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Wind & Wildlife

Key Research Topics

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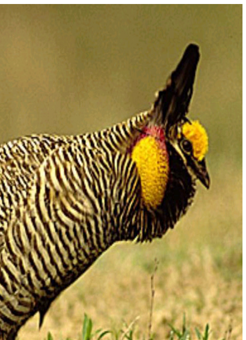
PREPARED BY
THE NATIONAL WIND COORDINATING COLLABORATIVE
WILDLIFE WORKGROUP



National Wind Coordinating Collaborative

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Preface

This document is a product of the Wildlife Workgroup of the National Wind Coordinating Collaborative (NWCC). The NWCC was formed in 1994 as a collaborative endeavor composed of representatives from diverse sectors including electric utilities and their support organizations, state utility commissions, state legislatures, consumer advocates, wind equipment suppliers and developers, green power marketers, environmental organizations, and state and federal agencies. The NWCC identifies issues that affect the use of wind power, establishes dialogue among key stakeholders, and catalyzes appropriate activities to support the development of an environmentally, economically and politically sustainable commercial market for wind power.

The mission of the NWCC Wildlife Workgroup is to identify, define, discuss, and through collaboration address wind-wildlife and wind-habitat interaction issues by seeking broad stakeholder involvement on scientific and public policy questions. This document and other wind/wildlife resources are available on the NWCC's website: www.nationalwind.org. For comments on this document or questions on wind energy and wildlife interaction, contact the National Wind Coordinating Collaborative Outreach Coordinator c/o RESOLVE, 1255 23rd Street NW, Suite 875, Washington, DC; 20037; phone: (888) 764-WIND; email: nwcc@resolv.org.

Overview

Growing demands for clean energy options, such as wind power, have increased the need to address issues (real and perceived) associated with impacts of wind development on wildlife and habitat. While there are research[1] activities at prospective and developed sites across the country focused on specific research questions, there is not a coordinated national research strategy program in the United States. Since its inception, the National Wind Coordinating Collaborative (NWCC) Wildlife Workgroup (WLWG) has tracked both domestic and international wind/wildlife interaction research and monitoring studies. Since 1994, WLWG has hosted six National Wildlife Research Meetings at which project results (including research and monitoring studies) were presented. During these meetings, additional research needs were discussed and identified, and some have been pursued. Proceedings from all these workshops are available on the NWCC website, www.nationalwind.org.

In 2006, the WLWG prepared a draft list of research priorities, based on survey results and a prioritization meeting held in June 2006. The WLWG chose to postpone further prioritization work until a number of other scientific and technical institutions completed their own lists of research priorities. In Fall 2007, the WLWG resumed work on the research priorities task. This draft summarizes key topics and suggested research proposed by the NWCC and the following institutions and their products:

- The Wildlife Society, in *Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat* (October 2007), summarizes wind energy impacts to wildlife and habitat, provides information on permitting processes, and discusses challenges associated with current research, predictive models, and monitoring methods. References to this report within the following document appear as "TWS".
- The National Academy of Sciences covers what is known – and suggests methods for determining what is unknown – about the impacts of wind development in the mid-Atlantic region to the environment and wildlife in *Environmental Impacts of Wind-Energy Projects* (April 2007). References to this report within the following document appear as "NAS".
- California Energy Commission's Public Interest Energy Research – Environmental Area (PIER-EA) program developed a list (January 2007) of *"Research needs to support avian/bat assessements and mitigation at wind facilities in California"*. References to this report within the following document appear as "CEC PIER-EA".
- In January 2007, the NWCC surveyed WLWG members representing conservation and wildlife NGOs, state agencies, consulting firms, and industry about perceived research priorities about methods and processes currently in use. References to this report within the following document appear as "NWCC".
- In 2006, the New York State Energy Research & Development Authority (NYSERDA) convened a wind and wildlife workshop discussing priority research needs. References to the summary of research topics resulting from the workshop appear within the following document as "NYSERDA".
- This report incorporates additional resources articulating research needs regarding habitat issues not addressed by the above institutions. Comparatively little information about wind energy's potential impacts to wildlife habitat exists; this document references one study on wind energy's impacts to

[1] In the context of this report, research refers to studies designed to answer specific pre-defined questions through the direct evaluation of specific hypothesized cause and effect relationships. Monitoring refers to studies designed to answer specific pre-defined questions through the collection and analysis of repeated observations or measurements to document the status or trend in the parameters of interest. Monitoring lacks the experimental control common to research projects and can only infer cause and effect through correlation.

grassland species and infers research needs from other studies examining potential and observed wildlife habitat impacts from other forms of energy development.

Though the purposes and approaches of these documents vary, there is a notable similarity between them in terms of the research priorities. While each document should be consulted for further clarity and detail, this white paper synthesizes the papers in order to provide a broader perspective of the current research needs.

Research priorities are grouped below under several headings but do not reflect any overall ranking of importance or degree of urgency. The description of each need is quoted directly, where practical, from one of the referenced sources.

