the pre-construction assessment will guide possible project modifications, mitigation or the need for and design of post-construction studies. Analysis of the results of post construction studies can test design modifications and operational activities to determine their effectiveness in avoiding or minimizing significant adverse impacts. When there is considerable uncertainty over the appropriate mitigation for a project, AM is typically the preferred approach to testing the effectiveness of alternative approaches.

Adaptive management should be reserved for situations where adverse impacts to species of concern are significant. This can be best determined by communication between the project operator, the Service field office, and the state wildlife agency, on a project-by-project basis. For adaptive management to be effective there must be agreement to adjust management and/or mitigation measures if monitoring indicates that anticipated impacts are being exceeded. Such agreement should include a timeline for periodic reviews and adjustments as well as a mechanism to consider and implement additional mitigation measures as necessary after the project is developed. The DOI Adaptive Management Technical Guide is located on the web at: www.doi.gov/initiatives/AdaptiveManagement/index.html.

Coordination with Other Federal Agencies

Other Federal agencies, such as the Bureau of Land Management, National Park Service, U.S. Department of Agriculture Forest Service and Rural Utility Service, and Department of Energy are often interested in and involved with wind project developments. These agencies have a variety of expertise and authorities they implement. State and local agencies and Tribes also have additional interests and knowledge. The Service recommends that wind project developers contact these agencies early in the tiered process and work closely with them throughout project planning and development to assure that projects address issues of concern to those agencies.

Relationship to Other Guidelines

These Guidelines replace the Service's 2003 interim voluntary guidelines. The Service intends that these Guidelines, when used in concert with the appropriate regulatory tools, will be the best practical approach for conservation of species of concern**.** For instance, when developers encounter an endangered or threatened species, they should comply with Section 7 or 10 of the ESA to obtain incidental take authorization. Other federal, state, tribal and local governments may use these Guidelines to complement their efforts to address wind energy development/fish and wildlife interactions. They are not intended to supplant existing regional or local guidance, or landscape-scale tools for conservation planning, but were developed to provide a means of improving consistency with the goals of the wildlife statutes that the Service is responsible for implementing. The Service will continue to work with states, tribes, and other local stakeholders on map-based tools, decision-support systems, and other products to help guide future development and conservation. Additionally, project proponents should utilize any relevant guidance of the appropriate jurisdictional entity, which will depend on the species and resources potentially affected by proposed development.

Chapter 2

Tiered Approach and Tier 1 – Preliminary Site Evaluation

This chapter briefly describes the tiered approach, with subsequent chapters outlining BMPs during site construction, retrofitting, repowering and decommissioning phases of a project. The five tiers are:

Tier 1 – Preliminary evaluation or screening of potential sites

Tier 2 – Site characterization

Tier 3 – Field studies to document site wildlife conditions and predict project impacts

Tier 4 – Post-construction studies to estimate impacts

Tier 5 – Other post-construction studies and research

The first three tiers correspond to the pre-construction evaluation phase of wind energy development. At each of the three tiers, the Guidelines provide a set of questions that developers attempt to answer, followed by recommended methods and metrics to use in answering the questions. Some questions are repeated at each tier, with successive tiers requiring a greater investment in data collection to answer certain questions. For example, while Tier 2 investigations may discover some existing information on federal or state-listed species and their use of the proposed development site, it may be necessary to collect empirical data in Tier 3 studies to determine the presence of federal or state-listed species.

Developers decide whether to proceed to the next tier. Timely communication will allow the opportunity for the Service to provide, and developers to consider, technical advice. A developer should base the decision on the information obtained from adequately answering the questions in this tier, whether the methods used were appropriate for the site selected, and the resulting assessment of risk posed to species of concern and their habitats.

Tier 1 - Preliminary Evaluation or Screening of Potential Sites

For developers taking a first look at a broad geographic area, a preliminary evaluation of the general ecological context of a potential site or sites can serve as useful preparation for coordination with the federal, state, tribal, and/or local agencies. The Service is available to assist wind energy project developers to identify potential wildlife and habitat issues and should be contacted as early as possible in the company's planning process. With this internal screening process, the developer can begin to identify broad geographic areas of high sensitivity due to the presence of: 1) large blocks of intact native landscapes, 2) intact ecological communities, 3) fragmentation-sensitive species' habitats, or 4) other important landscape-scale wildlife values. Tier 1 may be used in any of the following three ways:

1. To identify regions where wind energy development poses substantial risks to species of concern or their habitats, including the fragmentation of large-scale habitats and threats to regional populations of federal- or state-listed species.
2. To “screen” a landscape or set of multiple potential sites to avoid those with the highest habitat values.
3. To begin to determine if a single identified potential site poses serious risk to species of concern or their habitats.

Tier 1 can offer early guidance about the sensitivity of the site within a larger landscape context; it can help direct development away from sites that will be associated with additional study need, greater mitigation requirements, and uncertainty; or it can identify those sensitive resources that will need to be studied further to determine if the site can be developed without significant adverse impacts to the species of concern or local population(s). This may facilitate discussions with the federal, state, tribal, and/or local agencies in a region being considered for development. In some cases, Tier 1 studies could reveal serious concerns indicating that a site should not be developed.

