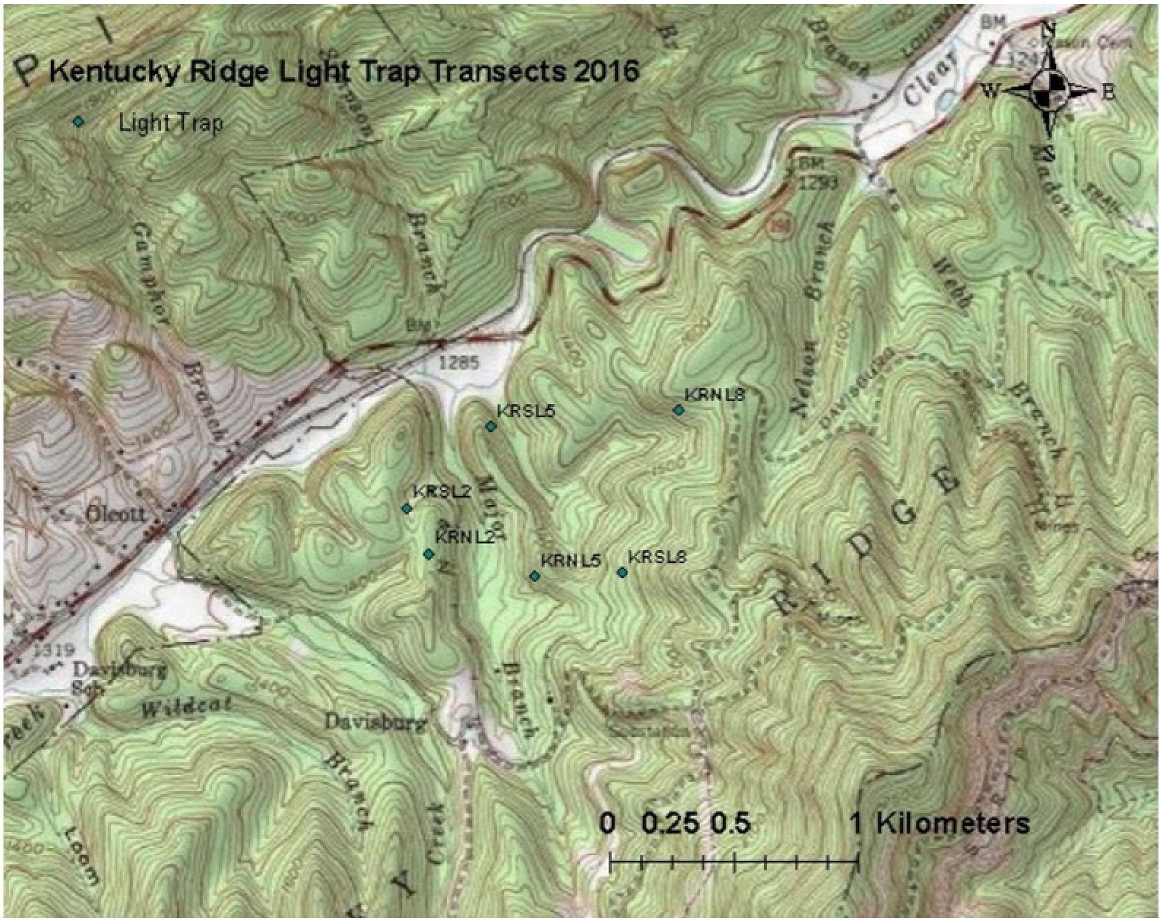


Figure 12. Pre-harvest (2016) light trap transects at the Kentucky Ridge tract.

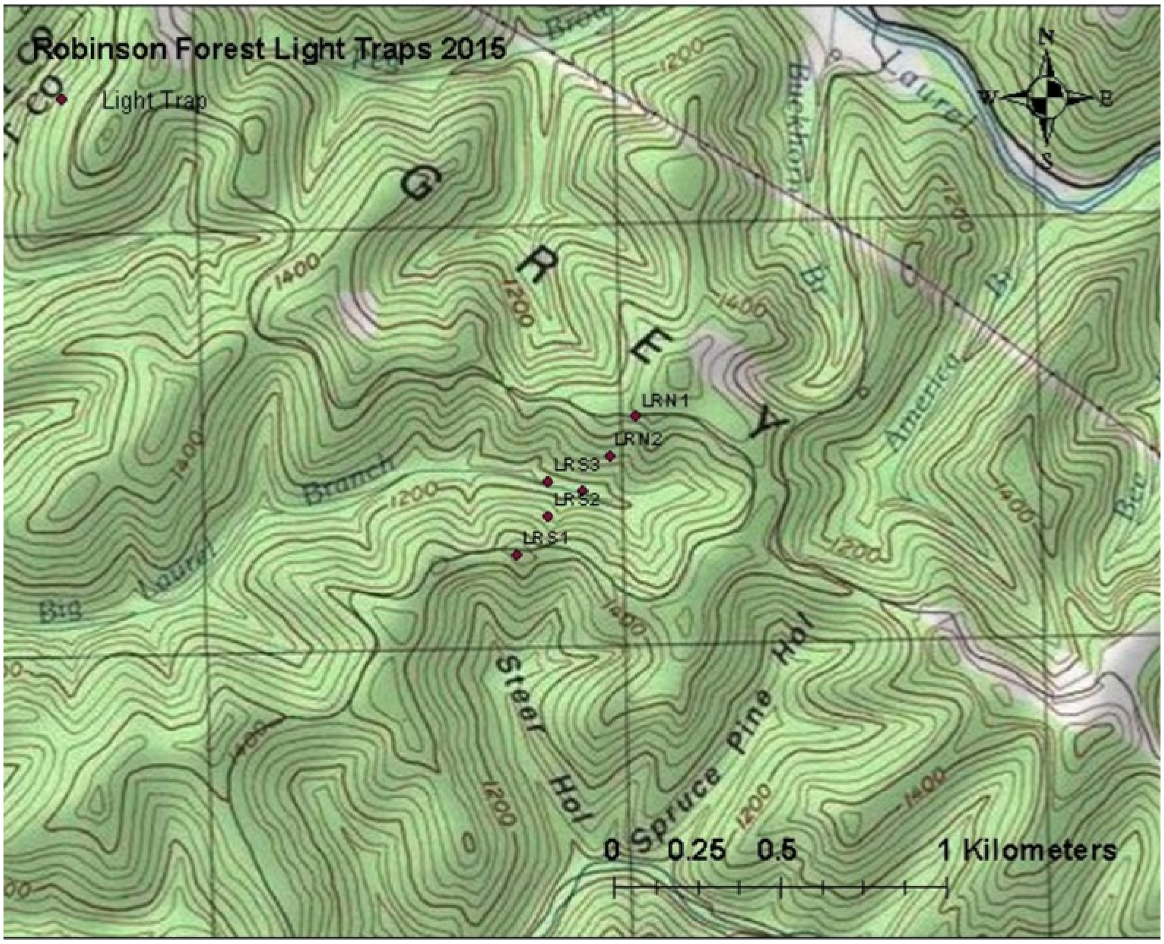


Figure 13. Pre-harvest (2015) light trap transects at the Laurel Ridge tract, Robinson Forest.

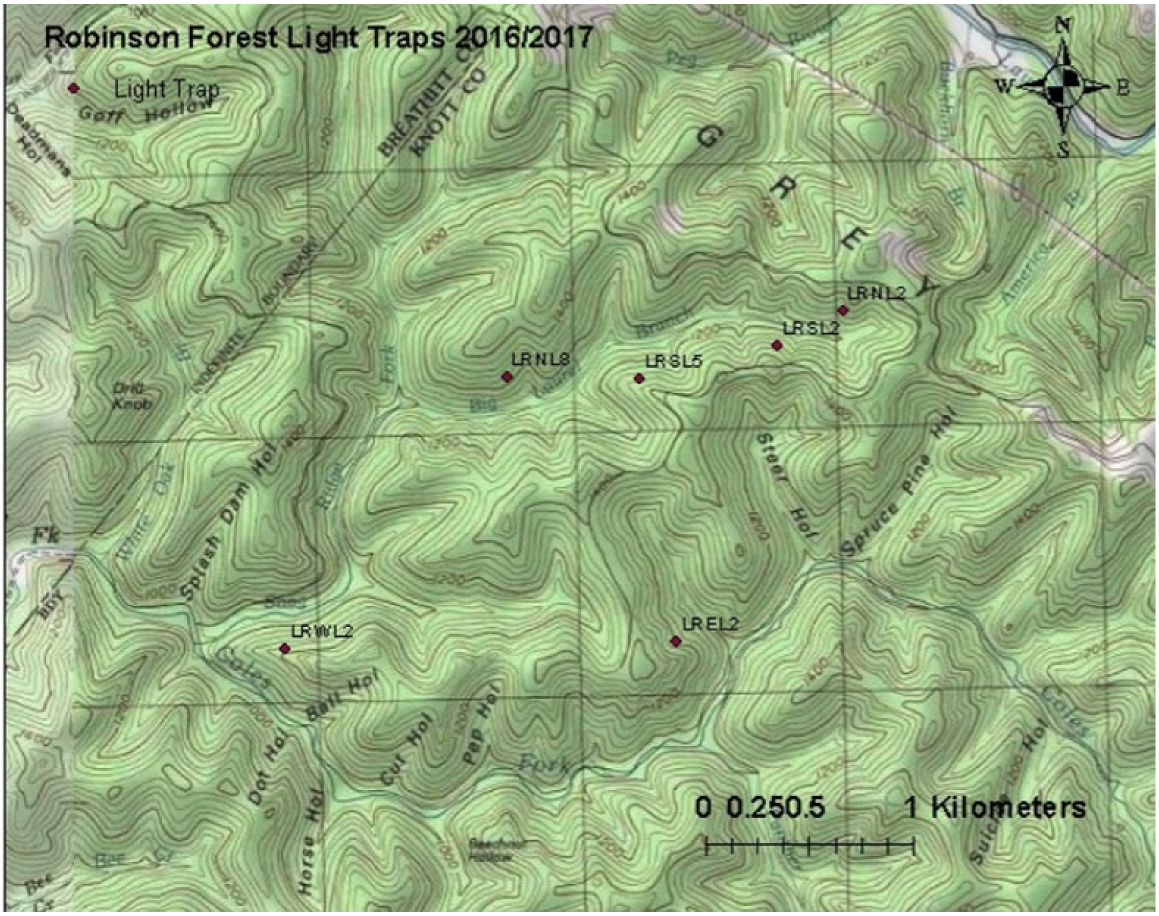


Figure 14. Pre-harvest (2016-17) light trap transects at the Laurel Ridge tract, Robinson Forest.