References and citations in this document: Direct quotations are referenced in parentheses following each statement. Concurring or related references are included in brackets following these statements, with the full text of those references included in the endnotes beginning on page 10. In some cases, quoting directly from one reference resulted in the loss of critical details contained in another related reference. in such instances, this document substitutes a summary statement drawing from more than one reference, indicating in brackets the references which influenced that statement.

Key Research Topics

Pre-construction Tools, Methods & Metrics

Problem

Better methods, metrics, and predictive models are needed to more accurately predict the potential for impacts to wildlife populations from various levels of wind energy development (NYSERDA 6). [CEC PIER-EA, NAS, NWCC, TWS]

- Evaluate the efficacy of tools needed to make reliable predictions that would assess measures to reduce the risk of fatalities (NAS 133).
  - What factors contribute to fatalities, and are these factors incorporated into predictions (NWCC 11)?
  - How well does observation data on bird/bat use and behavior predict potential levels of mortality (CEC PIER-EA 2)?
  - There is a need to determine what information on migratory songbird and bat habitat use and migration is needed to predict mortality, and to determine which combination of sensing techniques (e.g. radar, thermal imagery, acoustic monitoring, etc.) provides the best data on migratory songbird and bat occurrence.[1 2]
- Develop new quantitative tools to predict fatalities at proposed and existing wind-energy facilities (NAS 133). Th[is] is particularly important in landscapes where unusually high bird and bat fatalities have already been reported and in regions where facilities are planned where little is known about migration, foraging, and fatalities associated with wind-energy facilities (NAS 132).
  - Develop estimates of exposure for use in evaluating fatalities and for estimating risk (NAS 133).
  - Develop models to predict risk based on geographic region, topography, season, weather, lunar cycles, and characteristics of different turbines (NAS 133).
  - Determine whether it's possible to accurately predict fatalities (number and species) prior to construction. If so, determine what data are required and what methods most accurately predict fatalities.[3]
- Determine necessary data and develop protocols for the collection of that data for accurate predictions of risk to wildlife.[4]
- How do birds & bats use airspace on a temporal basis and spatial basis in and around areas proposed for wind development (NWCC 1)? Can this information be used to site turbines in a manner that avoids flight paths (NWCC 4)?

For pre-construction research priorities relating to habitat, see the Habitat section on page 4: bullets on noise, BLM EIS footprint estimate, deferred predation, blade movement, avoidance buffers, potential benefits to bats, and disturbances to bats.

Post-construction Tools, Methods & Metrics

Problem

Methods that accurately predict effective and efficient documentation of post-construction impacts to wildlife and habitat are needed. Pre-construction impact predictions will benefit from improved post-construction data collection methods. [CEC PIER-EA, NAS, NWCC, NYSERDA, TWS]

- Determine the timing, intensity, and duration of monitoring necessary to collect the most accurate post-construction data. [5]

- Methods are needed to accurately assess what are the impacts and effects of a wind facility, including: altered breeding density, loss of population density, habitat abandonment, loss of refugia, attraction, behavior modification, disturbance, habituation, potential positive impacts to habitat. Do these variables differ by region (NWCC 12)? [6]
- Identify potential biases associated with equations and estimation of fatalities, including necessary search effort, the probability that a carcass will be detected if present, and the probability that a carcass will be removed so that its detection probability is zero (NAS 133). [7]
- What is the most appropriate fatality metric (e.g. fatality/MW, fatality/actual MW output/bird utilization) to adequately compare sites (CEC PIER-EA 24)?
- Develop offshore retrieval or estimation methods (TWS 37).

Mitigation Measures

Problem

Additional mitigation measures are needed on- and off-site. Research is required to identify and implement available (or potential) mitigation measures and activities, monitor their performance over time, and develop objective scientific evaluations of their effectiveness. [CEC PIER-EA, NAS, NWCC, NYSERDA, TWS]

For example, on site:

- Conduct studies to identify methods of mitigating impacts of wind turbines on bats, birds, and other wildlife (editor: e.g. turbine design, synchronizing turbine strings, re-powering with different sized turbines, painting blades, and sound or visibility techniques (NAS 134).[8] [9]
- Establish the efficacy of alerting and deterring methods such as infrasound and ultrasonic sound emission for each turbine design.[10]
- Studies have reported that a large proportion of bat fatalities occur on nights with low winds and relatively low levels of power production[11]. Should this pattern prove to be consistent, curtailing operations during predictable nights or periods of high bat kills could reduce fatalities considerably, potentially with modest reduction in power production and associated economic impact on project operations. Rigorous experimentation of moving and non-moving turbines at multiple sites to evaluate the effect on bird and bat fatality and the associated economic costs are needed (TWS 36).[12]

For additional needs relating to mitigation of habitat concerns, see Habitat section on page 4: bullet on sound muffling devices. Also see footnotes 9d and 9f.