Development in some areas may be precluded by federal law. This designation is separate from a determination through the tiered approach that an area is not appropriate for development due to feasibility, ecological reasons, or other issues. Developers are encouraged to visit Service databases or other available information during Tier 1 or Tier 2 to see if a potential wind energy area is precluded from development by federal law. Some areas may be protected from development through state or local laws or ordinances, and the appropriate agency should be contacted accordingly. The local Service office is available to answer questions regarding the designation and how it may apply to wind energy development.

Some areas may be inappropriate for large scale development because they have been recognized according to scientifically credible information as having high wildlife value, based solely on their ecological rarity and intactness (e.g., Audubon Important Bird Areas, The Nature Conservancy portfolio sites, state wildlife action plan priority habitats). It is important to identify such areas through the tiered approach, as reflected in Tier 1, Question 2 below. Many of North America's native landscapes are greatly diminished, with some existing at less than 10 percent of their pre-settlement occurrence. Herbaceous sub-shrub steppe in the Pacific Northwest and old growth forest in the Northeast are representative of such diminished native resources. Important remnants of these landscapes are identified and documented in various databases held by private conservation organizations, state wildlife agencies, and, in some cases, by the Service. Developers should collaborate with such entities specifically about such areas in the vicinity of a prospective project site.

Tier 1 Questions

Questions at each tier help determine potential environmental risks at the landscape scale for Tier 1 and project scale for Tiers 2 and 3. Suggested questions to be considered for Tier 1 include:

1. Are there species of concern present on the potential site(s), or is habitat (including designated critical habitat) present for these species?
2. Does the landscape contain areas where development is precluded by law or areas designated as sensitive according to scientifically credible information? Examples of designated areas include, but are not limited to: "areas of scientific importance;" "areas of significant value;" federally-designated critical habitat; high-priority conservation areas for non-government organizations (NGOs); or other local, state, regional, federal, tribal, or international categorizations.
3. Are there known critical areas of wildlife congregation, including, but not limited to: maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?

Comment [UF&WS3]: ASK FAC – need citation/reference/definition

4. Are there large areas of intact habitat with the potential for fragmentation, with respect to species of habitat fragmentation concern needing large contiguous blocks of habitat?

Tier 1 Methods and Metrics

Developers who choose to conduct Tier 1 investigations would generally be able to utilize existing public or other readily available landscape-level maps and databases from sources such as federal, state, or tribal wildlife or natural heritage programs, the academic community, conservation organizations, or the developers' or consultants' own information. The Service recommends that developers conduct a review of the publicly available data. The analysis of available sites in the region of interest will be based on a blend of the information available in published and unpublished reports, wildlife range distribution maps, and other such sources. The developer should check with the Service Field Office for data specific to wind energy development and wildlife at the landscape scale in Tier 1.

Use of Tier 1 Information

The objective of the Tier 1 process is to help the developer identify a site or sites to consider further for wind energy development. Possible outcomes of this internal screening process include the following:

1. One or more sites are found within the area of investigation where the answer to each of the above Tier 1 questions is "no," indicating a low probability of significant adverse impact to wildlife. The developer proceeds to Tier 2 investigations and characterization of the site or sites, answering the Tier 2 questions with site-specific data to confirm the validity of the preliminary indications of low potential for significant adverse impact.

2. A "Yes" answer to one or more of the Tier 1 questions indicates a higher probability of significant adverse impacts to wildlife. Consideration of the area may be abandoned, or effort may be devoted to identifying possible means by which the project can be modified to avoid or minimize significant adverse impacts.

3. The data available in the sources described above are insufficient to answer one or more of the Tier 1 questions. The developer proceeds to Tier 2, with a specific emphasis on collecting the data necessary to answer the Tier 2 questions, which are inclusive of those asked at Tier 1.

Chapter 3

Tier 2 – Site Characterization

At this stage, the developer has narrowed consideration down to specific sites, and additional data may be necessary to systematically and comprehensively characterize a potential site in terms of the risk wind energy development would pose to species of concern and their habitats. In the case where a site or sites have been selected without the Tier 1 preliminary evaluation of the general ecological context, Tier 2 becomes the first stage in the site selection process. The developer will address the questions asked in Tier 1; if addressing the Tier 1 questions here, the developer will evaluate the site within a landscape context. However, a distinguishing feature of Tier 2 studies is that they focus on site-specific information and should include at least one visit to each of the prospective site(s). Because Tier 2 studies are preliminary, normally one reconnaissance level site visit will be adequate as a "ground-truth" of available information. Notwithstanding, if key issues are identified that relate to varying conditions and/or seasons, Tier 2 studies should include enough site visits during the appropriate times of the year to adequately assess these issues for the prospective site(s).

Tier 2 Questions

Questions suggested for Tier 2 can be answered using credible, publicly available information that includes published studies, technical reports, databases, and information from agencies, local conservation organizations, and/or local experts. Developers or consultants working on their behalf should contact the federal, state, tribal, and local agencies that have jurisdiction or management authority and responsibility over the potential project.

1. Are there known species of concern present on the proposed site, or is habitat (including designated critical habitat) present for these species?