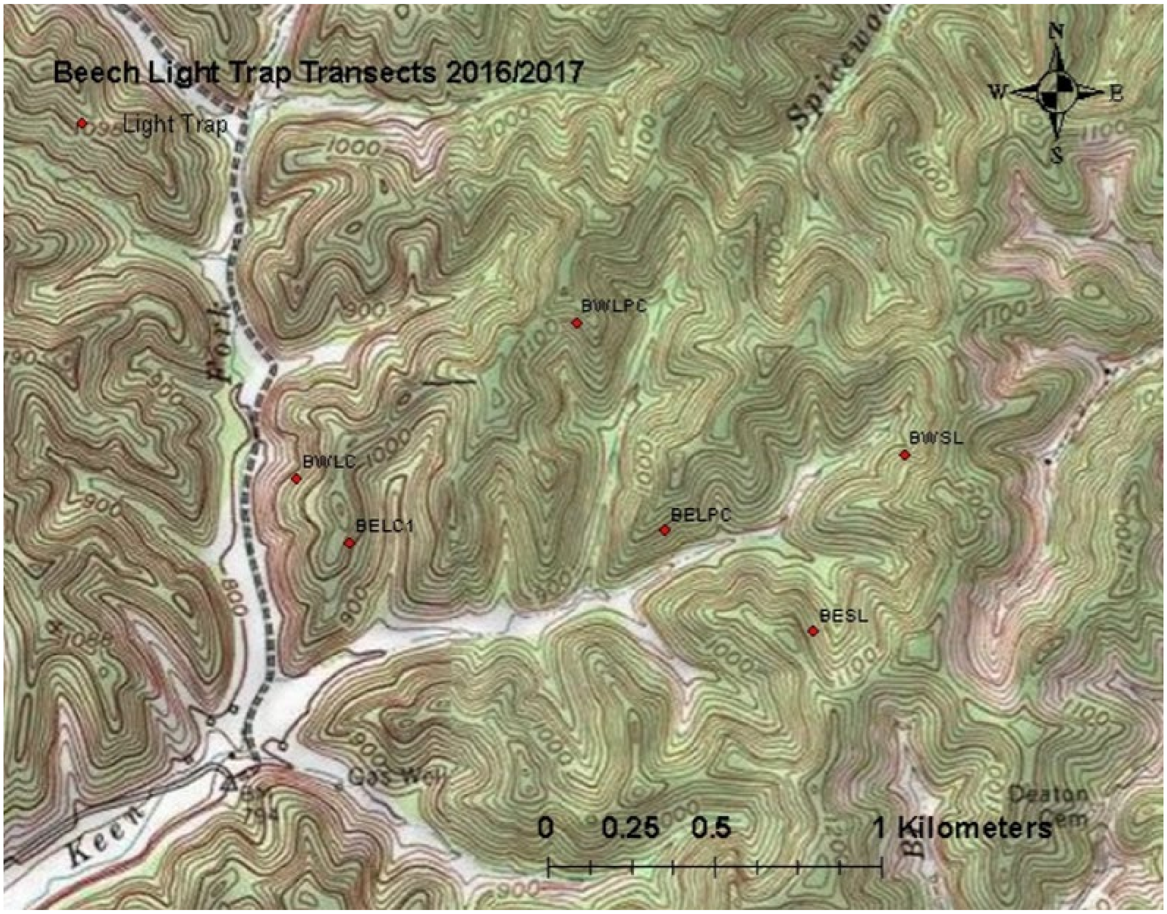


Figure 15. Post-harvest (2016-17) light trap transects at the Beech tract.

Figure 16. Post-harvest (2017) light trap transects at the Kentucky Ridge tract.

Mist Net Sampling

Bats were captured at Robinson Forest from 19 May to 20 August 2016, 9 May to 1 August 2017, and 23 May to 13 July 2018. Netting sites were determined, in part, based upon results of acoustic data, with netting taking place in the vicinity of sampling points with high amounts of acoustic activity of Myotis bats. Robinson Forest was netted in four locations: camp, Little Buckhorn, Big Laurel Ridge, and Medicine Hollow from 2016 through 2018. Roughly 103 net nights occurred, with each net night being a pole set left up for several hours. Big Laurel Ridge and Medicine Hollow were within the study site, Laurel Ridge tract. Netting was rotated between these sites to capture and radio-tag northern long-eared bats from 2016 through 2017. Netting during 2018 was focused on determining species presence and presence of northern long-eared bats at the Laurel Ridge tract post-harvest. Camp was netted to train technicians to extract bats, determine species and sex of bats present in buildings, and determine if pups were being successfully reared in the residential buildings.

Closed canopy roads and streams were typical locations where nets were set to capture bats. Net were predominately placed across single-lane dirt roads using 2.6 X 2.6-m mist nets. However, net width ranged from 2.6 to 18 m in length and varied from single to triple-high sets depending on the location surveyed. Nets were raised using Avinet poles (Dryden, NY) as single highs, and as double and triple highs with the forest filter pole system (Bat Conservation and Management, Inc., Carlisle, PA). Post-harvest skidder trail roads, patch cuts, intact areas near shelterwood harvests, and the edge of logging roads were also sampled with nets using the forest filter system.

Additional mist netting occurred at the Beech tract from May to September 2015 to 2017 at two habitat types, along streams within the unharvested section and in the skidder trails between patch cuts. Eleven net nights occurred, 9 in 2016 and 2 in 2017. The patch cuts at the Beech tract were surveyed with the forest filter system. Netting at the Beech tract was aimed at confirming determining species presence on the site.

I collected data on all bats captured, including: mass (g), right forearm length (mm), reproductive condition, Reichard wing score (Reichard and Kunz 2009), sex, age (Brunet-Rossinni and Wilkinson 2009), height in net, and presence of parasites. Age was determined by shining a light through the joints of the finger bones. Adult bones are ossified, and light does not pass through. Juvenile bones are not fully ossified, and light passes between the bones in the finger joints. Pregnancy was determined by a swollen stomach. Palpation for fetuses did not occur. Lactation was determined when a patch of hair around the mammary glands was absent. Reproductive status of males was determined by examining the scrotal region for descended epididymes. During 2016, all captured bats were banded with 2.4- or 2.9-mm aluminum bands supplied by the Kentucky Department of Fish and Wildlife Resources (KDFWR). Bands were attached with banding pliers. Males were banded on the right forearm and females on the left forearm. In 2017 and 2018, only federally protected species were banded.

Radio-Telemetry

I attached radio-transmitters to captured Myotis bats to radio-track them to roost trees. Northern long-eared bats and Indiana bats were either banded or fitted with a transmitter. No individual received both to ensure <5% of the bat's body mass was added (Aldridge and Brigham 1988). LB-2XT transmitters (Holohil Systems, Ltd., Ontario, Canada) were glued between the shoulder blades of bats with surgical cement (Perma-Type Company, Inc., Plainville, CT). I tracked radio-tagged bats to roost trees daily using 3 or 5-element yagi antennae (Wildlife Materials, Inc., Murphysboro, IL) combined with either Icom IC-R20 radio receivers (Icom America, Inc, Kirkland, WA), R-1000 receivers (Communication Specialists, Inc., Orange, CA), or TRX-2000 receivers (Wildlife Materials, Inc., Murphysboro, IL). Bats were searched for each day until the transmitter was found dead or the bat could not be located for 3 consecutive days. In order to locate a signal, the yagi was placed out the window as we drove down the roads on Robinson Forest. The extensive road network allowed us to cover a large portion of the forest and was present in both riparian and ridgetop areas. If a signal was not located from the road network, we hiked from ridgetop to ridgetop to attempt to locate a signal. The signal was only periodically checked for beyond the 3-day limit if the bat was not located.

Description of Day Roosts

Trees located by radio-telemetry and confirmed by exit counts were designated as roost trees. Tree roosts that I located were identified to species and decay class recorded. Each located roost was geolocated with a Garmin GPSMAP 64. These units are accurate within 5 to 15 m, depending on conditions. The tree also received a permanent tree tag. I also sampled trees at randomly chosen plots. Random plots were assigned either 0 or 180 degrees to ensure they were located on either ridge top or mid-slope positions; the only landscape positions where northern long-eared bats were found roosting. These plots were determined using a random compass orientation between 0 or180 degrees, and a random distance >50 m from a known roost tree. Trees in a 10-m radius around each random sampling point were measured. I collected data on species and decay class for all stems with a dbh greater than 2.54 cm.

As bats were tracked to multiple roost trees, an exit count was performed the first night after a new roost was discovered. Counts started 20 min before sunset and ended 10 min after the last bat emerged from the roost. Personnel positioned themselves in an orientation that ensured the bats were silhouetted against the sky.

Results

Acoustic Sampling

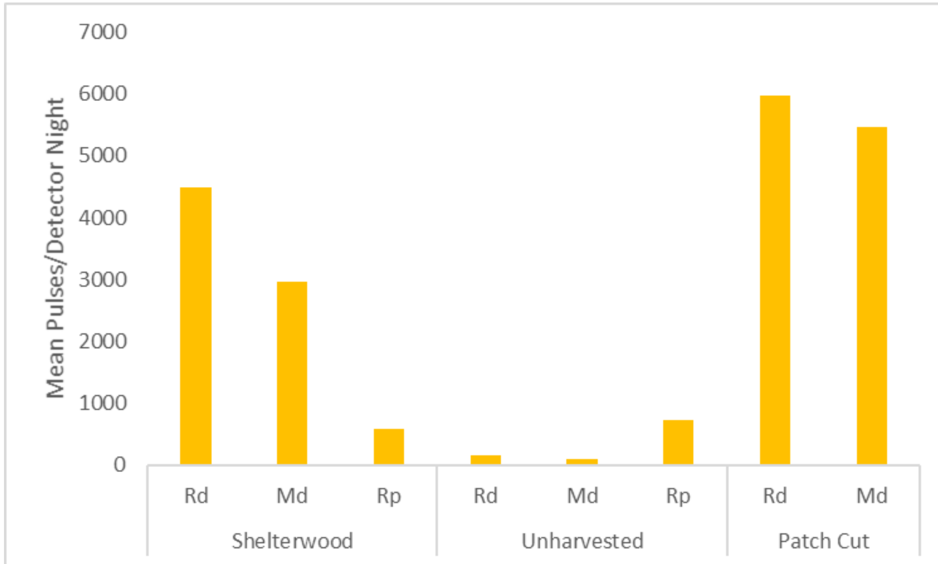
Acoustic sampling occurred in pre-harvest sites from late July 2015 thru early September 2017. During 2015, 310 nights of acoustic sampling data were collected from the Beech, Kentucky Ridge, and Laurel Ridge tracts. Data were used to determine the pre-harvest assemblage of bats present. Significant differences were found between sites for the number of silver-haired bat and northern long-eared bat calls. More silver-haired bat calls were detected at the Beech tract than Kentucky Ridge or Laurel Ridge tracts. More northern long-eared bat calls were detected at Laurel Ridge than at the Kentucky Ridge or Beech tracts (Table 1). The observed difference in bat assemblages across sites pre-harvest resulted in analyses being made for each site separately.

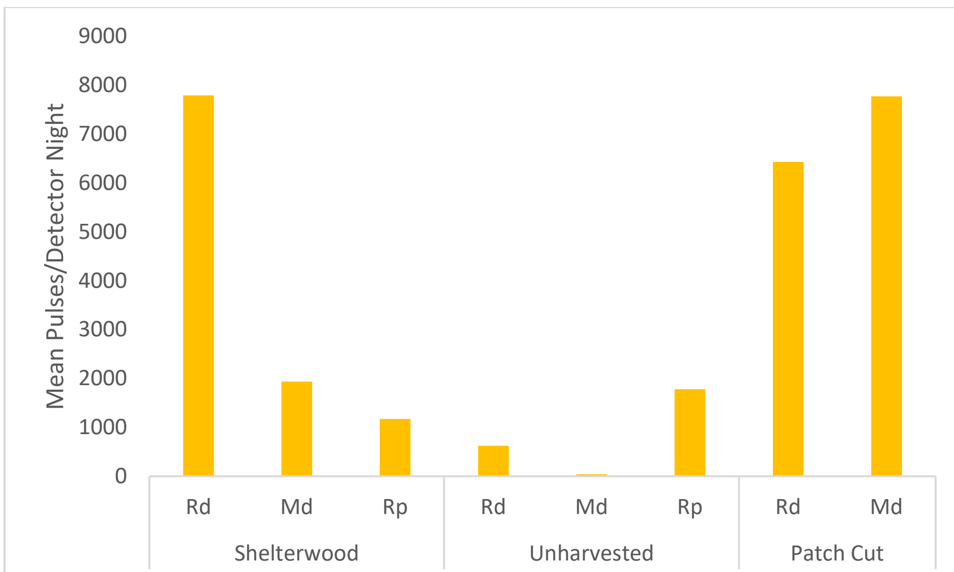
In total, 649 acoustic nights (1 detector per night = acoustic night) of data were collected at the Beech tract. Post-harvest, 2016 and 2017, 154 acoustic nights of data were collected from unharvested forest, 173 from the shelterwood, and 163 from the patch cut. At the Kentucky Ridge tract, 492 acoustic nights of data were collected. Post-harvest 2017, 59 acoustic nights were collected from the unharvested forest, 77 from the shelterwood harvests, and 63 from the patch cut harvests.