Comparative Alternatives Analysis

Problem

The environmental and human-health risk reduction benefits of wind-powered electricity generation accrue through its displacement of electricity generation using other energy sources (e.g. fossil fuels), thus displacing the adverse effects of those other generators. Moreover, the only way to fully evaluate the environmental effects of generating electricity from wind energy is to understand all the [editor: current and predicted] adverse life-cycle effects of those electricity sources, and to compare them all to the adverse effects of wind energy (NAS 28). [NYSERDA]

Impacts to Habitat

Problem

There is concern that impacts to habitat, and some species' ability to use affected habitats, from wind energy development may cumulatively pose a population threat to birds, bats, and other wildlife. Particular concerns include: abandonment or avoidance of habitat due to disturbances produced at wind energy facilities (e.g. noise, visual, etc); diminished quality of habitat; diminished quantity of habitat; and habitat fragmentation resulting from scattered development in traditionally contiguous habitat areas. The Wildlife Society has said that, "[u]ltimately, the greatest habitat-related impact to wildlife may result from disturbance and avoidance of habitat. Because direct habitat loss appears to be relatively small for wind power projects, the degree to which this disturbance results in habitat fragmentation depends on the behavioral response of animals to turbines and human activity within the wind facility" (TWS 23).[NAS][13]

Sound

- Investigate whether sounds (including low and ultra-low frequency) produced by wind turbines and maintenance roads result in long-term reductions of suitable habitat for grassland species similar to those observed in response to oil development in those areas. (TWS 22[14], Holloran 108-109[15], 111[16])
- If noise is found to negatively impact prairie grouse habitat, determine whether installation of sound muffling devices sufficiently mitigate these impacts. (Holloran 111)

Movement

- Determine whether movement, in addition to human disturbance and noise, results in disturbance of nesting birds. (Robel 6)[17], (Leddy 103)

Footprint

- [Evaluate the appropriateness by region of] the BLM Programmatic Environmental Impact Statement (BLM 2005) estimate that the permanent footprint of a facility is 5 percent to 10 percent of the site, including turbines, roads, buildings, and transmission lines. This estimate was made for the more arid West and may differ for areas in the East, particularly in mountainous regions (TWS 22).

Avoidance

- The avoidance buffers around oil/gas wellheads, electric transmission lines, and buildings must be recognized and integrated into environmental assessments of the development of petroleum resources and the construction of industrial wind energy facilities (Robel 8-9).[18]
- Determine whether avoidance of wind energy facilities by predators leads to higher rates of predation at nearby leks otherwise unaffected by the wind facilities. (Holloran 110)[19]
- Investigate whether the presence of wind turbines results in the avoidance of grassland species from using otherwise suitable habitat. (Leddy 102-103)[20]

Behavior/migration

- Determine the degree to which habitat impacts to lesser prairie-chicken from anthropogenic structures observed by Robel et al. (2004) apply to other prairie grouse and ground-nesting birds, and whether they affect other species in various landscapes. (Robel 8-9)
- Determine whether migratory birds and bats adjust their migratory paths or exhibit other behaviors that may cause them to avoid turbines (NAS 134).
- Clarify the relationship of small-scale (e.g. habitat disturbance and species displacement) vs. large-scale impacts (e.g. landscape alteration and fragmentation) of development on bird and bat populations (NAS 137).[21]

Bat issues

- Test the hypothesis that, unlike some forest-dependent species, bats may actually benefit from modifications to forest structure and the landscape (bats are known to forage readily in small clearings[22] like those around turbines; however, the removal of roost trees would be detrimental to bats) resulting from construction of a wind facility. (TWS 26)[23]
- Determine the degree of disturbance to tree- and crevice-roosting bats from wind turbines (TWS 26).
- Test the hypothesis that increased human activity at wind facilities could disturb roosting bats, as no data exist. (TWS 26)[24]

Devise tests to assess the validity of several extant bat-specific habitat-related hypotheses, see Bat-Specific Needs section: Linear Corridor Hypothesis, Roost Attraction Hypothesis, Landscape Attraction Hypothesis

Existing and Needed Impact, Population, Migration, and Behavioral Data

Problem

More empirical data are needed to thoroughly assess the potential impacts of wind power development on avian and bat species. Areas of particular interest in New York State include population estimates; concentration areas; behavioral avoidance of wind facilities by different species; and migration patterns and routes. (NYSERDA 7). [CEC PIER-EA, NAS, NWCC, TWS]