2. Does the landscape contain areas where development is precluded by law or designated as sensitive according to scientifically credible information? Examples of designated areas include, but are not limited to: "areas of scientific importance;" "areas of significant value;" federally-designated critical habitat; high-priority conservation areas for NGOs; or other local, state, regional, federal, tribal, or international categorizations.

3. Are there plant communities of concern present or likely to be present at the site(s)?
4. Are there known critical areas of congregation of species of concern, including, but not limited to: maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?
5. Using best available scientific information has the developer or relevant federal, state, tribal, and/or local agency identified the potential presence of a population of a species of habitat fragmentation concern?
6. Which species of birds and bats, especially those known to be at risk by wind energy facilities, are likely to use the proposed site based on an assessment of site attributes?

Tier 2 Methods and Metrics

Obtaining answers to Tier 2 questions will involve a more thorough review of the existing site-specific information than in Tier 1. Tier 2 site characterizations studies will generally contain three elements:

1. A review of existing information, including existing published or available literature and databases and maps of topography, land use and land cover, potential wetlands, wildlife, habitat, and sensitive plant distribution. If agencies have documented potential habitat for species of habitat fragmentation concern, this information can help with the analysis.
2. Contact with agencies and organizations that have relevant scientific information to further help identify if there are bird, bat or other wildlife issues. The Service recommends that the developer make contact with federal, state, tribal, and local agencies that have jurisdiction or management authority over the project or information about the potentially affected resources. In addition, because key NGOs and relevant local groups are often valuable sources of relevant local environmental information, the Service recommends that developers contact key NGOs, even if confidentiality concerns preclude the developer from identifying specific project location information at this stage. These contacts also provide an opportunity to identify other potential issues and data not already identified by the developer.

3. One or more reconnaissance level site visits by a wildlife biologist to evaluate current vegetation/habitat coverage and land management/use. Current habitat and land use practices will be noted to help in determining the baseline against which potential impacts from the project would be evaluated. The vegetation/habitat will be used for identifying potential bird and bat resources occurring at the site and the potential presence of, or suitable habitat for, species of concern. Vegetation types or habitats will be noted and evaluated against available information such as land use/land cover mapping. Any sensitive resources located during the site visit will be noted and mapped or digital location data recorded for future reference. Any individuals or signs of species of concern observed during the site visit will be noted. If land access agreements are not in place, access to the site will be limited to public roads.

Specific resources that can help answer each Tier 2 question include:

1. **Are there known species of concern present on the proposed site, or is habitat (including designated critical habitat) present for these species?**

   Information review and agency contact: locations of state and federally listed, proposed and candidate species and species of concern are frequently documented in state and federal wildlife databases. Examples include published literature such as: Natural Heritage Databases, State Wildlife Action Plans, NGOs publications, and developer and consultant information, or can be obtained by contacting these entities.

   Site Visit: to the extent practicable, the site visit(s) should evaluate the suitability of habitat at the site for species identified and the likelihood of the project to adversely affect the species of concern that may be present.

2. **Does the landscape contain areas where development is precluded by law or designated as sensitive according to scientifically credible information?** Examples of designated areas include, but are not limited to: "areas of scientific importance;" "areas of significant value;" federally-designated critical habitat; high-priority conservation areas for NGOs; or other local, state, regional, federal, tribal, or international categorizations.

Information review and agency contact such as: maps of political and administrative boundaries; National Wetland Inventory data files; USGS National Land Cover data maps; state, federal and tribal agency data on areas that have been designated to preclude development, including wind energy development; State Wildlife Action Plans; State Land and Water Resource Plans; Natural Heritage databases; scientifically credible information provided by NGO and local resources; and the additional resources listed in Appendix C of this document, or through contact of agencies and NGOs, to determine the presence of high priority habitats for species of concern or conservation areas.

Site Visit: to the extent practicable, the site visit(s) should characterize and evaluate the uniqueness of the site vegetation relative to surrounding areas.

3. Are plant communities of concern present or likely to be present at the site(s)?

Information review and agency contact such as: Natural Heritage Data of state rankings (S1, S2, S3) or globally (G1, G2, G3) ranked rare plant communities, such as tall grass prairies.

Site Visit: to the extent practicable, the site visit should evaluate the topography, physiographic features and uniqueness of the site vegetation in relation to the surrounding region.

4. Are there known critical areas of wildlife congregation, including, but not limited to, maternity roosts, hibernacula, staging areas, winter ranges, nesting sites, migration stopovers or corridors, leks, or other areas of seasonal importance?

Information review and agency contact such as: existing databases, State Wildlife Action Plan, Natural Heritage Data, and NGO and agency information regarding the presence of Important Bird Areas, migration corridors or stopovers, leks, bat hibernacula or maternity roosts, or game winter ranges at the site and in the surrounding area.

Site Visit: to the extent practicable, the site visit should evaluate the topography, physiographic features and uniqueness of the site in relation to the surrounding region to assess the potential for the project area to concentrate resident or migratory birds and bats.

5. **Using best available scientific information, has the developer or relevant federal, state, tribal, and/or local agency independently identified the potential presence of a population of a species of habitat fragmentation concern?** If not, the developer need not assess impacts of the proposed project on habitat fragmentation.

