Develop Recommendations to Reduce Fatality of Migratory Tree Bats at Wind Energy Facilities in USFWS Region 3

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Decision Problem

Wind energy is one of the fastest growing sources of renewable energy in the United States and is expected to triple from the current 75,000 megawatts (MW) to 224,000 MW by 2030 (USDOE 2015, AWEA 2016). The U.S. Fish and Wildlife Service (Service) is engaged with wind industry and other partners to facilitate development of wind energy while protecting and enhancing the Nation's natural resources. In the Service's Midwest Region (Region 3), our coordination has primarily involved endangered species, especially the endangered Indiana bat (*Myotis sodalis*), and migratory birds. However, the species most frequently killed at wind turbines are long-distance migratory tree-roosting bats, including hoary bats (*Lasiurus cinereus*), eastern red bats (*L. borealis*), and silver-haired bats (*Lasionycteris noctivagans*). Region 3 (R3) led an expert elicitation in 2014 to gather population demography information to aid us in assessing whether current and projected levels of migratory tree bat fatalities from wind projects are sustainable. The results of preliminary modeling from that effort suggest that there is cause for concern, but there is considerable uncertainty regarding the vital rates for migratory tree bats and in the projected growth of the number of wind turbines on the landscape. We are attempting to address these uncertainties and refine our modeling to improve our ability to predict how wind turbine fatalities will affect migratory tree bat populations. However, it could take a considerable amount of time to gather data for these model refinements and in the interim large numbers of migratory tree bats continue to be killed by wind turbines. The number of bats of these three species being killed at wind energy facilities far exceeds any other documented natural or human-caused sources of fatality (O'Shea et al. 2016) and given our preliminary modeling results we believe immediate action is warranted. Through this Structured Decision Making (SDM) workshop we created a framework for developing steps that can be taken now to reduce fatalities of migratory tree bats at wind energy facilities in R3, and to identify the data gaps that are most relevant to helping us better assess the impact that wind turbine fatalities are having on bat populations. Using the framework created through this SDM process, we will develop a set of recommendations for the R3 Assistant Regional Director for Ecological Services

on steps the Service could take to reduce fatality of migratory tree bats at wind energy facilities in R3.

Background

Legal, regulatory, and political context

As the principal federal agency responsible for administering the Endangered Species Act (ESA), the Service takes the lead in protecting, recovering and conserving our Nation's imperiled species. With reference specifically to wind energy development, our statutory authority and responsibility under ESA mandates that we work with the wind industry to address impacts to threatened and endangered bat species. The species of bats most frequently killed by wind turbines -- hoary bats, eastern red bats, and silver-haired bats -- are not protected by ESA. Further, there is no international treaty, comparable to the Migratory Bird Treaty Act, to protect migratory bats.

In addition to our responsibilities to conserve and pursue recovery of species listed under ESA; we also work in partnership with others to conserve candidate species and species-at-risk; if successful, these efforts may preclude the need for listing under the ESA. In that regard, the Service is working to raise awareness of the impacts of wind energy development on non-listed bats, particularly migratory tree bats, and to promote measures that will reduce fatalities of all species of bats. Such measures are in the best interest of bat conservation, and are also in the best interest of industry if these measures preclude the need for future listings of species of migratory tree bats.

Ecological context

In the U.S., bat fatalities at wind turbines were first reported in the 1990s (Johnson et al. 2003), but it was not until 2003, when unexpectedly high fatality events were observed in Pennsylvania and West Virginia, that turbine-related fatalities of bats became a concern (Arnett 2005). Since then, our understanding of the extent and magnitude of the impact of wind energy facilities on bats has increased and consistent patterns in fatality, including seasonality and species composition, have been identified. The best available data suggest that hundreds of thousands of bats are killed by wind turbines each year (Arnett and Baerwald 2013). Of the reported fatalities, nearly 78% are migratory tree bats, though high proportions of cave-roosting bats, such as the little brown bat (*M. lucifugus*) and tri-colored bat (*Perimyotis subflavus*) have been reported at several wind energy facilities (Arnett and Baerwald 2013). Bats have a low reproductive rate (i.e., most species have only 1 or 2 pups/year) and require high adult survivorship to avoid population declines (Barclay and Harder 2003); these life history traits limit the ability of bats to recover from population declines. Given the level of migratory tree bat fatalities at wind turbines and the predicted expansion of wind energy over the next 15 years, there is concern that the impacts to migratory tree bat populations may not be sustainable (Cryan 2011, O'Shea et al. 2016). Baerwald (2016) studied fatalities of hoary bats at wind energy facilities in North America and demonstrated that fatality rates of hoary bats declined over time at 64% of sites examined, potentially suggesting a decline in the population. She also reported on population

modeling of hoary bats that suggests that current fatality levels could cause a 91% decrease in the North American population of hoary bats within 50 years.