- Do patterns of bird and bat avoidance and scavenger use change after construction of wind facilities (CEC PIER-EA 26)?
- Determine the relationship between waterfowl ability to avoid turbines and weather conditions and availability of other suitable habitats. (TWS 25)[25]
- Establish a mechanism for data collection from both public and private sources. Synthesize and analyze existing data. Test hypotheses for possible patterns with more extensive pre- and post-construction surveys. Enumerate hypotheses regarding possible solutions for testing. [26] [27]
- Encourage and conduct studies to support impact assessments (NAS 133).
  - Assess effects of changing technologies on bird & bat fatalities (NAS 133).
  - Identify impacts of different types of lighting on bird & bat fatalities (NAS 133).
  - Assess how different landscape features may affect bird and bat fatalities (NAS 133).
  - Assess how weather fronts influence bird and bat fatalities (NAS 133).
  - Identify bird and bat migratory patterns over space and time (NAS 133).
  - Determine whether fatalities from turbines reduce the breeding or stopover density and reproductive success of birds and bats (NAS 133).
- Are the heights of bird migration routes generally higher than collision risk zones (CEC PIER-EA 5)?
- Determining numbers of individuals, for both birds and bats, and their exposure to risk at turbines, is critical for developing a context upon which to evaluate fatalities (TWS 35).
- Bird and bat behaviors: Determine typical airspace use behaviors, whether those are altered by weather patterns, and whether birds and bats adjust behavior to avoid risky flight paths.
- Further investigat[e] relationships between passage of storm fronts, weather conditions, turbine blade movement and bat fatality to determine predictability of periods of highest fatality (TWS 36).
- Are birds, bats, and insects attracted to turbines? If they are, what specific mechanism(s) are involved (NWCC 10)?

For additional impact, population, migration and behavioral data needs, see Habitat section on page 4: bullets on migratory path adjustment, noise, predator avoidance, weather-related concerns on waterfowl flight abilities.

Bat Specific Needs

Problem:

Knowledge about bat fatalities at wind-energy plants is very limited, mainly because the large number of bats killed has been recognized only recently (NAS 134). [TWS]

- Devise tests to assess the validity of several extant bat-specific hypotheses:
  - Linear Corridor Hypothesis. Wind-energy facilities constructed along forested ridge tops create clearings with linear landscapes that are attractive to bats. Bats frequently use these linear landscapes during migration and while commuting and foraging[28], and thus may be placed at increased risk of being killed[29] (NAS 134).
  - Roost Attraction Hypothesis. Tree-roosting bats commonly seek roosts in tall trees[30] and thus if wind turbines are perceived as potential roosts[31], their presence could contribute to increased risks of being killed when bats search for night roosts or during migratory stopovers (NAS 134).
  - Landscape Attraction Hypothesis. Modifications of landscapes needed to install wind-energy facilities, including the construction of wide power-access corridors and removal of trees to create clearings (usually .5-2 ha) around each turbine site, create conditions favorable for insects on which bats feed (Attributed to Lewis 1970; Grindal and Brigham 1998; von Hensen 2004 in NAS 124). Thus, bats that are attracted to and feed on insects in these altered landscapes may be at an increased risk of being killed by wind turbines (NAS 134).
  - Bats appear to investigate turbines, perhaps for a number of reasons – acoustic and/or visual response to blade movement, sound attraction, and possible investigation of turbines as roosts, seem plausible given the findings and current state of knowledge. As such, further investigations are needed to determine causes of behavioral response to turbines and how to best mitigate or eliminate factors that put animals at risk of collision (TWS 35).
  - Additional priority research… includes… comparing different methods & tools (editor: e.g., radar, thermal imaging, and acoustic detectors) simultaneously to better understand bat activity, migration, proportions of bats active in the area of risk, and bat interactions with turbines (TWS 36). (CEC PIER-EA)
  - What factors need attention and evaluation to identify the causes of bat fatalities (NWCC 7)?
  - Low Wind Velocity Hypothesis. Fatalities of aerial feeding and migrating bats are highest on nights during periods of low wind velocity (Attributed to Fiedler 2004; von Hensen 2004; Arnett 2005 in 135), in part because flying insects are most active under these conditions (Attributed to Ahlén 2002, 2003 in NAS 134) (NAS 134).
  - Heat Attraction Hypothesis. Flying insects are attracted to the heat produced by nacelles of wind turbines (Attributed to Corten and Veldkamp 2001; Ahlén 2002, 2003; Hensen 2004 in NAS 135). As bats respond to high densities of flying insects near wind turbines, they may be at increased risk of being struck by turbine blades (NAS 135).
  - Acoustic Attraction Hypothesis. Bats are attracted to audible and/or ultrasonic sound produced by wind turbines (Attributed to Schmidt and Joermann 1986; Ahlén 2002, 2003 in NAS 135). Sounds produced by the turbine generator and the swishing sounds of rotating turbine blades may attract bats, thus increasing risks of collision and fatality (NAS 135).
  - Echolocation Failure Hypothesis. Migrating and foraging bats fail to detect wind turbines by echolocation, or miscalculate rotor velocity (Attributed to Ahlén 2002, 2003 in NAS 135). If

bats are unable to detect the moving turbine blades, they may be struck and killed directly (NAS 135).