Habitat fragmentation is defined as the separation of a block of habitat for a species into segments, such that the genetic or demographic viability of the populations surviving in the remaining habitat segments is reduced; and risk, in this case, is defined as the probability that this fragmentation will occur as a result of the project. Site clearing, access roads, transmission lines and turbine tower arrays remove habitat and displace some species of wildlife, and may fragment continuous habitat areas into smaller, isolated tracts. Habitat fragmentation is of particular concern when species require large expanses of habitat for activities such as breeding and foraging.

Consequences of isolating local populations of some species include decreased reproductive success, reduced genetic diversity, and increased susceptibility to chance events (e.g. disease and natural disasters), which may lead to extirpation or local extinctions. In addition to displacement, development of wind energy infrastructure may result in additional loss of habitat for some species due to "edge effects" resulting from the break-up of continuous stands of similar vegetation resulting in an interface (edge) between two or more types of vegetation. The extent of edge effects will vary by species and may result in adverse impacts from such effects as a greater susceptibility to colonization by invasive species, increased risk of predation, and competing species favoring landscapes with a mosaic of vegetation.

If the answer to Tier 2 Question 5 is yes, developers should use the general framework for evaluating habitat fragmentation at a project site in Tier 2 outlined below. Developers and the Service may use this method to analyze the impacts of habitat fragmentation at wind development project sites on species of habitat fragmentation concern. Service field offices may be able to provide the available information on habitat types, quality and intactness. Developers may use this information in combination with site-specific information on the potential habitats to be impacted by a potential development and how they will be impacted.

General Framework for Evaluating Habitat Fragmentation at a Project Site (Tier 2)

A. The developer should define the study area. The study area should include the Project Site (see Glossary) for the proposed project. The extent of the study area should be based on the distribution of habitat for the local population of the species of habitat fragmentation concern.

B. The developer should analyze the current habitat quality and spatial configuration of the study area for the species of habitat fragmentation concern.

i. Use recent aerial and remote imagery to determine distinct habitat patches, or boundaries, within the study area, and the extent of existing habitat fragmenting features (e.g., highways).

ii. Assess the level of fragmentation of the existing habitat for the species of habitat fragmentation concern and categorize into three classes:

- High quality: little or no apparent fragmentation of intact habitat
- Medium quality: intact habitat exhibiting some recent disturbance activity (e.g., off-road vehicle (ORV) trails, roadways)
- Low quality: Extensive fragmentation of habitat (e.g., row-cropped agricultural lands, active surface mining areas)

C. The developer should determine potential changes in quality and spatial configuration of the habitat in the study area if development were to proceed as proposed using existing site information.

D. The developer should provide the collective information from steps A-C for all potential developments to the Service for use in assessing whether the habitat impacts, including habitat fragmentation, are likely to affect population viability of the potentially affected species of habitat fragmentation concern.

6. Which species of birds and bats, especially those known to be at risk by wind energy facilities, are likely to use the proposed site based on an assessment of site attributes?

Information review and agency contact: existing published information and databases from NGOs and federal and state resource agencies regarding the potential presence of:

- Raptors: species potentially present by season
- Prairie grouse and sage grouse: species potentially present by season and location of known leks
- Other birds: species potentially present by season that may be at risk of collision or adverse impacts to habitat, including loss, displacement and fragmentation
- Bats: species likely to be impacted by wind energy facilities and likely to occur on or migrate through the site

Site Visit: To the extent practicable, the site visit(s) should identify landscape features or habitats that could be important to raptors, prairie grouse, and other birds that may be at risk of adverse impacts, and bats, including nesting and brood-rearing habitats, areas of high prey density, movement corridors and features such as ridges that may concentrate raptors. Raptors, prairie grouse, and other presence or sign of species of concern seen during the site visit should be noted, with species identification if possible.

Tier 2 Decision Process

Possible outcomes of Tier 2 include the following:

1. If the results of the site assessment indicate that one or more species of concern are present, a developer should consider applicable regulatory or other agency processes for addressing them. For instance, if migratory birds and bats are likely to experience significant adverse impacts by a wind project at the proposed site, a developer should identify and document possible actions that will avoid those impacts on birds and bats (e.g., in documents such as operational plans or an Avian and Bat Protection Plan). Such actions might include, but not be limited to, altering locations of turbines or turbine arrays, operational modifications, or compensatory mitigation. If bald or golden eagles are present and likely to be affected by a wind project located there, a developer should consider preparing an ECP and, if necessary, apply for a programmatic take permit. If

endangered or threatened species are present and likely to be affected by a wind project located there, a federal agency should consult with the Service under Section 7(a)(2) of the ESA if the project has a federal nexus or the developer should apply for a section 10(a)(1)(B) incidental take permit if there is not a federal nexus, and incidental take of listed wildlife is anticipated. State, tribal, and local jurisdictions may have additional permitting requirements.

2. The most likely outcome of Tier 2 is that the answer to one or more Tier 2 questions is inconclusive to address wildlife risk, either due to insufficient data to answer the question or because of uncertainty about what the answers indicate (for example, Tier 2 site characterization may capture the presence of features indicating wildlife congregation, but may not capture seasonality and spatial variation of wildlife use). The developer proceeds to Tier 3, formulating questions, methods, and assessment of potential mitigation measures based on issues raised in Tier 2 results.