Early studies focused on understanding the extent and magnitude of impacts of wind energy development on bats. Patterns consistent among projects indicated that a substantial portion of bat fatalities occurred during relatively low wind speed conditions during late summer and autumn (Arnett and Baerwald 2013). This led to investigations into the effectiveness of changing turbine operations, specifically feathering blades[1] and raising the cut-in speed[2] above the manufacturer's cut-in speed, which for modern turbines ranges from 3.0–4.0 m/s, to reduce bat fatalities. This impact reduction strategy is often called curtailment or operational minimization. Several studies have demonstrated that raising the cut-in speed by 1.5–3.0 meters/second (m/s) above the manufacturer's cut-in speed results in a mean reduction in bat fatality of about 50% compared to normally operating turbines (Baerwald et al. 2009, Arnett et al. 2011, Good et al. 2011). However, altering turbine operations potentially results in lost power generation and lost revenues for project operators.

The wind industry recently endorsed a practice to reduce bat fatality at wind turbines; specifically, to feather turbines blades, during the late summer and fall (fall bat migration season), when wind speeds are below the manufacturer's cut-in speed (AWEA 2015). This operational minimization would be applied to turbines at night when the temperature exceeds 50 degrees Fahrenheit. In one study, feathering alone, without raising cut-in speed above the manufacturer's cut-in speed, reduced bat fatalities by nearly 36% (Good et al. 2012). This strategy has the added benefit of low economic cost incurred by the wind industry. Some facilities are expected to adopt this practice during this fall (2016) bat migration season; however, participation is voluntary so we do not know the extent to which this practice will be adopted. Widespread adoption of this impact reduction strategy would lead to a decrease in bat fatalities, but not necessarily sufficient reduction to ensure sustainable populations of migratory tree bats. Our SDM workshop team met to discuss additional steps that could be taken to reduce fatalities of migratory tree bats at wind energy facilities, specifically in R3.

Decision Structure

Objectives

On the first day of our SDM workshop, our team discussed objectives. We started with multiple fundamental objectives, but through an iterative process one overarching fundamental objective was ultimately identified during the workshop. The single fundamental objective was to maximize implementation of strategies to reduce adverse impacts to migratory tree bats from wind turbines (Figure 1). The measurable attribute for the objective was "expected reduction in the number of bats killed" and was calculated as:

$$E_R = F_R * P_A$$

[1] turbine blades pitched parallel with the wind direction, causing them to only spin at very low rotation rates, if at all
[2] wind speed at which wind turbines begin generating power and sending it to the electrical grid

where, E_R is the expected reduction in the average number of bats killed, F_R is the average reduction in the fatality rate, and P_A is the proportion of wind facilities willing to adopt the conservation strategy. Fatality reduction, F_R, was measured in average bats killed per year and proportion of adoption, P_A, was measured on a constructed scale (Table 1). A greater proportion of expected industry participation was linked to higher flexibility, greater tangible benefits to industry, higher predictability, and lower cost alternatives.