- Electromagnetic-Field Disorientation Hypothesis. If bats have receptors sensitive to magnetic fields (Attributed to Buchler and Wasilewski 1985 in NAS 135), and wind turbines produce complex electromagnetic fields in the vicinity of the nacelle, the flight behavior of bats may be altered by these fields and thus increase their risk of being killed by rotating turbine blades (NAS 135).
- Decompression Hypothesis. Bats flying in the vicinity of turbines may experience rapid decompression (Attributed to Dürr and Bach 2004; von Hensen 2004 in NAS 135). Rapid pressure change may cause internal injuries or disorientation, thus increasing risk of death (NAS 135).
- Thermal Inversion Hypothesis. The altitude at which bats migrate and or feed may be influenced by thermal inversions, forcing them to the altitude of rotor-swept areas (Attributed to Arnett 2005 in NAS 135). The most likely impact of thermal inversions is to create dense fog in cool valleys, possibly concentrating both bats and insects on ridges, and thus encouraging bats to feed over the ridges on those nights, if for no other reason than to avoid the cool air and fog (NAS 135).

For additional bat-specific research needs, see Habitat section on page 4: bullets on potential benefits to bats, disturbance of tree-and crevice-roosting bats, and impacts of human activity at sites on bats.

Habitat and Resource Development Land-Use Mapping

Problem

Conduct regional on- and off-shore assessments to: identify areas where wind resource areas overlap with critical habitat, ecologically important intact landscapes, or habitat of endangered and protected species; project land-use and conservation conflicts extending beyond wind production; synthesize local and small-scale impacts to identify possible large-scale impacts. Utilize this information to conduct pre-siting studies comparing multiple sites for use in siting wind facilities. [CEC PIER-EA, NAS, NYSERDA, TWS]

- Can information on bird use, bird abundance, species vulnerability, [and] topography lead to an indicator of high-risk situations (CEC PIER-EA 3)?
- Conduct regional assessments and forecasting of cumulative land-use and impacts from energy development. Give projected increases in multiple sources of energy development, including biomass, wind, and oil and gas development, future conflicts surrounding land-use, mitigation, and conservation strategies should be anticipated. Habitat mitigation options, for example, when developing wind in open prairie, may be compromised by development of other energy sources. Regional assessments of existing and multiple forecasts of possible land uses are needed, and planning regional conservation strategies among industries, agencies, and private landowners could reduce conflicts and increase options for mitigation and conservation (TWS 39).
- The location, magnitude and timing of movements of bats and birds during spring and fall migration need to be determined (TWS 37).
- Identification of locations where species of concern and threatened or endangered species (bats and birds) occur during breeding and non-breeding periods is warranted (TWS 37).
- Identify species of special concern and their habitat needs; these include species listed under the federal Endangered Species Act, as well as species listed by the appropriate state (NAS 137).

- Identify where wind power potential and important wildlife resources overlap on public lands and evaluate this overlap in relation to potential impacts from wind energy development (NYSERDA).
- Conduct pre-siting studies that allow the comparison of multiple sites when making decisions about where to develop wind energy (NAS 137).

Cumulative/Population Impacts

Problem

There is concern that cumulative impacts from the proposed expansion of wind energy development could potentially reduce the viability of bird and bat populations. Better methods, metrics and predictive models are needed to more accurately predict the potential for impacts to wildlife populations from various levels of wind energy development (NYSERDA 6). [CEC PIER-EA, NAS, NWCC, TWS]

- Develop methods to accurately predict pre-construction estimates of potential biological significance of fatalities based on estimated fatality rates and demographics of the species of concern (NAS 137).
- Develop predictive and risk-assessment models of potential cumulative impacts of proposed wind-energy facilities, based on monitoring studies and hypothesis-based research (NAS 138).
- We need to know not only how likely impacts are to occur but also what the consequences will be cumulatively over time. Given the projected development of wind energy, biologically significant cumulative impacts are likely for some species. Broader assessments of the cumulative impacts for both birds and bats clearly are warranted (TWS 37). [32]

For habitat related cumulative effects, also see Habitat section on page 4: problem statement and bullet on large vs. small scale impacts.

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[1] What combination of bat and migratory songbird sensing techniques (radar, acoustic monitoring, thermal imaging, night vision devices) provides the most reliable data set on bat and migratory songbird occurrence (CEC PIER-EA 12)?

a) Is radar an effective method for determining risk (CEC PIER-EA 6)?
b) How do site utilization metrics differ by the use of different technologies (radar, thermal imaging, and acoustic detections) (CEC PIER-EA 11)?

[2] What information on bat and migratory songbird migration and habitat use would be useful for predicting mortality (CEC PIER-EA 13)?