3. Sufficient information is available to answer all Tier 2 questions, and the answer to each Tier 2 question indicates a low probability of significant adverse impact to wildlife (for example, infill or expansion of an existing facility where impacts have been low and Tier 2 results indicate that conditions are similar, therefore wildlife risk is low). The developer may then decide to proceed to obtain state and local permit (if required), design, and construction following best management practices (see Chapter 7).

4. The answers to one or more Tier 2 questions indicate a high probability of significant adverse impacts to species of concern or their habitats, or plant communities of concern, that cannot be adequately mitigated. The proposed site should be abandoned.

Chapter 4

Tier 3 – Field Studies to Document Site

Wildlife Conditions and Predict Project Impacts

Tier 3 is the first tier in which a developer would conduct quantitative and scientifically rigorous studies to assess the potential risk of the proposed project. Specifically, these studies provide pre-construction information to:

- Further evaluate a site for determining whether the wind energy project should be developed or abandoned
- Design and operate a site to avoid or minimize significant adverse impacts if a decision is made to develop
- Design compensatory mitigation measures if significant adverse habitat impacts cannot acceptably be avoided or minimized
- Determine duration and level of effort of post-construction monitoring. If warranted, provide the pre-construction component of post-construction studies necessary to estimate and evaluate impacts

At the beginning of Tier 3, a developer should communicate with the Service on the pre-construction studies. At the end of Tier 3, developers should coordinate with the Service to complete the Tier 3 decision process. The Service will provide written comments to a developer on study and project development plans that identify concerns and recommendations to resolve the concerns.

Not all Tier 3 studies will continue into Tiers 4 or 5. For example, surveys conducted in Tier 3 for species of concern may indicate one or more species are not present at the proposed project site, or siting decisions could be made in Tier 3 that remove identified concerns, thus removing the need for continued efforts in later tiers. Additional detail on the design issues for post-construction studies that begin in Tier 3 is provided in the discussion of methods and metrics in Tier 3.

Tier 3 Questions

Tier 3 begins as the other tiers begin, with problem formulation: what additional studies are necessary to enable a decision as to whether the proposed project can proceed to construction or operation or should be abandoned? This step includes an evaluation of data gaps identified by Tier 2 studies as well as the gathering of data necessary to:

- Design a project to avoid or minimize predicted risk
- Evaluate predictions of impact and risk through post-construction comparisons of estimated impacts
- Identify compensatory mitigation measures, if appropriate, to offset unavoidable significant adverse impacts

The problem formulation stage for Tier 3 also will include an assessment of which species identified in Tier 1 and/or Tier 2 will be studied further in the site risk assessment. This determination is based on analysis of existing data from Tier 1 and existing site-specific data and Project Site (see Glossary) visit(s) in Tier 2, and on the likelihood of presence and the degree of adverse impact to species or their habitat. If the habitat is suitable for a species needing further study and the site occurs within the historical range of the species, or is near the existing range of the species but presence has not been documented, additional field studies may be appropriate. Additional analyses should not be necessary if a species is unlikely to be present or is present but adverse impact is unlikely or of minor significance.

Tier 3 studies address many of the questions identified for Tiers 1 and 2, but Tier 3 studies differ because they attempt to quantify the distribution, relative abundance, behavior, and site use of species of concern. Tier 3 data also attempt to estimate the extent that these factors expose these species to risk from the proposed wind energy facility. Therefore, in answering Tier 3 questions 1-3, developers should collect data sufficient to analyze and answer Tier 3 questions 4-6.

If Tier 3 studies identify species of concern or important habitats, e.g., wetlands, which have specific regulatory processes and requirements, developers should work with appropriate state, tribal, or federal agencies to obtain required authorizations or permits.

Tier 3 studies should be designed to answer the following questions:

1. Do field studies indicate that species of concern are present on or likely to use the proposed site?
2. Do field studies indicate the potential for significant adverse impacts on affected population of species of habitat fragmentation concern?
3. What is the distribution, relative abundance, behavior, and site use of species of concern identified in Tiers 1 or 2, and to what extent do these factors expose these species to risk from the proposed wind energy project?
4. What are the potential risks of adverse impacts of the proposed wind energy project to individuals and local populations of species of concern and their habitats? (In the case of rare or endangered species, what are the possible impacts to such species and their habitats?)
5. How can developers mitigate identified significant adverse impacts?
6. Are there studies that should be initiated at this stage that would be continued in post-construction?

Tier 3 Methods and Metrics[3]

The Service encourages the use of common methods and metrics in Tier 3 assessments for measuring wildlife activity and habitat features. Common methods and metrics provide great benefit over the long-term, allowing for comparisons among projects and for greater certainty regarding what will be asked of the developer for a specific project. Deviation from commonly used methods should be carefully considered, scientifically justifiable and discussed with federal, tribal, or state natural resource agencies, or other credible experts, as appropriate. It may be

[3] The references cited herein were provided by the Wind Turbine Guidelines Advisory Committee. Additional information is available in Appendix C.

useful to consult other scientifically credible information sources. A list of references citing common methods and metrics is provided in Appendix C, including the National Wind Coordinating Collaborative's Studying Wind Energy/Wildlife Interactions: A Guidance Document (2011).