Figure 17 is a qualitative comparison of the harvest types. Data from Laurel Ridge is provided, but will not be extensively discussed because it occurred after my thesis work had concluded. Both the shelterwood and patch cut harvests had higher activity than the unharvested treatment at the Beech and Kentucky Ridge sites. The ridgetop and mid-slope positions in patch cuts had similar activity levels at both Beech and Kentucky Ridge sites. The ridgetop position in the shelterwood had higher activity than the mid-slope position at both the Beech and Kentucky Ridge sites, and both positions had higher activity than the respective unharvested sections. Laurel Ridge had high activity in the ridgetop of the impacted control, likely because the ridgetop roads were harvested. The high activity in the riparian area of the shelterwood in Laurel Ridge was likely due to the stream being perennial and wider than the intermittent streams near the control and patch cut treatments.

A quasi-poisson model comparing years showed significant increase in activity post-harvest at the Kentucky Ridge (649 acoustic nights) and Beech properties (492 acoustic nights). A quasi-poisson model comparing slope positions post-harvest, showed differences between shelterwood slope positions. At the Beech property the ridge top and mid-slope positions had more bat activity than the riparian positions. The shelterwood harvest ridge top at the Kentucky Ridge tract had more bat activity than the mid-slope or riparian positions. No difference was found between the ridgetop and mid-slope positions within patch cuts (Table 2).

A quasi-poisson model comparing species activity pre-and post-harvest was performed for the Beech (601 acoustic nights) and Kentucky Ridge sites (435 acoustic nights). At the Beech tract activity increased for big brown bat, red bat, silver-haired bat, evening bat, and tri-colored bat. Activity of little brown bat increased the second-year post-harvest, but not the first year. No consistent trend occurred with hoary bat. Activity of northern long-eared bat decreased; activity of Indiana bat was too infrequent to determine any patterns (Table 3). At the Kentucky Ridge tract activity increased for Rafinesque big-eared bat, big brown bat, red bat, silver-haired bat, hoary bat, little brown bat, and tri-colored bat. No consistent trend was observed for evening bat. Activity of northern long-eared bat and Indiana bat was too low to determine any patterns (Table 4). The harvest at Laurel Ridge occurred after the completion of my thesis work and will not be detailed in this document; however, Figure 18 serves as a visual reference of results including the post-harvest data from the Laurel Ridge tract.


Mean Pulses/Detector Night
7000
6000
5000
4000
3000
2000
1000
0
Rd
Md
Rp
Rd
Md
Rp
Rd
Md
Shelterwood
Unharvested
Patch Cut
a.


Mean Pulses/Detector Night
9000
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4000
3000
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Shelterwood
Unharvested
Patch Cut
b.

c.

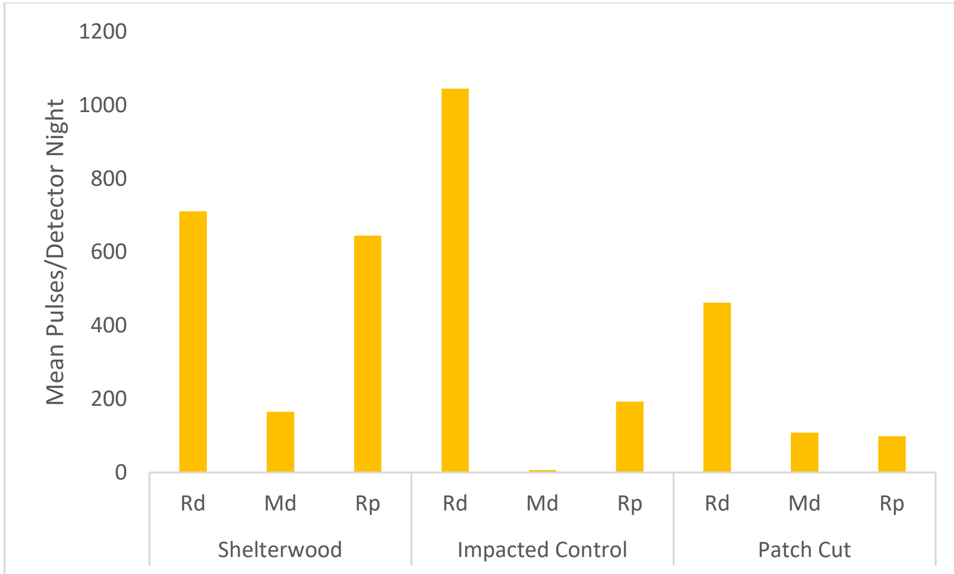
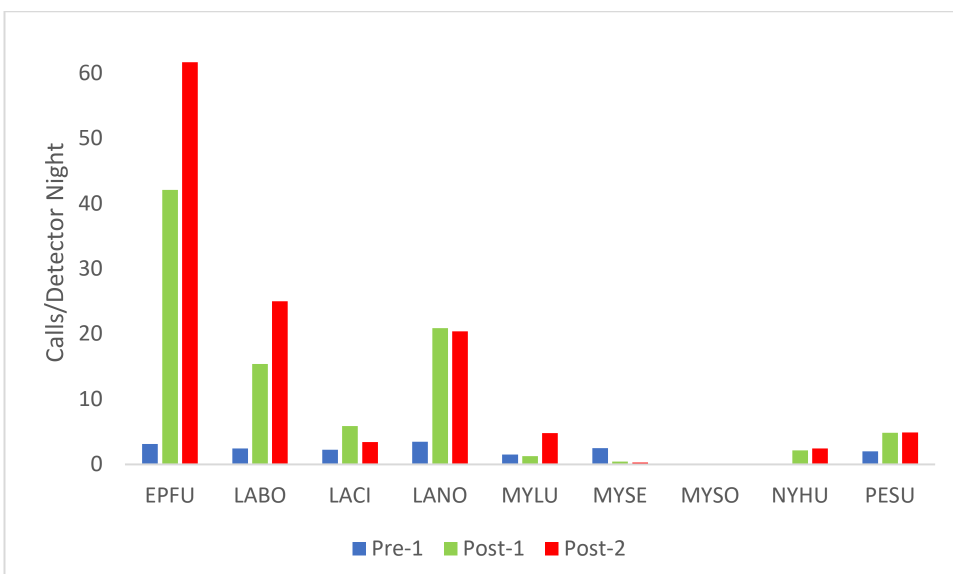
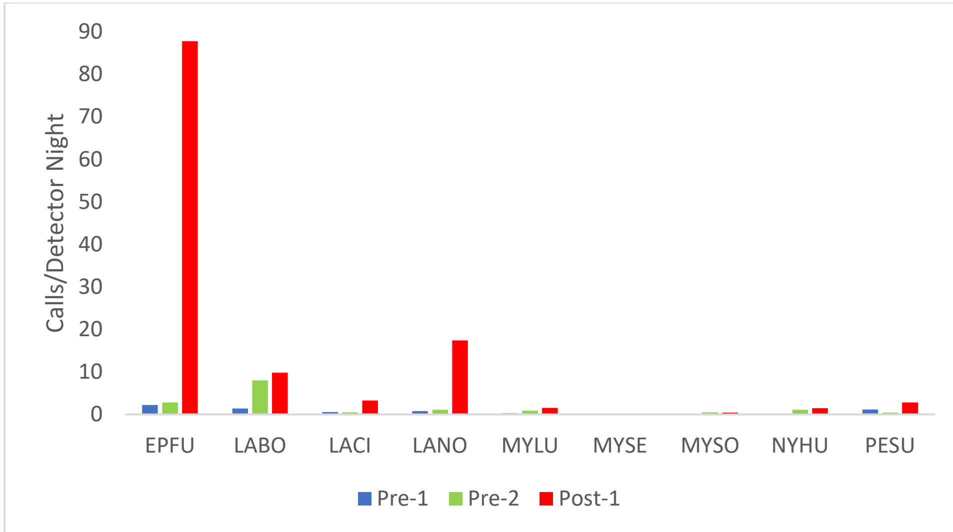


Figure 17. Comparison of activity of bats in different treatments and slope positions; ridgetop (rd), mid-slope (md), and riparian (rp). Beech (a), Kentucky Ridge (b), and Laurel Ridge (c) tracts in eastern Kentucky.

a.



b.



c.

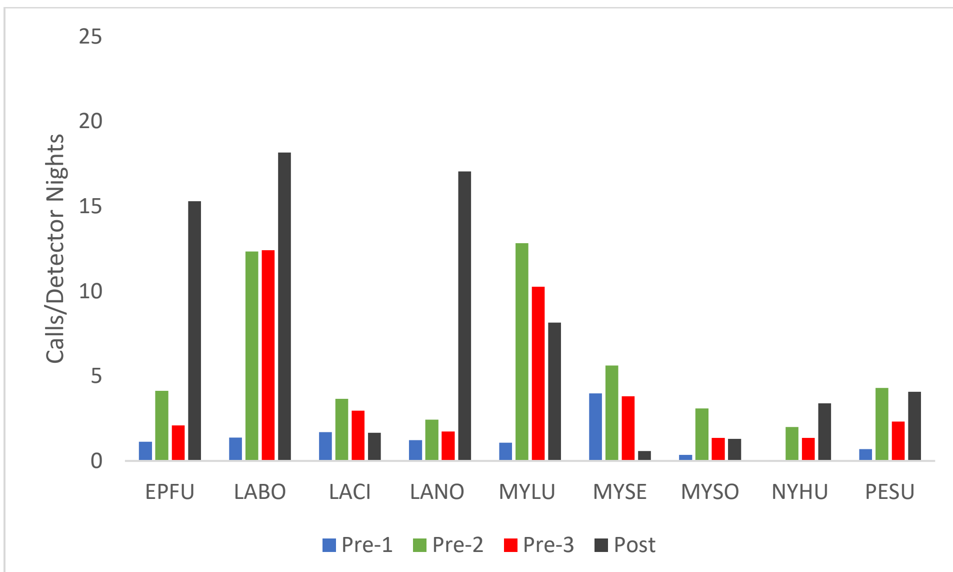


Figure 18. Activity of bat species pre-and post-harvest at; Beech (a), Kentucky Ridge (b), and Laurel Ridge (c) tracts in eastern Kentucky. (Blue (2015), Green (2016), Red (2017), and Black (2018). The pre-x designation denotes the site had not yet been harvested and the number of seasons the site has been sampled pre-harvest. The post-x designation denotes the site has been harvested and the number of seasons the site has been sampled post-harvest.

Table 2. Comparison of mean pulses per detector night at the slope position in each treatment at Beech tract, Oakdale, KY and Kentucky Ridge State Forest, Chenoa, KY.

Parameter	Ridgetop	Mid-slope	Riparian	df		F-value	P-value
	Mean ± SE	Mean ± SE	Mean ± SE	x	y		
Control Beech	149 [a] ± 36	84.3 [a] ± 23.6	723 [b] ± 166	2	154	13.1	<0.001
Shelterwood Beech	4490 [a] ± 556	2960 [a] ± 362	573 [b] ± 122	2	173	28.4	<0.001
Patch Cut Beech	5980 ± 1040	5470 ± 791	N/A	1	163	0.144	0.705
Control Kentucky Ridge	626 [b] ± 219	38.9 [a] ± 9.64	1780 [ab] ± 556	2	59	4.63	0.0135
Shelterwood Kentucky Ridge	7990 [a] ± 1320	1940 [b] ± 250	1170 [b] ± 341	2	77	20.2	<0.001
Patch Cut Kentucky Ridge	6430 ± 1510	7770 ± 1510	N/A	1	63	0.437	0.511

[a,b] Within rows, means without common letters are groups with statistical difference.