[3]

a) Is it possible to predict what fatalities (number and species) will occur before construction begins, and what data should be collected to accurately predict fatalities? (NWCC 2)
b) What data are needed to validate pre-construction fatality predictions after operation begins? (NWCC 6)
c) What methods are needed to validate pre-construction mortality impacts with post construction monitoring? In other words, what methods would develop more concurrent post-construction monitoring needs? (NWCC 8)

[4]

a) What are the appropriate frequencies, durations, and radii of point counts/visual observation scans (CEC PIER-EA 1)?
b) Can surveys conducted at dawn and dusk alone predict risk (CEC PIER-EA 7)?
c) What are adequate time intervals to conduct surveys (ground and radar) to account for seasonal and annual variation of use (CEC PIER-EA 8)?
d) Can use data alone effectively micro-site turbines in low-risk locations (CEC PIER-EA 9)? What are the appropriate metrics to determine site use (CEC PIER-EA 10)?
e) What is the percentage of actual fatalities found necessary to provide confidence in estimating mortality (CEC PIER-EA 17)?

[5]

a) What are the adequate search intervals and search radii for the various turbine heights to capture a high percentage of fatalities (CEC PIER-EA 16)?
b) What is the appropriate duration of monitoring to adequately account for annual variation in fatalities due to annual variation in use? Can long-term periodic monitoring (e.g. every 3 years) capture that variation as well as yearly monitoring (CEC PIER-EA 15)?

[6] Can the use of dogs to find carcasses be efficient and cost-effective (CEC PIER-EA 23)?

[7]

a) Are the equations used to estimate scavenger removal appropriate (CEC PIER-EA 22)?
b) Is the number of dead bats and songbirds found an accurate indication of bats and songbirds killed (CEC PIER-EA 19)?
c) What is the appropriate duration and metric (some use percentage of carcasses remaining after so many days and some use mean number of days until all carcasses are removed) to measure scavenger removal rates (CEC PIER-EA 21)?
d) How does the taxa, size, and condition (i.e. frozen) of different species affect the outcome of scavenger removal trials (CEC PIER-EA 20)?

[8] What available mitigation techniques are most effective at a particular site (e.g. synchronizing turbine strings, re-powering with different sized turbines, painted blades, sound or visibility techniques, and the possible use of shut downs in specified circumstances and times) (NWCC 15)?

[9]

a) What turbine designs are more likely to result in collision (CEC PIER-EA 29)?
b) Can micro-siting in low risk areas and removing turbines from high risk areas sufficiently reduce fatalities (CEC PIER-EA 30)?
c) Can blades be made more visible to birds and bats (CEC PIER-EA 31)?
d) How can habitat manipulations (e.g. rodent control, other prey reduction techniques) reduce bird use near turbines and reduce fatalities to acceptable levels? What impacts would they have on other species (CEC PIER-EA 33)?
e) Are there ways to deter birds and bats from turbines (CEC PIER-EA 35)?
f) How effective is providing habitat off-site as a measure to compensate for impact at wind facilities (CEC PIER-EA 36)?

[10]

a) Additional priority research … includes … investigating approaches for developing possible deterrents; testing any such deterrents should be performed under controlled conditions first, and then under a variety of environmental and turbine conditions at multiple sites (TWS 36).

b) Some research has been suggested on the use of infrasound, which appears to deter homing pigeons (Columba livia; Hagstrum 2000), but no studies have yet been conducted on this potential tool … Development and testing of ultrasonic sound emission as a possible deterrent to bats has been undertaken in the United States (E.B. Arnett, Bat Conservation International, unpublished data); more research is needed to quantify the effectiveness at an operating facility that will include measures of fatality reduction as well as behavioral responses of bats (TWS 37).

c) Are deterrents effective? If so, what types of deterrents are the most effective for each turbine design (NWCC 14)?

[11] Attributed to Feidler 2004, Arnett 2005, Brinkman 2006 in TWS 36.

[12] Can periodic shut downs reduce fatalities (CEC PIER-EA 32)?

[13] Little is known about habitat impacts from development associated with wind facilities. Most permitting documents contain estimates of short- and long-term disturbance, but seldom include estimates of indirect impact. Additionally, efforts to follow up with post-construction estimates of actual impact are rare (TWS 21).

[14] It is not likely that noise generated by turbines influences roosting bats, but no empirical data exist to support or refute this contention (TWS 26).

[15] Investigating changes in the number of male greater sage-grouse occupying a lek relative to cumulative gas field development levels using principal components analysis suggested that as the distance from leks to drilling rigs, producing wells, and main haul roads decreased, and as main haul road densities within 3 km and the number of directions to producing wells within 5km (i.e. the lek became more centrally located within the developing field) increased, lek attendance by males approached zero (Holloran 109-110).

[16] The effect-distance from disturbance sources to leks during the breeding season could be conservatively estimated at 3-5km, especially if that source was located where sound propagation towards a lek was intensified by environmental factors (i.e. prevailing wind direction). Therefore, sound muffling devices installed on noisy gas field structures could reduce the negative consequences on breeding grouse (Holloran 111).

[17] We did not attempt to determine causative factors associated with nesting lesser prairie chicken avoidance of anthropogenic features, however, it appears that movement and noise might be implicated… Additional research is needed to determine why the anthropogenic features we examined deterred lesser prairie-chickens from nesting near them. Such answers may allow modification of those features to reduce their negative impacts on nest placement by lesser prairie-chickens, and possible other avian species sensitive to human activity (Robel 6).