Tier 3 studies will be designed to accommodate local and regional characteristics. The specific protocols by which common methods and metrics are implemented in Tier 3 studies depend on the question being addressed, the species or ecological communities being studied and the characteristics of the study sites. Federally-listed threatened and endangered species, eagles, and some other species of concern and their habitats, may have specific protocols required by local, state or federal agencies. The need for special surveys and mapping that address these species and situations should be discussed with the appropriate stakeholders.

In some instances, a single method will not adequately assess potential collision risk or habitat impact. For example, when there is concern about moderate or high risk to nocturnally active species, such as migrating passerines and local and migrating bats, a combination of remote sensing tools such as radar, and acoustic monitoring for bats and indirect inference from diurnal bird surveys during the migration period may be necessary. Answering questions about habitat use by songbirds may be accomplished by relatively small-scale observational studies, while answering the same question related to wide-ranging species such as prairie grouse and sage grouse may require more time-consuming surveys, perhaps including telemetry.

Because of the points raised above and the need for flexibility in application, the Guidelines do not make specific recommendations on protocol elements for Tier 3 studies. The peer-reviewed scientific literature (such as the articles cited throughout this section) contains numerous recently published reviews of methods for assessing bird and bat activity, and tools for assessing habitat and landscape level risk. Details on specific methods and protocols for recommended studies are or will be widely available and should be consulted by industry and agency professionals.

Many methods for assessing risk are components of active research involving collaborative efforts of public-private research partnerships with federal, state and tribal agencies, wind energy developers and NGOs interested in wind energy-wildlife interactions (e.g., Bats and Wind Energy Cooperative and the Grassland Shrub Steppe Species Cooperative). It is important to recognize the need to integrate the results of research that improves existing methods or describes new methodological developments, while acknowledging the value of utilizing common methods that are currently available.

The remainder of this section outlines the methods and metrics that may be appropriate for gathering data to answer Tier 3 questions. These are not meant to be all inclusive and other methods and metrics are available, such as the NWCC Methods & Metrics document (Strickland et al. 2011).

Elements to Consider When Determining What to Study

Several factors can be considered to assess the potential effects to various species. Not all of these may be considered at all locations. First, the potential for presence of the species in the project area during the life of the project should be considered. Assessing species use from databases and site characteristics is a potential first step; however, it can be difficult to assess potential use by certain species from site characteristics alone. Various species in different locations may require developers to use specific survey protocols or make certain assumptions regarding presence. Seek local wildlife expertise, such as Service Field Office staff, in using the proper procedures and making assumptions.

Species that are rare or cryptic; that migrate, conduct other daily movements, or use areas for short periods of time; that are small in size or nocturnal; or that have become extirpated in parts of their historical range will present particular challenges when trying to determine potential presence. One of these challenges is "migration," broadly defined as the act of moving from one spatial unit to another (Baker 1978), or as a periodic movement of animals from one location to another. Migration is species-specific, and for birds and bats occurs throughout the year. Such movements should be considered for all potentially affected species, including flying insects and species that migrate on the ground.

Developers should conduct monitoring of potential sites to determine the types of migratory species present, what type of spatial and temporal use these species make of the site (e.g., chronology of migration or other use), and the ecological function the site may provide in terms of the migration cycle of these species. Wind developers need to determine not only what species may migrate through a proposed development site and when, but also whether a site may function as a staging area or stopover habitat for wildlife on their migration pathway.

For some species, movements between foraging and breeding habitat, or between sheltering and feeding habitats, occur on a daily basis. Consideration of daily movements (morning and evening; coming and going) is a critical factor when considering project development.

Once likely presence has been determined or assumed, determine level of exposure regarding various risk factors, including abundance, frequency of use, habitat use patterns, and behavior. Finally, consider and/or determine the consequences to the "populations" and species. Below is a brief discussion of several types of risk factors that can be considered. This does not include all potential risk factors for all species, but addresses the most common ones.

a. <u>Collision and Barotrauma</u>

Collision likelihood for individual birds and bats at a particular wind energy facility may be the result of complex interactions among species distribution, "relative abundance," behavior, visibility, weather conditions, and site characteristics. Collision likelihood for an individual may be low regardless of abundance if its behavior does not place it within the "rotor-swept zone." Individuals that frequently occupy the rotor-swept zone but effectively avoid collisions are also at low likelihood of collision with a turbine.

Alternatively, if the behavior of individuals frequently places them in the rotor-swept zone, and they do not actively avoid turbine blade strikes, they are at higher likelihood of collisions with turbines regardless of abundance. Some species, even at lower abundance, may have a higher collision rate than similar species due to subtle differences in their ecology and behavior. At many projects, the numbers of bat fatalities are higher than the numbers of bird fatalities, but the exposure risk of bats at these facilities is not fully understood. Researchers (Horn et al. 2008 and Cryan 2008) hypothesize that some bats may be attracted to turbines, which, if true, would further complicate estimation of exposure. Further research is required to determine whether bats are attracted to turbines and if so, whether this increased individual risk translates into higher population-scale effects.