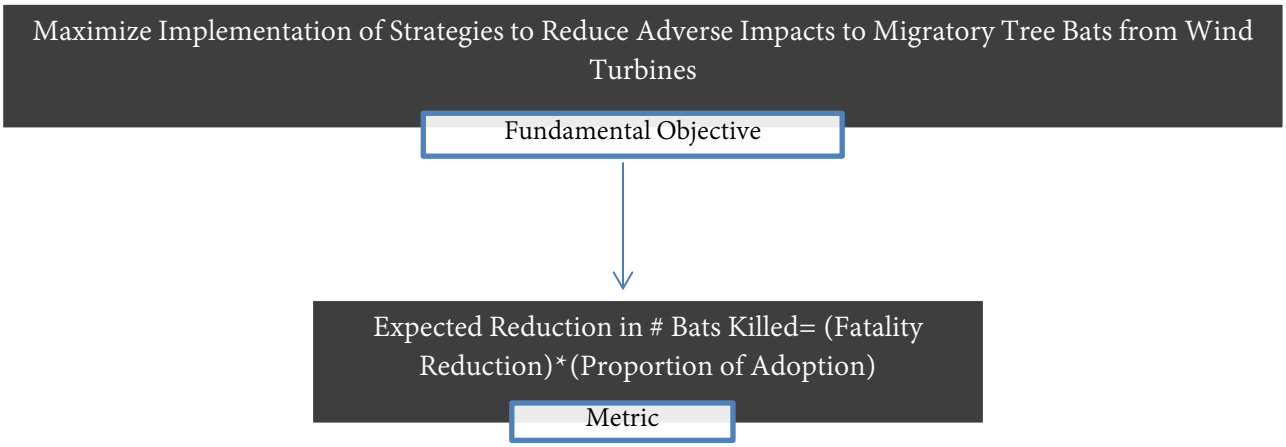

Figure 1. Single fundamental objective and measurable attribute.

Table 1. Constructed metric for expected industry participation migratory tree bat fatality reduction strategies.

Expected Industry Participation	***Ranking***	***Description***
None	0	No flexibility or predictability; economically not viable; no tangible benefits to industry
Low	1	Flexibility and predictability, measureable/likely tangible benefits, but costs exceed X*
Moderate	2	Flexible or predictable, likely measureable tangible benefits, costs less than X*
High	3	Flexible, predictable, costs less than X*, likely tangible benefits (e.g., improve image of the company)

** X is an (unspecified) amount that is the maximum cost industry would consider reasonable*

Alternative actions

Next, we identified alternative actions to reduce fatality of migratory tree bats at wind energy facilities. We identified alternative actions in three categories: operational measures that could be applied now to reduce migratory tree bat fatality at wind turbines; long-term measures that include research and other actions that would allow us to improve our recommendations and our ability to conserve migratory tree bats over time; and industry engagement measures that would improve industry adoption of fatality reduction strategies:

Operational measures:

These are measures that could be implemented now based on sufficient information available to develop meaningful measures and technological capabilities. Note, due to time constraints at the workshop we did not actually define some of the variables that would be incorporated into these measures, but we think adequate data are available that we can define those variables. Changes in turbine operation would be applied to turbines at night.

1. Feather turbines below manufacturer's cut-in during period when migratory tree bats are most likely to be present (e.g., 1 March - 30 November).

2. Feather turbines below manufacturer's cut-in during period when migratory tree bats are most likely to be present (e.g., 1 March - 30 November), with Y* monitoring.

3. Feather turbines below manufacturer's cut-in except during the period of highest risk to migratory tree bats (e.g. 1 August - 30 September); add another reduction measure in the highest risk period.

4. Feather turbines below manufacturer's cut-in except during the period of highest risk to migratory tree bats (e.g., 1 August - 30 September); add another reduction measure in the highest risk period, with Y* monitoring.

5. Achieve X*% reduction in migratory tree bat fatality with Y* monitoring.

6. Feather turbines below S* m/s (S is an unspecified wind speed that is above the manufacturer’s cut-in wind speed) during the period of highest risk to migratory tree bats (e.g., 1 August - 30 September) when temperature is above 50 degrees Fahrenheit, with Y* monitoring.

7. Set a threshold of N* migratory tree bat fatalities/megawatt for a given season. If that fatality threshold is reached, then the following season feather turbines below S* m/s. With Y* monitoring.

8. Further refine fatality thresholds. Set a threshold of N* migratory tree bat fatalities/megawatt for a given season. If that fatality threshold is reached, then the following season feather turbines below S* m/s. If season threshold is still exceeded, then the following season further raise the cut-in speed during the period of highest risk

to migratory tree bats (e.g., feather turbines up to S+* m/s during 1 August - 30 September) with Y* monitoring.

**Additional information needed to define N, S, X, Y*

In order to move forward with our recommendations, we need to search available information and decide on the most appropriate values (based on best science available now) for N, S, X, and Y. We also need to define the periods "when migratory tree bats are most likely to be present" and "of highest risk to migratory tree bats."