Table 3. Pre- and post-harvest species activity (calls per detector night) based upon Kaleidoscope species assignments at Beech tract, Oakdale, KY.

Parameter	**2015 - Pre**	**2016 – Post 1st**	**2017 – Post 2nd**	**df**		**F-value**	**P-value**
	Mean ± SE	Mean ± SE	Mean ± SE	x	y		
COTO	0.106 [a] ± 0.0347	0.317 [b] ± 0.0595	0.163 [a] ± 0.0315	2	601	4.97	0.00725
EPFU	3.15 [a] ± 0.835	42.1 [b] ± 4.92	61.7 [c] ± 7.46	2	601	19.8	<0.001
LABO	2.47 [a] ± 0.679	15.4 [b] ± 1.51	25 [c] ± 2.95	2	601	21.6	<0.001
LACI	2.24 [a] ± 0.806	5.87 [ab] ± 0.68	3.44 [b] ± 1.04	2	601	4.2	0.0154
LANO	3.49 [a] ± 0.779	20.9 [b] ± 1.84	20.4 [b] ± 2.83	2	601	14.5	<0.001
MYLE	0.0611 ± 0.0210	0.0284 ± 0.0106	0.022 ± 0.0976	2	601	2.12	0.121
MYLU	1.53 [a] ± 0.431	1.26 [a] ± 1.53	4.8 [b] ± 0.881	2	601	11.5	<0.001
MYSE	2.48 [a] ± 0.757	0.419 [b] ± 0.0881	0.304 [b] ± 0.0661	2	601	13.3	<0.001
MYSO	0.0534 ± 0.0463	0.0732 ± 0.0210	0.119 ± 0.0292	2	601	1.19	0.304
NYHU	0.0763 [a] ± 0.0369	2.13 [b] ± 0.222	2.44 [b] ± 0.285	2	601	21.5	<0.001
PESU	2.02 [a] ± 0.619	4.83 [b] ± 0.647	4.9 [b] ± 0.721	2	601	4.28	0.0143

[a,b,c] Within rows, means without common letters are groups with statistical difference.

Table 4. Pre- and post-harvest species activity (calls per detector night) based upon Kaleidoscope species assignments at Kentucky Ridge State Forest, Chenoa, KY.

Parameter	2015 - Pre	2016 - Pre	2017 – Post 1st	df		F-value	P-value
	Mean ± SE	Mean ± SE	Mean ± SE	x	y		
COTO	0.0606 [a] ± 0.0296	0.114 [a] ± 0.0531	1.63 [b] ± 0.389	2	435	9.38	<0.001
EPFU	2.21 [a] ± 0.721	2.8 [a] ± 0.901	87.8 [b] ± 9.29	2	435	51	<0.001
LABO	1.42 [a] ± 0.387	7.98 [ab] ± 2.22	9.79 [b] ± 1.38	2	435	3.38	0.0351
LACI	0.545 [a] ± 0.124	0.52 [a] ± 0.0853	3.26 [b] ± 0.506	2	435	17.4	<0.001
LANO	0.803 [a] ± 0.228	1.11 [a] ± 0.247	17.4 [b] ± 1.42	2	435	79.4	<0.001
MYLE	0.0758 [ab] ± 0.0328	0.194 [a] ± 0.0571	0.0558 [b] ± 0.0193	2	435	3.47	0.0319
MYLU	0.258 ± 0.0817	0.863 ± 0.151	1.53 ± 0.417	2	435	2.71	0.0679
MYSE	0.0455 ± 0.0258	0.0514 ± 0.0203	0.0609 ± 0.0235	2	435	0.0897	0.914
MYSO	0.0909 ± 0.0417	0.508 ± 0.139	0.381 ± 0.124	2	435	1.53	0.218
NYHU	0.0152 ± 0.0152	1.09 ± 0.426	1.46 ± 0.245	2	435	2.86	0.0582
PESU	1.17 [a] ± 0.418	0.417 [a] ± 0.0791	2.85 [b] ± 0.447	2	435	14.2	<0.001

[a,b,c] Within rows, means without common letters are groups with statistical difference.

Arthropod Sampling

Data for arthropods by slope position (ridge top, mid-slope, and riparian) generated in 2015 were compared using ANOVAs. Seven separate tests were ran for each metrics of insect presence: total abundance of insects, number of arthropod orders, lepidopteran abundance (moths), coleopteran abundance (beetles), hymenopteran abundance (wasps, bees and ants), dipteran abundance (flies and mosquitoes), and hemipteran abundance (true bugs) (Table 5). Ridge top communities contained a higher mean abundance of insects and lepidopterans than riparian communities (Table 5). Mid-slope communities were not different than ridge top or riparian communities (Table 5). There was no difference between the ridge top and mid-slope samples (Table 5). There was no difference among ridge top, mid-slope, and riparian communities in number of arthropod orders, coleopteran abundance, hymenopteran abundance, dipteran abundance, or hemipteran abundance (Table 1).

Data for all years of sampling (2015, 2016, and 2017) were compared using ANOVAs. Seven separate tests were ran for each metrics of insect presence: total abundance of insects, number of arthropod orders, lepidopteran abundance, coleopteran abundance, hymenopteran abundance, dipteran abundance, and hemipteran abundance (Table 6). The number of arthropod orders collected was significantly different between 2015 and 2017 (Table 2), with the mean number of orders in 2015 being higher than in 2017. The outcome was potentially influenced by sampling effort. Most of the additional orders collected were incidental and sporadic observations, and would have likely been detected in a more intensive survey in 2017. There was no difference in the number of orders collected between 2016 and 2015, or 2016 and 2017. No difference was found between 2015, 2016, and 2017 in the total abundance of insects, lepidopteran abundance, coleopteran abundance, hymenopteran abundance, dipteran abundance, or hemipteran abundance (Table 6). Variation among sites (Beech, Kentucky Ridge, Laurel Ridge) was compared using seven different metrics of insect presence with no difference observed for any metric evaluated (Table 7).

The harvest treatment type (unharvested, shelterwood, and patch cut) was evaluated using seven separate ANOVA tests on the total abundance of insects, number of arthropod orders, lepidopteran abundance, coleopteran abundance, hymenopteran abundance, dipteran abundance, and hemipteran abundance (Table 8). The mean number of lepidopterans collected was lower at shelterwood and patch cut stands than unharvested stands (Table 8). There was no difference between shelterwood and patch cut stands (Table 8). No difference was found among treatment type in total abundance of insects, number of arthropod orders, coleopteran abundance, hymenopteran abundance, dipteran abundance, or hemipteran abundance (Table 8).

Table 5. Effects of slope position on insect diversity and abundance (# per trap night) at three sites: Laurel Ridge, Clayhole, KY; Beech tract, Oakdale, KY; and Kentucky Ridge State Forest, Chenoa, KY.

Parameter	Ridgetop	Mid-slope	Riparian	df	F	p-value
	Mean SE	Mean SE	Mean SE	x, y		
Total Abundance	701^{ab}, 152	386^{ab}, 76.3	259^{b}, 40	2, 20	4.68	0.0215
Number of Orders	6.25, 0.366	6, 0.535	6.42, 0.896	2, 20	0.122	0.886
Lepidoptera	546^{a}, 106	315^{ab}, 69.9	196^{b}, 37.7	2, 20	4.98	0.0176
Coleoptera	130, 16.8	47.8, 86.4	36.4, 8.38	2, 20	0.932	0.410
Hymenoptera	10.1, 2.11	9.5, 2.62	8.57, 2.26	2, 20	0.107	0.899
Diptera	4.5, 1.32	3.63, 0.730	2.71, 1.57	2, 20	0.515	0.605
Hemiptera	6, 2.79	7.25, 4.19	4.71, 1.46	2, 20	0.159	0.854

^{a,b} Within rows, means without common letters are groups with statistical difference.

Table 6. Effects of year on control samples of insect diversity and abundance (# per trap night) at three sites: Laurel Ridge, Clayhole, KY; Beech Tract, Oakdale, KY; and Kentucky Ridge State Forest, Chenoa, KY.

Parameter	2015 Mean SE	2016 Mean SE	2017 Mean SE	df x, y	F	p-value
Total Abundance	386, 76.3	386, 42.5	516, 97.5	2, 58	1.13	0.330
Number of Orders	6[a], 0.535	6.58[ab], 0.222	4.8[b], 0.414	2, 58	8.56	0.0005
Lepidoptera	315, 69.9	294, 33.4	456, 84.8	2, 58	2.32	0.107
Coleoptera	47.8, 16.8	68.6, 12.4	38.3, 9.39	2, 58	1.66	0.199
Hymenoptera	9.5, 2.62	7.52, 1.01	13.2, 4.61	2, 58	1.2	0.308
Diptera	3.63, 0.730	5.61, 0.982	4.7, 2.55	2, 58	0.238	0.789
Hemiptera	7.25, 4.19	3.61, 1.4	2.85, 1.05	2, 58	0.954	0.391

[a,b] Within rows, means without common letters are groups with statistical difference.

Table 7. Site differences in light trap sampling for insect diversity and abundance (# per trap night) at three sites: Laurel Ridge, Clayhole, KY: Beech tract, Oakdale, KY; and Kentucky Ridge State Forest, Chenoa, KY.

Parameter	Beech	Kentucky Ridge	Laurel Ridge	df	F	p-value
	Mean SE	Mean SE	Mean SE	x, y		
Total Abundance	443, 97.8	409, 42.9	470, 69.2	2, 73	0.266	0.767
Number of Orders	5.77, 0.323	6.53, 0.283	5.61, 0.331	2, 73	2.6	0.0813
Lepidoptera	317, 53.8	333, 35.3	393, 62	2, 73	0.523	0.595
Coleoptera	111, 53.1	51.1, 9.92	52.5, 10.9	2, 73	2.12	0.128
Hymenoptera	5.92, 0.902	7.8, 1.04	12.6, 2.88	2, 73	2.14	0.125
Diptera	2.39, 0.549	5.5, 1.04	5.06, 1.60	2, 73	0.916	0.405
Hemiptera	3.15, 1.04	4.8, 1.41	3.94, 1.45	2, 73	0.239	0.788

[a,b] Within rows, means without common letters are groups with statistical difference.

Table 8. Effects of harvest treatment on insect diversity and abundance (# per trap night) at two sites, Beech Tract, Oakdale, KY, and Kentucky Ridge State Forest, Chenoa, KY.

Parameter	Control	Patch Cut	Shelterwood	df	F	p-value
	Mean SE	Mean SE	Mean SE	x, y		
Total Abundance	392, 58.5	303, 70.6	237, 49.2	2, 43	1.58	0.218
Number of Orders	5.39, 0.311	5.31, 0.395	5.24, 0.474	2, 43	0.0314	0.969
Lepidoptera	342[a], 56	171[b], 34.8	137[b], 28.9	2, 43	7.29	0.0019
Coleoptera	36.9, 8.8	119, 49	88.5, 33.1	2, 43	1.19	0.315
Hymenoptera	5.46, 0.867	4.94, 1.09	4.88, 1.46	2, 43	0.0626	0.939
Diptera	2.92, 0.645	3.75, 1.23	2.29, 0.731	2, 43	0.655	0.525
Hemiptera	2.15, 1.06	0.875, 0.301	1.18, 0.346	2, 43	1.17	0.32

[a,b] Within rows, means without common letters are groups with statistical difference.