b. Habitat Loss and Degradation

Wind project development results in direct habitat loss and habitat modification, especially at sites previously undeveloped. Many of North America's native landscapes are greatly diminished or degraded from multiple causes unrelated to wind energy. Important remnants of these landscapes are identified and documented in various databases held by private conservation organizations, state wildlife agencies, and, in some cases, by the Service. Species that depend on these landscapes are susceptible to further loss of habitat, which will affect their ability to reproduce and survive. While habitat lost due to footprints of turbines, roads, and other infrastructure is obvious, less obvious is the potential reduction of habitat quality.

c. Habitat Fragmentation

Habitat fragmentation separates blocks of habitat for some species into segments, such that the individuals in the remaining habitat segments may suffer from effects such as decreased survival, reproduction, distribution, or use of the area. Site clearing, access roads, transmission lines, and arrays of turbine towers may displace some species or fragment continuous habitat areas into smaller, isolated tracts. Habitat fragmentation is of particular concern when species require large expanses of habitat for activities such as breeding, foraging, and sheltering.

Habitat fragmentation can result in increases in "edge" resulting in direct effects of barriers and displacement as well as indirect effects of nest parasitism and predation. Sensitivity to fragmentation effects varies among species. Habitat fragmentation and site modification are important issues that should be assessed at the landscape scale early in the siting process. Identify areas of high sensitivity due to the presence of blocks of native habitats, paying particular attention to known or suspected "species sensitive to habitat fragmentation."

d. Displacement and Behavioral Changes

Estimating displacement risk requires an understanding of animal behavior in response to a project and its infrastructure and activities, and a pre-construction estimate of presence/absence of species whose behavior would cause them to avoid or seek areas in proximity to turbines, roads, and other components of the project. Displacement is a function of the sensitivity of individuals to the project and activity levels associated with operations.

e. Indirect Effects

Wind development can also have indirect effects to wildlife and habitats. Indirect effects include reduced nesting and breeding densities and the social ramifications of those reductions; loss or modification of foraging habitat; loss of population vigor and overall population density; increased isolation between habitat patches, loss of habitat refugia; attraction to modified habitats; effects on behavior, physiological disturbance, and habitat unsuitability. Indirect effects can result from introduction of invasive plants; increased predator populations or facilitated predation; alterations in the natural fire regime; or other effects, and can manifest themselves later in time than the causing action.

Each question should be considered in turn, followed by a discussion of the methods and their applicability.

1. Do field studies indicate that species of concern are present on or likely to use the proposed site?

In many situations, this question can be answered based on information accumulated in Tier 2. Specific presence/absence studies may not be necessary, and protocol development should focus on answering the remaining Tier 3 questions. Nevertheless, it may be necessary to conduct field studies to determine the presence, or likelihood of presence, when little information is available for a particular site. The level of effort normally contemplated for Tier 3 studies should detect common species and species that are relatively rare, but which visit a site regularly (e.g., every year). In the event a species of concern is very rare and only occasionally visits a site, a determination of “likely to occur” would be inferred from the habitat at the site and historical records of occurrence on or near the site.

State, federal and tribal agencies often require specific protocols be followed when species of concern are potentially present on a site. The methods and protocols for determining presence of species of concern at a site are normally established for each species and required by federal, state and tribal resource agencies. Surveys should sample the wind turbine sites and applicable disturbance area during seasons when species are most likely present. Normally, the methods and protocols by which they are applied also will include an estimate of relative abundance. Most presence/absence surveys should be done following a probabilistic sampling protocol to allow statistical extrapolation to the area and time of interest.

Acoustic monitoring can be a practical method for determining the presence of threatened, endangered or otherwise rare species of bats throughout a proposed project (Kunz et al. 2007). There are two general types of acoustic detectors used for collection of information on bat activity and species identification: the full-spectrum, time-expansion and the zero-crossing techniques for ultrasound bat detection (see Kunz et al. 2007 for detailed discussion). Full-spectrum time expansion detectors provide nearly complete species discrimination, while zero-crossing detectors provide reliable and cost-effective estimates of total bat use at a site and some species discrimination. *Myotis* species can be especially difficult to discriminate with zero-crossing detectors (Kunz et al. 2007). Kunz et al. (2007) describe the strengths and weaknesses of each technique for ultrasonic bat detection, and either type of detector may be useful in most situations except where species identification is especially important and zero-crossing methods are inadequate to provide the necessary data. Bat acoustics technology is evolving rapidly and study objectives are an important consideration when selecting detectors. When rare or endangered species of bats are suspected, sampling should occur during different seasons and at multiple sampling stations to account for temporal and spatial variability.

Mist-netting for bats is required in some situations by state agencies, Tribes, and the Service to determine the presence of threatened, endangered or otherwise rare species. Mist-netting is best used in combination with acoustic monitoring to inventory the species of bats present at a site, especially to detect the presence of threatened or endangered species. Efforts should concentrate on potential commuting, foraging, drinking, and roosting sites (Kuenzi and Morrison 1998, O'Farrell et al. 1999). Mist-netting and other activities that involve capturing and handling threatened or endangered species of bats will require permits from state and/or federal agencies.