Further, the team recognizes the need to explore further refinements of our operational measures, develop additional tools to reduce bat fatality, and improve engagement with industry to encourage adoption of those measures. We discussed information and resource needs for refining operational measures and industry engagement. Potential areas for further effort include:

Long-term measures:

1. Evaluate data available to develop site- and condition-specific operating requirements. This is sometimes referred to as SMART curtailment, which incorporates variables in addition to wind speed (such as temperature) to reduce the time turbines are curtailed. The goal is to develop site- and condition-specific operating requirements to maximize reduction of bat fatality while minimizing the cost to the wind industry.

2. Conduct a meta-analysis of available data on spatial arrangement of bat fatalities in R3 to search for patterns that would aid us in siting recommendations and/or in spatially-explicit application of operational measures. Potential outcomes include:

    a) An ability to determine if "killer turbines" (specific turbines that kill far more bats than other turbines) exist within some wind energy facilities. If a few turbines account for most of the fatality, then applying strict operational measures to those turbines may reduce bat fatality more than applying less strict measures across the wind facility, and with less loss of energy production.
    b) Determine if migratory tree bats concentrate in pathways during migration, and use those pathways repeatedly across years. If so, avoiding these pathways when siting turbines could significantly decrease fatalities (or if turbines are already in these areas, applying stricter operational measures during migratory tree bat migration).
    c) Determine if specific topographic features are associated with high fatalities (e.g., ridgetops) and (if so) avoid siting turbines in these areas (or if turbines are already in these areas, applying stricter operational measures during migratory tree bat migration).

3. Improve understanding of:

    a) The impact of turbine fatalities (incrementally and cumulatively) on viability of migratory tree bat populations.

b) The relationship between bat behavior/biology and collision risk.
c) The natural history and population dynamics of migratory tree bats.
d) The ecological and economic benefits of migratory tree bats.
f) The period of highest risk of bat fatality at wind turbines, and how that risk varies across the landscape (and if it varies among years).

4. Improve our ability to measure magnitude of fatality. This would entail improving the consistency and quality of bat fatality monitoring, and improved access to bat fatality monitoring data for the Service and the scientific community.

5. Maximize the development of new measures/tools to reduce fatalities (e.g., acoustic or visual deterrents to keep bats away from turbines).

6. Provide and/or help secure grant funds to research and develop new operational measures or other bat fatality reduction tools.

7. Based on best available science, develop a communication strategy to increase awareness of migratory tree bat fatalities at wind turbines. Communicating ecological and economic benefits of bats could help garner support from stakeholders.

8. Engage agriculture/forestry communities to promote migratory tree bat conservation.

9. Engage U.S. Geological Survey, U.S. Department of Energy, and other federal agencies as appropriate for expertise and resources.

10. Engage turbine manufacturers to explore potential for bat-friendly turbine designs.

11. Consider potential alternative regulatory authorities.

12. Consider ESA Section 10 permits (research permits) to wind facilities for valid research to develop new operational measures or other tools.

Industry engagement measures:

1. Improve our understanding of industry objectives and constraints that may be barriers to adoption of bat fatality reduction strategies.

2. Develop a coordinated effort to avoid potential listing of migratory tree bats in the future. Effort would need to be evaluated relative to standards of the Policy for the Evaluation of Conservation Efforts (PECE).

3. Develop Candidate Conservation Agreements (CCAAs) with individual wind energy facilities and/or develop a template CCAA that any wind energy facility could adopt.

4. Pre-listing agreements (e.g., conservation banks).

5. Coordinate with and seek input from stakeholders (e.g., key wind industry representatives, States, Bat Conservation International, others).

6. Develop new frameworks to incentivize industry (e.g., "bat-friendly" certification).

7. Increase engagement of R3 Service personnel with wind energy/wildlife coalitions.

Portfolios

Once we identified alternative actions that could be employed, we began to develop collective sets of actions (portfolios). Our portfolios were composed of actions from the ***Operational measures*** list (described in detail above). To generate ideas, each of seven team members independently developed two portfolios. The first set of portfolios focused on operational measures that would be most beneficial to migratory tree bats only (did not consider industry participation) – these were referred to as Bat-Focused Alternatives. The second set of portfolios considered actions both in terms of benefits to migratory tree bats and wind industry participation – these were referred to as Combined-Focus Alternatives.

Note that the portfolios developed for the workshop were merely placeholders to evaluate our framework and metrics; therefore, specifics of the portfolios are not included in this report.