Mist Net Sampling

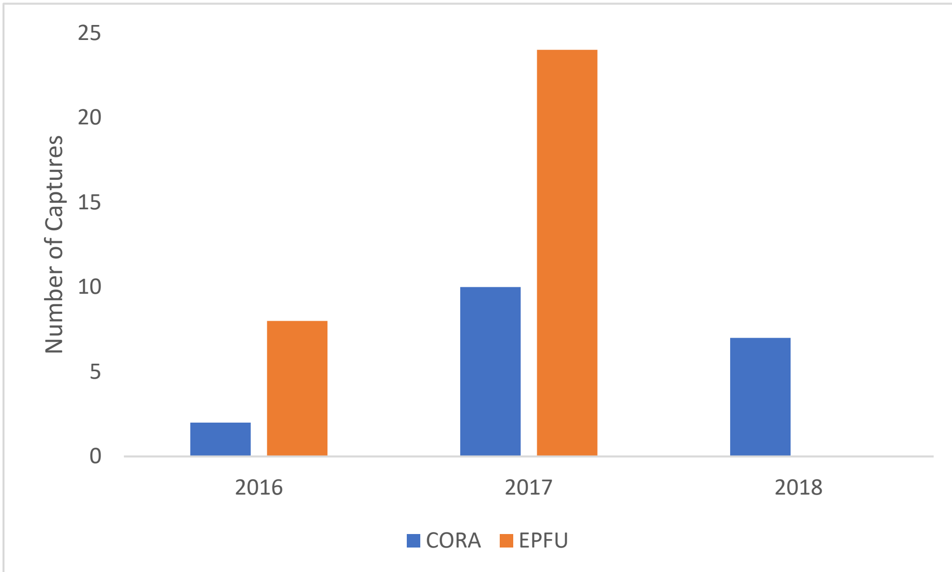
The camp at Robinson Forest has several maternity colonies of bats. A maternity colony of big brown bats numbering around 100 individuals roosted within the attics in two separate cabins. The office had a small bachelor colony of big brown bats, along with a small bachelor colony of Rafinesque big-eared bats, and a small maternity colony of Rafinesque big-eared bats. These groups live within different spaces within the structure and often emerge from different entrances. Both maternity colonies successfully rear young on a yearly basis.

Mist netting efforts at Robinson Forest resulted in the capture of 36 northern long-eared and one Indiana bat from 2016 through 2017 (Figure 19). Most northern long-eared bats were captured in 2.6 m nets over closed canopy ridge top roads. Sixteen northern long-eared bats (10 females, 4 males, and 2 juveniles) and one lactating female Indiana bat were radio-tagged and tracked. Ten northern long-eared bats (8 females, 2 males) were successfully tracked to day-roosts. The Indiana bat was not located despite use of a Cessna 172 plane being flown over the site in a 19.3-km radius. Other species captured, included adult male, female, and juvenile eastern red bats and big brown bats. I also captured two male silver-haired bats and one Rafinesque big-eared bat.

Two additional northern long-eared bats were captured during 2018 after the forest was harvested. One juvenile northern long-eared bat was captured adjacent to the shelterwood harvest on a ridge top road. Adult male, female, and juvenile eastern red bats and big brown bats were captured within the harvest treatments. A post-lactating female and a juvenile tri-colored bat were also captured in the riparian area adjacent to the shelterwood harvest.

Netting efforts at the Beech site resulted in the capture of eastern red bats, big brown bats, and tri-colored bats. Adult male, female, and juvenile eastern red bats, big brown bats, and tri-colored bats were captured within the openings of the patch cut harvest area.

a.


25
20
15
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5
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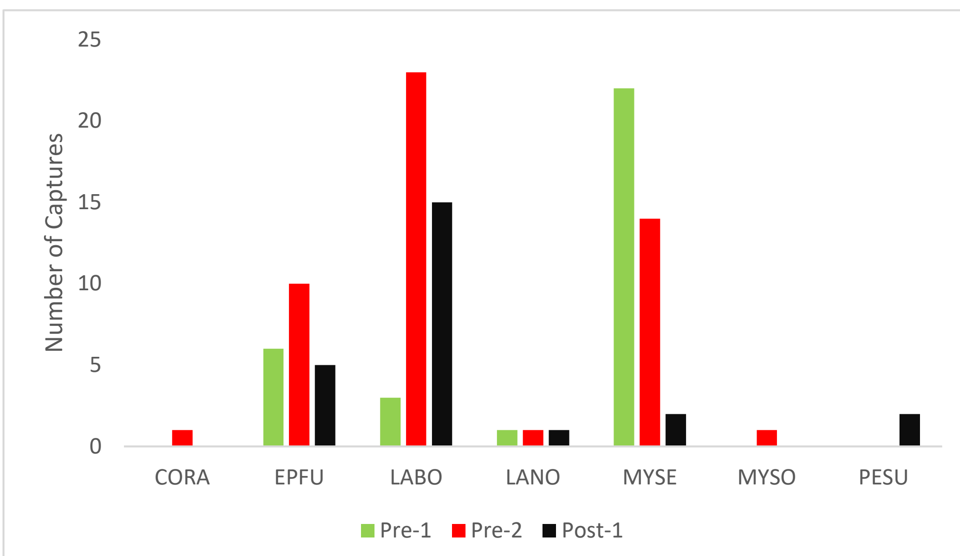
Number of Captures
2016
2017
2018
CORA
EPFU

b.


25
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Number of Captures
CORA
EPFU
LABO
LANO
MYSE
MYSO
PESU
Pre-1
Pre-2
Post-1

c.

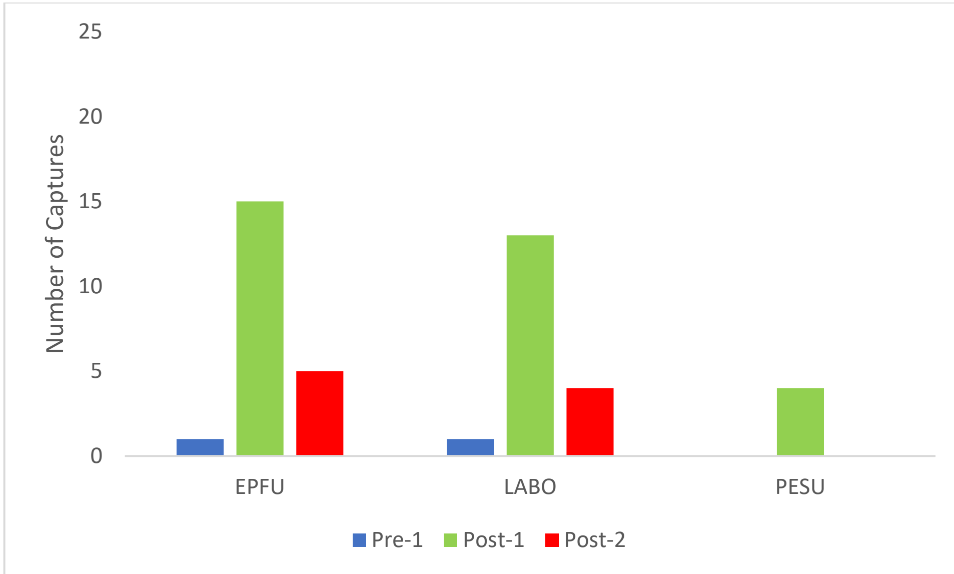

Figure 19. Results of bats captured during mist netting efforts. (a) Bats captured during mist netting efforts at Robinson Forest's camp. (b) Bats captured during surveys on Robinson Forest. (c) Bats captured during surveys on the Beech tract. (Blue (2015), Green (2016), Red (2017), and Black (2018).

Radio Tracking and Roost Trees

Sixteen individual northern long-eared bats had a radio-tag attached: males (4), females (10), and juveniles (2). Females (8) and males (2) were tracked to 20 different day roosts. Bats roosted in a five tree species: red maple (*Acer rubrum*), scarlet oak (*Quercus coccinea*), pitch pine (*Pinus rigida*), black oak (*Q. velutina*)*,* tulip poplar (*Liriodendron tulipifera*), and an unidentified snag (Table 9). Based upon random tree plots red maple was the most prominent tree species for roosting in the forest and occurred in various conditions from dead with peeling bark, declining trees with cavities, and live trees with small cavities (Table 10).

All roosts were within 100 m of a ridge top road (Figure 20), suggesting these bats preferentially chose roosts in the vicinity of forested flight corridors. Exit counts varied across the season. In early May, before pregnancy was detected individuals often roosted solitarily in small cavities large enough for only a single individual, within shaded areas of the forest with minimum solar exposure. At late-stage pregnancy and early lactation, adult females switched roosting preferences. Individuals clustered together in cavities or under bark in trees with reduced amounts of canopy cover. Trees occupied during this time had larger diameters and were predominately sub-canopy stems. Maximum group sizes of bats and consistent fission- fusion behavior was observed. As pups became closer to volancy, the size of the maternity colonies decreased although the type of roost did not change. Once pups became volant females chose roosts with reduced canopy cover and fewer surrounding trees. Roost switching was minimal, with females staying at the same site for several days in a row. Roost counts post-volancy were often of two individuals. In one case, a bat which was not radio-tagged was often a weak flyer and observed gliding out of the roost. Several times it was observed falling to the ground and the radio-tagged female would search the area to retrieve it. The trend lasted for a week or so. Females captured beyond this time roosted in a variety of roosts and seemed to be less selective. Males also displayed less selective behavior in roost choice. In late summer, bats roosted in a variety of structures including knotholes, peeling park, and small cavities. Individuals continued to roost near flyways. There were insufficient data to form an idea on their choice of canopy cover.

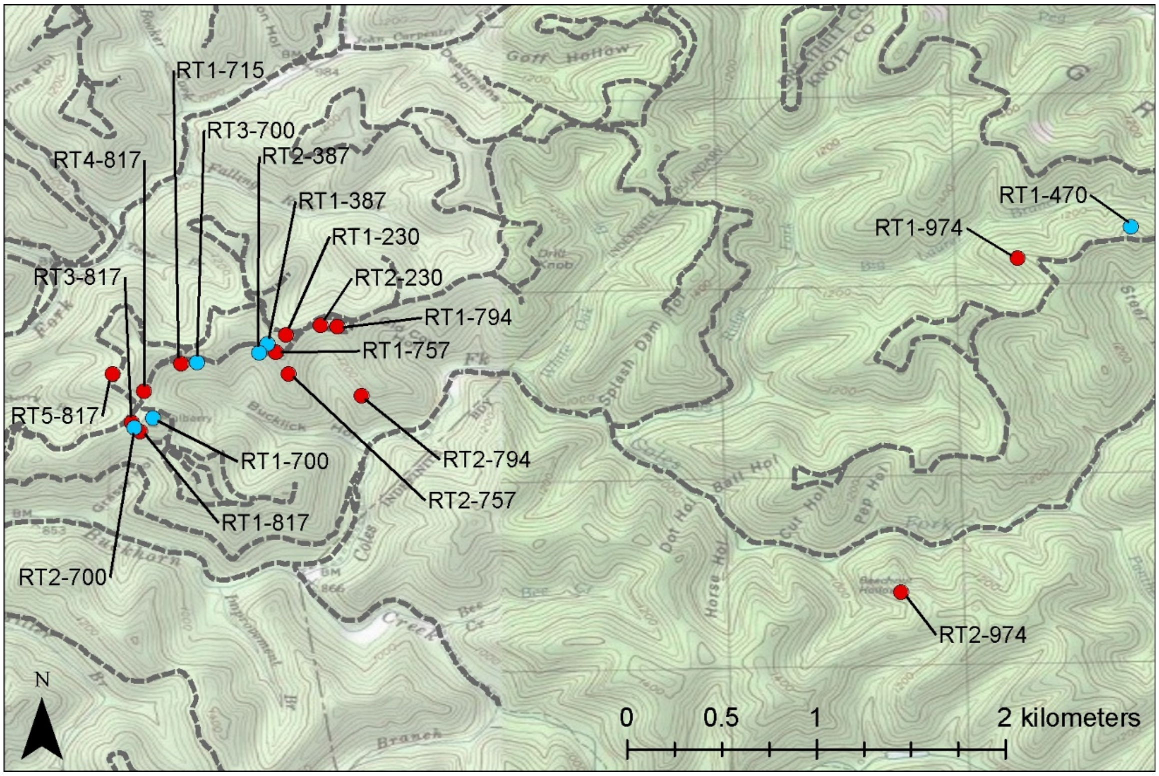

Figure 20. Roost trees located at Robinson Forest during tracking efforts from 2016-2017. Red dots are maternity roosts used by pregnant or lactating females. Blue dots are roost trees used by bats. The grey dotted line is the maintained closed canopy forest road. RT2-794 and RT2-974 both have non-maintained roosts within close proximity to the roosts which are not shown on the map because they are not mapped or maintained.