[18] In the future, the negative impacts of anthropogenic features should be considered when assessing the suitability of habitat for lesser prairie-chickens, purchasing or leasing habitat for those birds, or implementing management actions for the benefit of those populations. The avoidance buffers around oil/gas wellheads, electric transmission lines, and buildings must be recognized and integrated into environmental assessments of the development of petroleum resources and the construction of industrial wind energy facilities. The results of our research most likely apply to other prairie grouse, but specific studies are needed to determine the magnitude of the impacts on individual species in various landscapes (Robel et al. 8-9)

[19] Avoidance of gas field developments could be responsible for decreased male survival probabilities on leks situated near the edges of developing fields (i.e. lightly impacted leks) (Holloran 110).

[20] Although wind turbines may not directly cause mortality, the presence of wind turbines may indirectly affect local grassland bird populations by decreasing the area of grassland habitat available to breeding birds…Although research in the Netherlands also has indicated the presence of turbines has prevented waterfowl and wading bird species from using otherwise suitable habitat (Winkelman 1990, Pedersen and Poulsen 1991), mechanisms inhibiting birds from exploiting grasslands near turbines have not yet been identified. In addition to human disturbance and noise, the physical movements of the turbines when they are operating may have disturbed nesting birds. Maintenance trails between turbines that are driven daily may have further decreased the availability of grassland habitat adjacent to turbines (Leddy 102-103).

[21] [Of specific concern to prairie grouse], in addition to loss of habitat as a result of abandonment, it is probable that wind development will negatively affect landscape structure. Declining grouse populations are strongly affected by broad spatial landscape changes (e.g., fragmenting and diminishing prairie chicken home ranges) (TWS 25).

[22] Attributed to Grindal and Brigham 1998; Hayes 2003; Hayes and Loeb 2007 in TWS 26.

[23] Unlike some forest-dependent species, bats may actually benefit from modifications to forest structure and the landscape resulting from construction of a wind facility. Bats are known to forage readily in small clearings (Grindal and Brigham 1998, Hayes 2003, Hayes and Loeb 2007) like those around turbines … However, the removal of roost trees would be detrimental to bats (TWS 26).

[24] Increased human activity at wind facilities could disturb roosting bats, but … no data exist (TWS 26).

[25] Low estimated waterfowl mortality at [wind facilities] may be due to the ability of waterfowl to avoid turbines, as suggested by Fernley and Lowther (2006). However, ability to avoid turbines may be related to weather conditions and availability of other suitable habitats (TWS 25).

[26] More extensive pre- and post-construction surveys are needed to further elucidate patterns and test hypotheses regarding possible solutions (TWS 39).

[27] Can a meta-analysis of comparable data from several projects lead to an indicator of high risk situations (CEC PIER-EA 4)?

[28] Attributed to Limpens and Kapteyn 1991; Verboom and Spoelstra 1999; von Hensen 2004; Menzel et al. 2005 in NAS 134

[29] Attributed to Dürr & Bach 2004 in NAS 134.

[30] Attributed to Pierson 1998; Kunz and Lumsden 2004; Barclay and Kurta 2007 in NAS 134.

[31] Attributed to Ahlén 2002, 2003; von Hensen 2004 in NAS 134.

[32]

a) What are the cumulative population impacts of wind facilities on birds and bats (NWCC 5)
b) What is a credible approach to consider and compare direct, indirect, and cumulative wildlife effects from both wind and conventional electricity generation (NWCC 16)?
c) Is it feasible to design a study to determine population level effects of local fatalities (particularly for winter migrants) (CEC PIER-EA 34)?

Literature Cited

Ahlén, I. 2002. Bats and birds killed by wind power turbines [in Swedish]. Fauna och Flora 97(3): 14-21.

Ahlén, I. 2004. Heterodyne and time-expansion methods for identification of bats in the field and through sound analysis. Pp. 72-79 in Bat Echolocation Research: Tools, Techniques, and Analysis, R.M. Brigham, E.K.V. Kalko, G. Jones, S. Parsons, and H.J.G.A. Limpens, eds. Austin, TX: Bat Conservation International.

Arnett, E.B. 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

Arnett, E.B. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. Wildlife Soc. Bull. 34: 1440-1445.

Arnett, E.B., D.B. Inkley, D.H. Johnson, R.P. Larkin, S. Manes, A.M. Manville, J.R. Mason, M.L. Morrison, M.D. Strickland, and R. Thresher. 2007. Impacts of wind energy facilities on wildlife and wildlife habitat. Wildlife Society Technical Review 07-2. The Wildlife Society, Bethesda, Maryland, USA.

Barclay, R.M.R., and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Pp. 17-57 in Bats in Forests: Conservation and Management, M.J. Lacki, J.P. Hayes, and A. Kurta, eds. Baltimore, MD: John Hopkins University Press.