Decision Analysis

We developed a consequence table to compare the portfolios. Each team participant scored the performance of his/her portfolios (Tables 2 and 3). The Average Reduction is the expected percent reduction from the current level of fatality in the number of bats killed/year with implementation of the portfolio; Proportion of Adoption is expected proportion of wind industry facilities in R3 likely to adopt the portfolio measures; and Expected Results is the expected % reduction in bat fatalities compared to current fatality level.

Table 2. Bat-focused Portfolios Consequence Table.

	Bat-focused Alternatives						
	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7
Average % Reduction	80%	80%	80%	80%	80%	80%	80%
Proportion of Adoption	0.1	0.38	0.1	0.38	0.1	0.38	0.38
Expected Results	8%	30%	8%	30%	8%	30%	30%

Table 3. Combine-focused Portfolios Consequence Table.

	Combined-focus Alternatives						
	Portfolio1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7
Average % Reduction	50%	50%	50%	80%	50%	50%	50%
Proportion of Adoption	0.38	0.68	0.38	0.68	0.38	0.68	0.68
Expected Results	19%	34%	19%	54%	19%	34%	34%

There was relatively little variation in performance within the two thematic sets of portfolios (bat-focused and combined-focus). This outcome is not surprising given that the options we considered for both "Average Reduction" and "Proportion of Adoption" in this first prototype were limited. Also not surprising, the bat-focused alternatives yielded the greatest average reduction in fatalities. However, projected adoption rates were estimated to be low so the overall reductions in fatality (Expected Results) were generally low. The best-performing portfolio was Portfolio 4 under the Combined-Focused alternatives. This strategy included both high average reduction in bat fatalities and high industry adoption (see Table 3, Portfolio 4); the premise underlying this strategy was that by offering flexibility in how the facilities achieve the required reduction would make the alternative more acceptable. Although the team recognized the relationship between greater flexibility and increased industry participation, the strength of this relationship was not fully realized until the team discussed the results of the consequences analysis. Portfolio 4 expanded our team's perspective on potential alternatives and we will further explore the feasibility of portfolios of this nature as we move forward with formulating recommendations.

Predictive model

Selecting a preferred portfolio requires an understanding of the implications of the Expected Results on the viability of the bats. In other words, as the alternatives will vary in the level of expected fatality reductions, they also vary in the consequences for long-term persistence of migratory tree bat populations. Thus, to gain insights about how various levels of fatality reduction will affect the future persistence of migratory tree bats, we developed a stochastic, predictive model to forecast population numbers over time given different levels of hoary bat fatality at wind facilities (i.e., to evaluate how the portfolios will affect population trajectories). For logistical reasons, we are using the hoary bat as a proxy for all migratory tree bats. We have parameterized the population model using expert input for population size and population growth rate (as described in the **Decision Problem** section). Our team is in the process of developing best estimates for annual bat fatality (bats/year) given current wind energy capacity and future build-out of wind energy capacity (needed to estimate how bat fatality will change over time).

Uncertainty

There are several sources of uncertainty that could potentially influence the Expected Results of our portfolios as well as the results of our predictive model of bat population response. Sources of uncertainty include aspects of migratory tree bat ecology (e.g., population sizes, vital rates, migratory pathways, population response to loss of individuals), and uncertainty regarding future wind energy production. We want to rigorously explore the key uncertainties associated with developing effective recommendations and to identify those that are most urgent to investigate.

We describe key areas of uncertainty and ideas on how we may address those going forward under "Further development required" in the Discussion section, below.

Discussion

Value of decision structuring

Decision structuring was a value-added effort in addressing the issue of migratory tree bat fatality at wind energy facilities in R3 in that it allowed the team to clarify our decision problem, hone in on the fundamental objective, and identify a process for developing relevant and diverse alternatives. While developing conservation strategies remained our fundamental objective, it became apparent while working through the steps that development of strategies was not in itself an endpoint. Strategies must be accompanied by efforts to more effectively engage the wind energy industry and maximize implementation of those strategies. It also gave us clarity on which information is most relevant to our problem and allowed us to focus on the data that are needed to construct short-term recommendations and to identify data needs that must be addressed to develop long-term strategies.