Table 9. Roost trees and emergence counts of located northern long-eared bats, Robinson Forest, KY.

Roost Tree	Sex	Reproductive Status	Species	Dbh (inch)	Roost Character	Snag Class	Emergence Count	Date
RT1-817	Female	Pregnant	Scarlet Oak	10.6	Under Bark	5	13	5/25/16
RT3-817	Female	Pregnant	Scarlet Oak	22.1	Dead Limb	1	4	5/27/16
RT4-817	Female	Pregnant	Red Maple	4.1	Cavity	1	1	5/28/16
RT5-817	Female	Pregnant	Red Maple	6.1	Cavity	4	24	5/29/16
RT1-974	Female	Lactating	Scarlet Oak	4.5	Under Bark	4	3	7/17/16
RT2-974	Female	Lactating	Scarlet Oak	10.1	Cavity	2	2	7/19/16
							2	7/20/16
							2	7/21/16
							2	7/23/16
RT1-470	Female	Post-lactating	Red Maple	2.1	Cavity	1	1	8/5/16
RT1-700	Female	Pregnant	Snag	11.6	Cavity	5	1	5/11/17
RT2-700	Female	Pregnant	Red Maple	4.5	Cavity	2	0	5/13/17
RT3-700	Female	Pregnant	Red Maple	2.6	Cavity	1	1	5/15/17
RT1-230	Female	Lactating	Tulip Poplar	21.1	Under Bark	4	3	6/7/17
RT2-230	Female	Lactating	Scarlet Oak	17.1	Under Bark	4	2	6/8/17
RT1-715	Female	Lactating	Black Oak	10.2	Under Bark	4	8	6/7/17
							13	6/8/17
							15	6/9/17
							21	6/10/17
RT1-757	Female	Lactating	Scarlet Oak	6.1	Under Bark	4	-	6/17/17
RT2-757	Female	Lactating	Scarlet Oak	26.5	Under Bark	4	7	6/18/17
							3	6/20/17
RT1-387	Male	Non-reproductive	Red Maple	4.2	Dead Limb	1	0	6/18/17
RT2-387	Male	Non-reproductive	Scarlet Oak	9.9	Under Bark	4	1	6/19/17
RT1-794	Female	Lactating	Red Maple	1.6	Cavity	4	1 (carrying pup)	6/25/17
RT2-794	Female	Lactating	Pitch Pine	7.8	Under Bark	4	2	6/28/17
							2	6/29/17

Table 10. Potential roost trees (snags and cavities) present within tree plots at Robinson Forest in Eastern Kentucky.

Species	**Number**	**Roosts Used by MYSE**
Red Maple	57	7
Scarlet Oak	30	7
Sourwood	21	0
Chestnut Oak	16	0
Black Oak	8	1
Downy Serviceberry	6	0
Black Gum	5	0
White Oak	4	0
Sugar Maple	4	0
Tulip Poplar	4	1
Cucumber Magnolia	3	0
Red Oak	3	0
Pitch Pine	2	1

Discussion

The difference in activity patterns among species pre-harvest was likely due to the differences in forest structure across landscapes at the three sites. The Beech tract was a 40-ha forest adjacent to seed tree harvests which left a lower, undetermined basal area. The Beech tract provided excellent habitat for open space foragers before it was harvested which explains why it had statistically higher numbers of silver-haired bat calls than the other sites. To access the tract, bats were required to fly through the surrounding harvest. The risk of predation could have acted as deterrent for smaller bat species to forage within the harvest (Swystun *et al.,* 2001). Kentucky Ridge was a mosaic with a variety of features from farmlands, active roads, and tracts of intact forest. The well trafficked road could have acted as a barrier to some species (Bennett *et al.,* 2013). Robinson Forest is largely an intact interior forest with various harvests interspersed throughout. These areas are connected by a series of dirt roads along the ridgetops and streams. Robinson Forest's extensive road system within an interior forest likely provided suitable habitat for several species, especially the northern long-eared bat.

Pre-harvest data showed higher activity at ridge top and riparian areas than mid-slope areas. The difference in activity was due to streams and ridge top roads functioning as flyways (Menzel *et al.,* 2002; Caldwell *et al.,* 2019). The structural complexity and degree of clutter varied among sampling locations in pre-harvest sampling. Eastern Kentucky is a mixed mesophytic forest with a large variety of tree species and habitats. Most ridge top points were placed along roads or trails; however, some points were not and were instead in interior forest locations. A ridge top sampling location at Kentucky Ridge was a hemlock-rhododendron forest while another in Laurel Ridge was a closed canopy road. Mid-slope sites had varying degree of clutter ranging from thickets of rhododendron to mostly open forest. Riparian corridors varied widely in size. Streams ranged from first to third order. Stream width affects canopy closure which determines aerial flight space throughout the flight corridor. Size of flight corridors have been shown to influence bat species presence and levels of activity (O'Keefe *et al.,* 2013). This variation among sampling locations at the same slope position resulted in some areas not producing pre-harvest calls which limited the power of the statistical models.

Both Beech and Kentucky Ridge tracts had an increase in bat activity post-harvest. Shelterwood harvests and patch cuts had higher activity than the unharvested control stand and the pre-harvest data. Increases in bat activity after forests have been thinned or logged occurred in other studies (Titchenell *et al.,* 2011; O'Keefe *et al.,* 2013; Silvis *et al.,* 2016). Activity increased by over an order of magnitude at both sites, and within both treatments. Most of this activity can be attributed to big brown bats for the Beech and Kentucky Ridge tracts. Large numbers of calls from silver haired bats occurred within the forest harvests and it is possible these bats increased in activity within forest harvests. These bats are open-space foragers which take advantage of the newly created space for foraging. Eastern red bats also increased in activity at both sites post-harvest and were the second biggest contributor to the increase in activity. It appears eastern red bats behaved as generalists that were active in both harvests and interior forests. Evening bats increased in activity at the Beech tract post-harvest. However, there was no significant increase in activity at the Kentucky Ridge tract. Hoary bats had a mixed response to harvests; however, sampling units were placed at 1.5 m in height and likely missed some calls of these bats. Microphones placed higher or in open space may have detected more activity. Brigham *et al.,* (1997) found that hoary bats foraged well above the canopy. I had predicted hoary bats should have increased in activity because they are open-space foragers with high aspect ratios and high wing loadings (Lacki *et al.,* 2007). Also, Owen *et al.* 2004 found an increase in hoary bat activity post-harvest.

Unharvested sections in both the Beech and Kentucky Ridge tracts saw the highest activity levels in the riparian areas post-harvest. Other harvest projects have seen high levels of activity within riparian areas near harvests (O'Keefe *et al.,* 2013; Caldwell *et al.,* 2019). Riparian zones likely continue to act as flyways, especially for clutter-adapted species traversing through the harvests. The ridgetop at Kentucky Ridge saw a large increase in activity post-harvest. The activity was likely bats commuting along the ridgetop road to the forest harvests. The shelterwood harvests in both sites had the highest activity on the ridgetop and the lowest activity in the riparian area. The mid-slope in the Beech tract shelterwood had statistically similar activity to the ridgetop, while the mid-slope in the Kentucky Ridge tract was statistically similar to the riparian area in bat activity. The variation in responses was likely due to structural differences between sites. Loggers complied with FSC® standards for Best Management Practices (BMPs) and Streamside Management Zones (SMZs) across all study sites (FSC-US 2010). Complying with these standards left Kentucky Ridge with larger patches of vegetation in the shelterwood harvest than the Beech tract due to slope condition and the size of the streams within the harvest. The structural similarity between all patch cuts likely explains the uniform response seen across sites and slope positions.

Barclay (1999) eloquently explained that echolocation is a tool for bats to navigate across the landscape and capture prey, and is not intended to necessarily convey species specific information. Call output from all acoustic software packages, including Kaleidoscope, is based on probabilities, and calls of similar species can be misclassified, especially poor-quality calls (Murray *et al.,* 2001; Russo *et al.,* 2017). Thus, some level of misidentifications is assumed to have occurred within the dataset and the possibility of misclassification influences my interpretation of data patterns and test outcomes with the acoustic analyses presented.

Silver-haired bats are migratory, with subadult males being summer residents in Kentucky (Perry *et al.,* 2010). However, KDFWR has recently seen increased numbers of male silver-haired bats captured in Kentucky (T. Wethington, KDFWR, unpublished data). I captured two different silver-haired bats during my netting efforts, and both captures were males with large numbers of mites. A higher number of big brown bats were captured within forest harvests. On two different occasions over ten different individuals were captured in a single night. Kaleidoscope and other acoustic software programs often misclassify big-brown bat calls as silver-haired bats (Humboldt State University, 2011). The low number of captured individuals and potential for misclassification of calls suggests patterns seen for silver-haired bat activity could be influenced by the large number of big brown bats present within the harvests.

My netting efforts did not result in the capture of an evening bat, and while my netting efforts were not extensive, the data suggests they are not a prevalent species within my study site. Netting resulted in the capture of a large number of red bats which have a similar call to evening bats (Humboldt State University, 2011). Red bat calls could have impacted trends detected for evening bats. However, it is also possible this species has moved into the area, and future work should include netting data to validate species presence. Evening bat is currently expanding its range, including in Kentucky, and is becoming a common species in forested areas once dominated by *Myotis* (Thalken et al., 2018a).

Little brown bats are present in the region but were not captured historically during surveys at Robinson Forest nor were they detected during my netting efforts (Krupa and Lacki, 2002). However, these bats are historically present in these counties (T. Wethington, KDFWR, unpublished data). These bats tend to prefer riparian areas and could be present along the large streams just outside of the forest, or along the larger streams within the forest. My netting efforts focused on ridgetops and it is possible I did not net extensively enough to capture the sparse individuals present. Little brown bat calls overlap in characteristics with Indiana bat calls, and share similarities with calls of northern long-eared bats (Humboldt State University, 2011). Little brown bats have suffered tremendous declines in Appalachia and the Midwest and are now rare throughout the region (Dzal *et al.,* 2011; Thogmartin *et al.,* 2012). Indiana bats have also suffered declines across the Appalachia recovery unit, but historically were not a common species (USFWS, 2019). Netting efforts revealed Indiana bats were present on the site; however, their captures were infrequent compared to northern long-eared bat. Northern long-eared bat was the second most captured species on Robinson Forest. The species continues to decline but remnant populations remain in a few counties in Kentucky, West Virginia, and eastern Ohio (Reynolds *et al.*, 2016, Cruz *et al*., 2018). Trends seen for Indiana and little brown bats could be influenced by misclassification of northern long-eared bat calls.

Rafinesque big-eared bats are hard to detect with acoustic surveys and will not be discussed (Hurst and Lacki, 1999). Detections were limited even within Robinson Forest where two known maternity colonies are present.

Tri-colored bats increased their levels of activity in forest harvests. I only captured tri-colored bats in harvested areas during my study. Granted I seldom mist netted streams or water sources. Studies showed tri-colored bats in Western Kentucky roosted within 2.5 km of their original capture location (Schaefer, 2017). Tri-colored bats have relatively small movements, travelling 300 - 5000 m from a capture location (Veilleux *et al.,* 2001; Leput, 2004; Quinn and Broders, 2007); roost between 25 to 186 m from edge habitat (Veilleux, 2001; Veilleux *et al.,* 2003; Leput, 2004, Veilleux *et al.,* 2004; O'Keefe, 2009); and, roost between 34 - 212 m from water sources (Veilleux, 2001; Veilleux *et al.,* 2003; Leput, 2004; Poissant *et al.,* 2010). Their small home ranges and movements, along with the capture of several life stages, suggests they are actively choosing to forage and possible roost within harvested areas.