Brinkman, R. 2006. Survey of possible operational impacts on bats by wind facilities in southern Germany. Report for Administrative District of Freiburg – Department 56, Conservation and Landscape Management. Ecological Consultancy, Gundelfingen, Germany.

Buchler, E.R., and P.J. Wasilewski. 1985. Magnetic remembrance in bats. Pp. 483-487 in Magnetite Biomineralization and Magnetoreception in Organisms: A New Biomagnetism, J.L. Kirschvink, D.S. Jones, and B.J. MacFadden, eds. New York: Plenum Press.

California Energy Commission Public Interest Energy Research – Environmental Area. 2006. Meeting Proceedings. http://www.energy.ca.gov/renewables/06-OII-1/documents/2006-11-02_workshop/2007-01-09_DRAFT_LIST.PDF. California Energy Commission, Sacramento, California, USA.

Committee on Environmental Impacts of Wind Energy Projects, National Research Council. 2007. Environmental Impacts of Wind-Energy Projects. The National Academies Press, Washington, District of Columbia, USA.

Corten, G.P. and H.F. Veldkamp. 2001. Aerodynamics: Insects can halve wind-turbine power. Nature 12(6842): 42-43.

Dürr, T., and L. Bach. 2004. Bat deaths and wind turbines: A review of current knowledge, and of information available in the database for Germany [in German]. Bremer Beiträge für Naturkunde und Naturschutz 7:253-264.

Fiedler, J.K. 2004. Assessment of bat mortality and activity at Buffalo Mountain wind facility, eastern Tennessee. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Grindal, S.D., and R.M Brigham. 1998. Short-term effects of small-scale habitat disturbance on activity by insectivorous bats. Journal of Wildlife Management 62: 996-1003.

Hayes, J.P. 2000. Assumptions and practical considerations in the design and interpretation of echolocation-monitoring studies. Acta Chiropterologica 2: 225-236.

Hayes, J.P., and S.C. Loeb. 2007. The influences of forest management on bats in North America. Pages 207-235 in M.J. Lacki, A. Kurta, and J.P. Hayes, editors. Conservation and management of bats in forests. John Hopkins University Press, Baltimore, Maryland, USA.

Holloran, M. J. 2005. Greater Sage-Grouse (Centrocercus urophasianus) Population Response to Natural Gas Field Development in Western Wyoming. Ph.D. University of Wyoming, Laramie. http://www.sagebrushsea.org/pdf/Holloran_Grouse_Development_4_chap3.pdf

Kunz, T.H., and L.F. Lumsden. 2003. Ecology of cavity and foliage roosting bats. Pp. 3-89 in Bat Ecology, T.H. Kunz and M.B. Fenton, Eds. Chicago, IL: University of Chicago Press.

Leddy, K., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin 111:100-104. http://elibrary.unm.edu/sora/Wilson/v111n01/p0100-p0104.pdf.

Lewis, T. 1970. Patterns of distribution of insects near a windbreak of tall trees. Ann. Appl. Biol. 65:213-220.

Limpens, H.J.G.A., and K. Kapteyn. 1991. Bats, their behaviour and linear landscape elements. Myotis 29: 63-71.

Menzel, J.M., M.A. Menzel, Jr., J.C. Kilgo, W.M. Ford, J.W. Edwards, and G.F. McCracken. 2005. Effect of habitat and foraging height on bat activity in the coastal plain of South Carolina. J. Wildlife Manage. 69(1): 235-245.

National Wind Coordinating Collaborative. 2006. Draft NWCC Prioritized Research Needs White Paper. National Wind Coordinating Collaborative, Washington, District of Columbia, USA.

New York State Energy Research and Development Authority. 2006. Meeting Proceedings. New York State Energy Research and Development Authority, Albany, New York, USA.

Pierson, E.D. 1998. Tall trees, deep holes, and scarred landscapes: Conservation biology of North American bats. Pp. 309-325 in Bat Biology and Conservation, T.H. Kunz and P.A. Racey, eds. Washington, DC: Smithsonian Institution Press.

Robel, R. J., J. Harrington, J. A., C. A. Hagan, J. C. Pitman, and R. R. Reker. 2004. Effect of energy development and human activity on the use of sand sagebrush habitat by Lesser Prairie Chickens in southwestern Kansas. http://kec.kansas.gov/wptf/robertrobel.pdf.

Schmidt, U., and G. Joermann. 1986. The influence of acoustical interferences on echolocation in bats. Mammalia 50(3): 379-389.

Verboom, B., and K. Spoelstra. 1999. Effects of food abundance and wind on the use of tree lines by an insectivorous bat, *Pipistrellus pipistrellus*. Can. J. Zool. 77(9): 1393-1401.

von Hensen, F. 2004. Thought and working hypotheses on the bat compatibility of wind energy plants [in German]. Nyctalus 9(5): 427.436.