Further development required

As noted above, there is considerable uncertainty regarding population sizes, vital rates, migratory pathways, population response to loss of individuals, and future wind production. We documented some initial thoughts about key areas of uncertainty:

- Uncertainty related to wind industry participation
    - The metrics for proportion of adoption were based on professional opinion of the workshop participants. This uncertainty can be minimized by coordinating with wind industry.
- Uncertainty related to bat fatality reduction measures
    - The current percent reduction estimates are inexact and based on a limited number of studies. Additional research on how changes in cut-in speed impact bat fatality, and whether or not this relationship changes depending on geographic location of a wind facility, would decrease this uncertainty.
    - Additionally, many believe that the timing of cut-in measures can be refined based on environmental conditions, particularly temperature. We made inferences regarding cut-in effectiveness under differing temperatures based on

the correlations between bat activity and temperature. Reductions in bat fatality when operational measures are applied using temperature thresholds have not been rigorously studied; better data would improve our ability to identify effective alternatives.

  - Similarly, we assume the constant fatality rates across wind facilities when considering conservation measures. In reality, fatality rates vary across wind facilities and landscapes, and thus, the specific wind facilities that adopt our conservation recommendations will influence the realized bat fatality reductions. A landscape-based evaluation of the fatality rates across wind energy facilities would provide insights into where we should focus our industry outreach efforts (i.e., we could concentrate our efforts in areas of highest fatality).

- Uncertainty related to migratory tree bat populations and demographics
  - Currently, the population sizes and population structures of migratory tree bats are mostly unknown. The size of the population largely determines whether or not a given level of fatality is sustainable. Although traditional bat census methods are not possible for migratory tree bats, conservation genetics research can provide insights into the size and structure of migratory tree bat populations and may help inform the scope and scale of conservation measures.
  - Similarly, we currently do not understand the dynamics of bat fatalities as population size declines. It seems intuitive that as the number of bats decline, so too will the fatality rate (i.e., few bats means lower exposure rates). However, we do not know whether this intuition is correct nor do we understand the relationship of population size and likelihood of exposure (and hence, rate of decline). This relationship is influenced by the mechanism that causes bat fatalities. For example, if collisions occur randomly, we expect fatalities to be correlated with population declines. Conversely, if bats are actively attracted to turbines, then fatality rates may not be correlated with population size (or the correlation may not be as strong) because even as the population declines, the remaining bats will be attracted to (and collide with) turbines. Additional studies on the underlying causes of bat fatalities, including studies of the behavior of bats near wind turbines, are needed.

Recommendations

Our team has four steps to complete in developing our recommendations for reducing fatality of migratory tree bats at wind energy facilities in R3:

1) Refine hoary bat population model.

2) Refine bat fatality reduction portfolios and evaluate those relative to the hoary bat population model. That is, compare population trajectories with and without the implementation of bat fatality reduction portfolios. We will use these results to decide which portfolios we want to take forward as recommendations for implementation in R3 in the near term.

3) Develop recommendations for strategies to be implemented within R3 to engage the wind industry in the near term.

4) Develop and prioritize a list of long-term measures that are needed to improve bat fatality reduction strategies and industry engagement over time. These measures may include, for example, the development of population models for eastern red bats and silver-haired bats.

Once these steps are completed, we will present the results to R3 managers. We anticipate that our managers will have questions regarding some key issues, including:

1) How do these recommendations for bat fatality reduction compare to ongoing efforts to address wildlife impacts of wind energy development in R3, especially the Midwest Wind Energy Multi-Species Habitat Conservation Plan? This HCP is nearing completion and we expect that managers will want to know how the measures we are recommending to reduce migratory tree bat fatalities relate to measures that will be taken under the HCP. The activities covered under the multi-species HCP include the construction, operation, maintenance, and decommissioning of wind energy facilities throughout R3, as well as monitoring activities. Species covered by the plan include three species of bats (Indiana, northern long-eared, little brown), as well as Kirtland's warbler, interior least tern, bald eagle, and the Great Lakes and Great Plains populations of the piping plover.

2) What are the implications of the uncertainties moving forward, for example, uncertainties regarding the size and demographics of migratory tree bat populations? How have we considered those uncertainties in the development of our recommendations? As more information becomes available, can our modeling and our recommendations readily utilize that new information?

3) Obviously the engagement of wind industry is critical to implementing steps to reduce migratory tree bat fatality at wind turbines, but how can other partners, particularly States, be engaged in this process?

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