Myotis activity did not increase within forest harvests. Other studies have found closed-spaced foragers avoid foraging in harvests (Owen *et al.,* 2003; Patriquin and Barclay, 2003; Henderson and Broders, 2008; Titchenell *et al.,* 2011; Cadwell *et al.,* 2019). Several factors likely contribute to *Myotis* not foraging extensively within the harvest treatments. Lepidopterans, a favorite prey of these bats, decreased in number in response to cuts, suggesting reduced prey availability (Table 3, 4). Myotis bats may experience an increase in competition from big brown bats and eastern red bats, which increase their feeding activity in areas post-harvest for the available prey (Table 3, 4) Silvicultural practices, patch cuts and shelterwood harvests, both remove sub-canopy clutter. Sub-canopy clutter has been correlated to Myotis activity in other studies (Dodd *et al.,* 2012). White-nose syndrome has severely affected Myotis populations, especially those of northern long-eared bat, little brown bat, and Indiana bat (Dzal *e et al.*, 2011; Thogmartin *et al.,* 2012; Thomas and Toomey, 2017; Thalken *et al.,* 2018b). In a post-WNS world, interior forests in eastern North America are likely not at carrying capacity for closed-space foraging bat species. Given that prey are equally or more abundant than within unharvested areas (Table 8), and competition is now likely reduced within interior forest ecosystems, surviving Myotis bats may choose to occupy forested habitat to avoid competition and have increased access to prey. Variation in response to forest harvesting by tri-colored bats and Myotis bats has been documented across several studies (Yates and Muzika, 2006; Amelon, 2007; Womack *et al.,* 2013; Starbuck *et al.,* 2015). These differences may be attributed to the different level of competition present at each study area.

My study filled a research gap and provides replication across multiple areas with species-level resolution based upon acoustic and netting data (Menzel *et al.,* 2002; Adams *et al.,* 2009; Jung *et al.,* 2012; O'Keefe *et al.,* 2013; Silvis *et al.,* 2016). Captures of northern long-eared bats at Robinson Forest, post-white-nose syndrome, provide evidence for a relict population of these bats. The lack of activity of these bats in harvests, however, suggests they do not actively forage within cuts.

My study could be improved upon with additional replication and long-term data at each study area. Landscape features such as stream size and surrounding features such as forest harvests should be included within replicates. It is likely that larger riparian zones might help maintain activity of interior species if they are adjacent to interior forest. Detectors left out across an entire season might help discern how activity changes throughout the night, reproductive period, and seasons.

Forest harvesting temporarily impacts foraging habitat of northern long-eared bats; however, once the site regenerates the heavily compacted skid trails and harvest roads do not re-grow trees. These trails stay open and become surrounded by closed canopy forest. These areas become long-term flyways within the forest which are heavily trafficked by many bat species, especially *Myotis* (Menzel *et al.,* 2002; Caldwell *et al.,* 2019). All captures of northern long-eared bats occurred on these roads. Eastern red bats, big brown bats, and a Rafinesque big-eared bat were also captured along roads. The northern long-eared bats also preferred to roost on ridge tops near these flyways. Other studies have shown northern long-eared bats prefer ridge top roosting positions (Thalken *et al.,* 2018b; Thalken and Lacki, 2018; Cruz *et al.,* 2018).

The capture of juvenile northern long-eared bats within 50 m of the shelterwood harvest at the Laurel Ridge tract suggests the species uses the area for reproduction, at least to some extent. Forest harvests may take some potential roost trees, both primary and secondary, but northern long-eared bats will continue using a harvested site (Silvis *et al.,* 2015).

It is unknown if northern long-eared bats use torpor in the same manner as Indiana bat and little brown bat. Summer colony sizes of northern long-eared bats are smaller on average than those of Indiana bat and little brown bat and can occur in interior forest locations which do not have as high a solar exposure. Average sizes of northern long-eared bat colonies were historically larger than seen in my study (Sasse and Pekins, 1996 [n = 36]; Foster and Kurta, 1999 [n = 60]; Menzel *et al*., 2002 [n = 65]; Lacki *et al.*, 2009 [n = 56]). However, these are far smaller than that of little brown bat or Indiana bat colonies which commonly range into the hundreds. Further, Lacki and Schwierjohann (2001) found sizes in Eastern Kentucky to average 25.3 ± 10.2 bats during the pregnancy period, which is similar to the colony sizes recorded in my study. These differences suggest the species may use torpor more frequently or enter deeper torpor than little brown bat or Indiana bat to conserve energy and, thus, do not need to be as gregarious or select warmer roosts. Their behavior patterns likely explain their historically large numbers in interior forests. However, unlike Indiana bat and little brown bat this may require a species to seek out a variety of roosting microclimates to meet their shifting energetic needs throughout the summer season. An interesting example of this can be seen by the switching of a colony of northern long-eared bats from tree roosts to a barn during pregnancy and lactation (Henderson and Broders, 2008).

Northern long-eared bats choose to roost in different microclimates and in different numbers throughout the season. Their behavior can be grouped into five distinct phrases. First, use of small shaded cavity roosts during early pregnancy that permit females to engage in torpor bouts to conserve energy, which also slows the development of offspring and allows pregnant females to replenish lost fat reserves from winter hibernation. Second, during late-stage pregnancy and early lactation females switch roosts, with individuals clustering together in cavities or under bark in trees with low canopy cover. Trees used are predominately sub-canopy stems with peeling bark or cavities. During this time, females cluster to conserve heat and likely limit torpor use, with the clustering behavior likely facilitating faster growth of young. Third, the same types of trees are selected for in mid to late-lactation. However, the colony counts are smaller as females reduce colony size, possibly to minimize parasite loads and predation risks. As the young are now larger, it is likely that less body heat is required to maintain growth of non-volant young. Fourth, once pups become volant, females choose roosts with low canopy cover and few surrounding trees. Roost switching is minimal with a female staying at the same site for several days in a row. Females choose roosts in areas of reduced clutter perhaps to minimize flight collisions. The splintering of the colonies also reduces predation risk to vulnerable young who are learning to fly and are easy targets. Fifth, females captured after young become fully volant roost in a variety of structures and are less selective. During this time bats roost in a variety of micro-sites including knotholes, peeling park, and small cavities, and frequently switch roosting sites likely to select micro-climates suitable for minimizing energy expenditure and utilizing torpor to restore lost fat reserves for hibernation. Adult males displayed the fifth stage behavior throughout the season.

A variety of roosting patterns of northern long-eared bats has been seen in other studies. Lacki and Schwierjohann (2001) saw variation in colony size across reproductive conditions. The largest numbers were during pregnancy and decreased throughout lactation. Thalken (2018) and Garroway and Broders (2008) found differences in roosts between reproductive classes of northern long-eared bats. Other studies have shown big brown bat, western long-eared bat (*Myotis evotis*), and little brown bat change roosts to facilitate use of a different torpor strategy (Dzal and Brigham, 2013; Chruszcz and Barclay, 2002; Lausen and Barclay, 2003).

Data suggest that bat species actively decide whether or not to engage in torpor use based upon their energetic needs and that of their young. The smaller roost counts toward the end of the maternity season for many tree-roosting species suggest that bats balance risks based on energetic needs, access to available food sources, and predation risk.

Prior to white-nose syndrome, tri-colored bat and northern long-eared bat were common species in forested landscapes of eastern North America. Their populations have dramatically declined throughout their distributions (Francl *et al.,* 2012). Despite severe declines, however, some regional populations appear to be stabilizing (Dobony and Johnson, 2018; Frank *et al.,* 2019). Northern long-eared bat populations have persisted across multiple seasons of possible exposure to white-nose syndrome (Cruz *et al.,* 2018). As more impacted populations of northern long-eared bat become extirpated, remaining populations will become increasingly important to the survival of the species. The population within Central-Appalachia could become critical for the survival of the species, as some of these bats may adopt unknown hibernation locations and strategies that allow them to survive the harsh winter without succumbing to WNS. Based on my data, silvicultural management of forests can be done in a way which is consistent with providing habitat for surviving northern long-eared bats.

Research is beginning to suggest that surviving individuals are relying on alternative hibernation strategies such as hibernating in basements, tree cavities, culverts, and other locations which do not allow for the growth of the fungus. The population found in the coastal plains of North and South Carolina is one example of alternative hibernation strategies. Northern long-eared bats which live there are active year-round and continue to use tree roosts throughout winter and, thus, are not susceptible to WNS (Jordan, 2020). Individuals are also behaviorally adapting to the fungus. Individuals are storing more body fat to survive the arousals caused by the fungus (Lacki *et al*., 2015). Winter habitat that facilitates successful hibernation is a limiting factor in the recovery of many species, including the northern long-eared bat and tri-colored bat. Forest harvests also provide valuable habitat to bats within Appalachia. Big brown bat, eastern red bat, hoary bat, and tri-colored bat use these areas for foraging. Northern long-eared bats and possible tri-colored bats appear to roost within or near these harvests. Thus, patch cuts and shelterwood harvests may be valuable tools to promote successful reproduction in bat species that use harvested areas during summer months.

Management Recommendations

Shelterwood harvests and patch cuts improve habitat quality for red, big brown, and tri-colored bats. Immediately after harvests, *Myotis* did not increase activity in patch cuts or shelterwood harvests in my study. However, I believe harvests can provide essential habitat. The skid trails and harvest roads that allow harvested trees to be extracted often become heavily compacted and limit future tree growth in the corridor. Once the surrounding trees re-grow, these closed canopy spaces become semi-permanent flyways within the forest which are heavily trafficked by many bat species, including *Myotis* (O'Keefe *et al.,* 2013; Silvis *et al.,* 2016; Ketzler *et al.,* 2018). My study supports these observations. Myotis calls on Laurel Ridge occurred frequently on detectors placed along the roads. All of the northern long-eared bats I captured were on these ridgetop roads. The roost trees I located were within 100 m of the road. Other studies have also found northern long-eared bats to prefer roosting on ridgetops. Cruz *et. al* (2018) found that northern long-eared bats commonly roost within rocket boxes placed within forest harvests for utility lines within Appalachia. These populations return annually and successfully rear young. Unless harvests become a pervasive landscape issue, I believe they do not negatively affect the presence of northern long-eared bats.

When planning harvests, unharvested sections should be retained near or adjacent to shelterwood harvests or patch cuts. These areas provide foraging space to Myotis species and limit foraging competition with big brown bat, hoary bat, and eastern red bat. I recommend placing permanent small, unpaved dirt roads along ridgetops for long-term roosting potential for northern long-eared bats. These roads function as flight corridors and the dead trees adjacent to the road provide roosting habitat. These roads should be designed to have increased canopy closure as the site develops post-harvest. Maximizing connections between roads on different ridges to create a flyway matrix would be ideal. This matrix should allow for bats to travel and feed throughout the forest landscape. Any snag or tree with a cavity next to ridge top roads should be surveyed for bat use before it is cleared as these trees are likely to be potential roosting habitat. Natural roosts should also be sustained through active management such as retaining snags during harvests, especially those on forest edges and along roads. If need be, these natural roosts can be supplemented with rocket boxes placed within different microclimates on the landscape.

Forest harvests create openings in the forest providing foraging habitat for open-space foragers such as big brown bat and generalists such as the eastern red bat. Although eastern red bat, big brown bat, and hoary bat are currently common species in forested landscapes, management may be necessary for these species in the future. Prior to white-nose syndrome, little brown bats, tri-colored bats, and northern long-eared bats were common species in many areas (U.S. Department of the Interior, 2015). These formerly common species are clearly in need of conservation now and in the future. Hoary bat and eastern red bat are currently being killed in large numbers at wind turbines during migration (Kunz *et al.,* 2007). These impacts are likely to result in population level changes to these species as well.

Permits

All animal handling procedures used were approved by the University of Kentucky under IACUC Assurance No.: A3336-01. Data collection was supported through permits from the Kentucky Department of Fish and Wildlife Resources (SC1511245; SC1611176; SC171115; SC1811148) and the U.S. Fish and Wildlife Service (TE38522A-1).

Appendix I

Insect Analysis

```
#ANOVA

Detect <-lm(Count ~ Treatment,data = KR)

anova(Detect)

summary(Detect)
```

Quasi-Poisson Analysis

```
#Sorting Call Data

Pulses <- read.csv("C:/Users/PHILLIP/Desktop/Zeros Added Master.csv")


#Filter out poor quality call data for accurarcy

Filtered <- Pulses %>% filter(PULSES >= 4)

Filtered <- Filtered %>% filter(Qual <= 10)

Filtered <- Filtered %>% filter(MARGIN >= 0.3)


#Summarize data

Count <- count(Pulses, c("AUTO.ID","SITE","DATE.12","YEAR","Treatment", "Position","LOCATION"))

agg.sum <- aggregate(formula= freq ~ DATE.12 + Position + SITE + AUTO.ID + LOCATION + YEAR + Treatment,
data= Count, FUN=sum)

write.csv(agg.sum, file = 'C:/Users/PHILLIP/Desktop/Filter Count.csv')


#View data and run Poisson

p <- ggplot(aes(x = Treatment, y = freq), data = Pulses)

p + geom_boxplot() + facet_wrap(~ Treatment)

Pulse <-glm(freq ~ Treatment,data = Pulses, family = 'poisson')


# Check for overdispersion

# First is probably best as it can take variables into account

deviance(Pulse)/df.residual(Pulse)

# Another way, seems similar and gives more info

qcc.overdispersion.test(Pulses$Abundance, type = 'poisson')


# Quasipoisson adjusts standard errors based on the amount of overdispersion

# Estimates will stay the same but SEs will be larger
```

```
Pulses2 <-glm(freq ~ Treatment,data = Pulses, family = 'quasipoisson')
summary(Pulses2)

# Pull out means and SEs
str(Pulses2)
newdata <- data.frame(Treatment = unique(Pulses$Treatment))
pred <- predict(Pulses2, se.fit = TRUE, newdata = newdata, dispersion = 20.68806, type = 'response')
# Can get same result (SE models) using a Poisson as long as you correct for overdispersion
# Can find the overdispersion value in the summary of the quasipoisson model
cbind(newdata, pred)

# Check residuals
plot(Pulses2)
plot(resid(Pulses2) ~ Pulses2$fitted.values)

# Compare groups using generalized linear hypothesis test
Pulses2_glht <- glht(Pulses2, linfct = mcp(Treatment = 'Tukey'))

# Use the Bonferroni adjustment to adjust p-values and account for multiple comparisons
summary(Pulses2_glht, test = adjusted('bonferroni'))
cld(Pulses2_glht)

# Run an Ftest
summary(Pulses2_glht, test = Ftest())
```

Quasi-Poisson (Treatment)

```
Treatment <- read.csv("C:/Users/PHILLIP/Desktop/Pulses Summed.csv")

#Transform Year to a Factor
Treatment$Year <- factor(Treatment$YEAR)

B <- Treatment %>% filter(SITE == 'Beech')
B <- B %>% filter(YEAR != '2015')

p <- ggplot(aes(x = Treatment, y = PULSES), data = B)
```

```
p + geom_boxplot()
Pglm <-glm(PULSES ~ Treatment,data = B, family = 'poisson')

#ANOVA for comparison to data output
Detect <-lm(PULSES ~ Treatment,data = B)
anova(Detect)
summary(Detect)

# Check for overdispersion
# First is probably best as it can take variables into account
deviance(Pglm)/df.residual(Pglm)
# Another way, seems similar and gives more info
qcc.overdispersion.test(B$PULSES, type = 'poisson')

# Quasipoisson adjusts standard errors based on the amount of overdispersion
# Estimates will stay the same but SEs will be larger
Qglm <-glm(PULSES ~ Treatment,data = B, family = 'quasipoisson')
summary(Qglm)

# Pull out means and SEs
str(Pglm)
newdata <- data.frame(Treatment = unique(B$Treatment))
pred <- predict(Pglm, se.fit = TRUE, newdata = newdata, dispersion = 4570.679, type = 'response')
# Can get same result (SE models) using a Poisson as long as you correct for overdispersion
# Can find the overdispersion value in the summary of the quasipoisson model
cbind(newdata, pred)

out <- LSD.test(Detect,"Treatment", p.adj = "bonferroni")
out
out$means$std/(sqrt(out$means$r))

# Compare groups using generalized linear hypothesis test
Qglm_glht <- glht(Qglm, linfct = mcp(Treatment = 'Tukey'))

# Use the Bonferroni adjustment to adjust p-values and account for multiple comparisons
```

```
summary(Qglm_glht, test = adjusted('bonferroni'))
cld(Qglm_glht)

# Run an Ftest
summary(Qglm_glht, test = Ftest())
```

Quasi-Poisson (Pre- and Post-Harvest)

```
Year <- read.csv("C:/Users/PHILLIP/Desktop/Count Data with 0 for Species Added.csv")

#Transform Year to a Factor
Year$YEAR <- factor(Year$YEAR)

B <- Year %>% filter(SITE == 'Beech')
COTO <- B %>% filter(AUTO.ID == 'COTO')

p <- ggplot(aes(x = YEAR, y = freq), data = COTO)
p + geom_boxplot()
Pglm <-glm(freq ~ YEAR,data = COTO, family = 'poisson')

#ANOVA for comparison to data output
Detect <-lm(freq ~ YEAR,data = COTO)
anova(Detect)
summary(Detect)

# Check for overdispersion
# First is probably best as it can take variables into account
deviance(Pglm)/df.residual(Pglm)
# Another way, seems similar and gives more info
qcc.overdispersion.test(COTO$freq, type = 'poisson')

# Quasipoisson adjusts standard errors based on the amount of overdispersion
# Estimates will stay the same but SEs will be larger
Qglm <-glm(freq ~ YEAR,data = COTO, family = 'quasipoisson')
summary(Qglm)
```

```
# Pull out means and SEs
#Doesn't work accurately
str(Pglm)
newdata <- data.frame(YEAR = unique(COTO$YEAR))
pred <- predict(Pglm, se.fit = TRUE, newdata = newdata, type = 'response')
# Can get same result (SE models) using a Poisson as long as you correct for overdispersion
# Can find the overdispersion value in the summary of the quasipoisson model
cbind(newdata, pred)

out <- LSD.test(Detect,"YEAR", p.adj = "bonferroni")
out
out$means$std/(sqrt(out$means$r))

# Compare groups using generalized linear hypothesis test
Pglm_glht <- glht(Pglm, linfct = mcp(YEAR = 'Tukey'))

# Use the Bonferroni adjustment to adjust p-values and account for multiple comparisons
summary(Pglm_glht, test = adjusted('bonferroni'))
cld(Pglm_glht)

# Run an Ftest
summary(Pglm_glht, test = Ftest())
```

Quasi-Poisson (Slope Position)

```
Treatment <- read.csv("C:/Users/PHILLIP/Desktop/Pulses Summed.csv")

#Transform Year to a Factor
Treatment$Year <- factor(Treatment$YEAR)

B <- Treatment %>% filter(SITE == 'Beech')
B <- B %>% filter(YEAR != '2015')
Position <- B %>% filter(Treatment == "Control" )
Position <- B %>% filter(Treatment == "Patch Cut" )
Position <- B %>% filter(Treatment == "Shelterwood" )
```

```
p <- ggplot(aes(x = Position, y = PULSES), data = Position)
p + geom_boxplot()
Pglm <-glm(PULSES ~ Position,data = Position, family = 'poisson')

#ANOVA for comparison to data output
Detect <-lm(PULSES ~ Position,data = Position)
anova(Detect)
summary(Detect)

# Check for overdispersion
# First is probably best as it can take variables into account
deviance(Pglm)/df.residual(Pglm)

# Quasipoisson adjusts standard errors based on the amount of overdispersion
# Estimates will stay the same but SEs will be larger
Qglm <-glm(PULSES ~ Position,data = Position, family = 'quasipoisson')
summary(Qglm)

#SE and Groupings for ANOVA
out <- LSD.test(Detect,"Position", p.adj = "bonferroni")
out
out$means$std/(sqrt(out$means$r))

# Compare groups using generalized linear hypothesis test
Qglm_glht <- glht(Qglm, linfct = mcp(Position = 'Tukey'))

# Use the Bonferroni adjustment to adjust p-values and account for multiple comparisons
summary(Qglm_glht, test = adjusted('bonferroni'))
cld(Qglm_glht)

# Run an Ftest
summary(Qglm_glht, test = Ftest())
```

Code Designed by Wendy Leuenberger

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Vita

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Place of Birth
Martinsville, Indiana

Education

University of Southern Indiana Bachelor of Science, Biology	2012

Professional Positions

Scientist, Environmental Solutions and Innovations	2019 – 2020
Bat Biologist/Environmental Scientist I, Allstar Ecology, LLC	2018
Research/Teaching Assistant, University of Kentucky	2015 – 2018
Protein Analyst Technician, Aerotek/Kentucky Bioprocessing	2015
Acoustic Technician, Missouri Department of Conservation	2014
Bat Technician, West, Inc.	2014
Metrology Technician, Premier Scales and Systems	2014
Microbiology Technician, Aerotek/Mead Johnson Nutrition	2013
Intermittent Worker, DNR Fish and Wildlife	2012

Presentations

Effects of Shelterwood Harvests and Patch Cuts on Habitat Use of Myotis species in the central Appalachians. Arant, P.L. 2016. Kentucky Bat Working Group. Falls of the Rough, KY

Appalachia: A Refuge from White-Nose Syndrome? Arant, P.L. 2017. Kentucky Bat Working Group. Natural Bridge State Park, KY

Frontline Work on Forest Operations and Threatened and Endangered Species Sustainability. 2018. Stringer, J.W. and P.L. Arant. Southern Group of State Foresters. Lexington, KY

Bat Community Responses to Patch Cuts and Shelterwood Harvests in the Cumberland Plateau. 2018. Arant, P.L, M.J. Lacki, and J.W. Stringer. KY-TN Society of American Foresters. Buchanan, TN

Bat and Insect Responses to Shelterwood and Patch Cut Harvests in Appalachian Hardwood Forests. 2018. Arant, P.L, M.J. Lacki, and J.W. Stringer. North American Joint Bat Working Group Meeting. Roanoke, VA

The Impacts of Shelterwood Harvests and Patch Cuts on Bat Communities in Eastern Kentucky. 2018. Arant, P.L, M.J. Lacki, and J.W. Stringer. Kentucky Bat Working Group. Barren River Lake State Resort Park, KY.

Publications

Arant, P.L., D. White, and S.J. Price. 2019. *Diadophis punctatus* (Ring-necked snake) and *Storeria occipitomaculata* (Red-bellied Snake) predation. *Herpetological Review,* **50**(2):392

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Arant, P. L., M. J. Lacki, J. M. Lhotka, and J. W. Stringer. Summer populations of Northern Long-eared Bats on an eastern Kentucky forest following arrival of White-nose Syndrome.

Permits and Certificates

Endangered/Threatened Species Federal Recovery Permit (TE75551C-0)
Qualified Bat Surveyor – Pennsylvania
Wetland Delineation and Regional Supplement Training – Swamp School in Pennsylvania