Determining the presence of diurnally or nocturnally active mammals, reptiles, amphibians, and other species of concern will typically be accomplished by following agency-required protocols. Most listed species have required protocols for detection (e.g., the black-footed ferret). State, tribal and federal agencies should be contacted regarding survey protocols for those species of concern. See Corn and Bury 1990, Olson et al. 1997, Bailey et al. 2004, Graeter et al. 2008 for examples of reptile and amphibian protocols, survey and analytical methods.

2. Do field studies indicate the potential for significant adverse impacts on affected populations of species of habitat fragmentation concern?

If Tier 2 studies indicate the presence of species of habitat fragmentation concern, but existing information did not allow for a complete analysis of potential impacts and decision-making, then additional studies and analyses should take place in Tier 3.

As in Tier 2, the particulars of the analysis will depend on the species of habitat fragmentation concern and how habitat block size and fragmentation are defined for the life cycles of that species, the likelihood that the project will adversely affect a local population of the species and the significance of these impacts to the viability of that population.

To assess habitat fragmentation in the project vicinity, developers should evaluate landscape characteristics of the proposed site prior to construction and determine the degree to which habitat for species of habitat fragmentation concern will be significantly altered by the presence of a wind energy facility.

A general framework for evaluating habitat fragmentation at a project site, following that described in Tier 2, is outlined below. This framework should be used in those circumstances when the developer, or a relevant federal, state, tribal and/or other local agency demonstrates the potential presence of a population of a species of habitat fragmentation concern that may be adversely affected by the project. Otherwise, the developer need not assess the impacts of the proposed project on habitat fragmentation. This method for analysis of habitat fragmentation at project sites must be adapted to the local population of the species of habitat fragmentation concern potentially affected by the proposed development.

The developer should:

1. Define the study area. The study area for the site should include the "footprint" for the proposed facility plus an appropriate surrounding area. The extent of the study area should be based on the area where there is potential for significant adverse habitat impacts, including indirect impacts, within the distribution of habitat for the species of habitat fragmentation concern.

2. Determine the potential for occupancy of the study area based on the guidance provided for the species of habitat fragmentation concern described above in Question 1.

3. Analyze current habitat quality and spatial configuration of the study area for the species of habitat fragmentation concern.
    a. Use recent aerial or remote imagery to determine distinct habitat patches or boundaries within the study area, and the extent of existing habitat fragmenting features.
        i. Assess the level of fragmentation of the existing habitat for the species of habitat fragmentation concern and categorize into three classes:
            - High quality: little or no apparent fragmentation of intact habitat
            - Medium quality: intact habitat exhibiting some recent disturbance activity (e.g., timber clearing, ORV trails, roadways)

- Low quality: extensive fragmentation of habitat (e.g., row-cropped agricultural lands, active surface mining areas)

ii. Determine edge and interior habitat metrics of the study area:
- Identify habitat, non-habitat landscape features and existing fragmenting features relative to the species of habitat fragmentation concern, to estimate existing edge
- Calculate area and acres of edge
- Calculate area of intact patches of habitat and compare to needs of species of habitat fragmentation concern

b. Determine potential changes in quality and spatial configuration of the habitat in the study area if development proceeds as proposed using existing site information and the best available spatial data regarding placement of wind turbines and ancillary infrastructure:

i. Identify, delineate and classify all additional features added by the development that potentially fragment habitat for the species of habitat fragmentation concern (e.g., roads, transmission lines, maintenance structures, etc.)

ii. Assess the expected future size and quality of habitat patches for the species of habitat fragmentation concern and the additional fragmenting features, and categorize into three classes as described above

iii. Determine expected future acreages of edge and interior habitats

iv. Calculate the area of the remaining patches of intact habitat

c. Compare pre-construction and expected post-construction fragmentation metrics:

i. Determine the area of intact habitat lost (to the displacement footprint or by alteration due to the edge effect)

ii. Identify habitat patches that are expected to be moved to a lower habitat quality classification as a result of the development

4. Assess the likelihood of a significant reduction in the demographic and genetic viability of the local population of the species of habitat fragmentation concern using the habitat fragmentation information collected under item 3 above and any currently available demographic and genetic data. Based on this assessment, the developer makes the finding whether or not there is significant reduction. The developer should share the finding with the relevant agencies. If the developer finds the likelihood of a significant reduction, the developer should consider items a, b or c below:

    a. Consider alternative locations and development configurations to minimize fragmentation of habitat in communication with species experts, for all species of habitat fragmentation concern in the area of interest.

    b. Identify high quality habitat parcels that may be protected as part of a plan to limit future loss of habitat for the impacted population of the species of habitat fragmentation concern in the area.

    c. Identify areas of medium or low quality habitat within the range of the impacted population that may be restored or improved to compensate for losses of habitat that result from the project (e.g., management of unpaved roads and ORV trails).

This protocol for analysis of habitat fragmentation at project sites should be adapted to the species of habitat fragmentation concern as identified in response to Question 5 in Tier 2 and to the landscape in which development is contemplated.

3. What is the distribution, relative abundance, behavior, and site use of species of concern identified in Tiers 1 or 2, and to what extent do these factors expose these species to risk from the proposed wind energy project?

For those species of concern that are considered at risk of collisions or habitat impacts, the questions to be answered in Tier 3 include: where are they likely to occur (i.e., where is their habitat) within a project site or vicinity, when might they occur, and in what abundance. The spatial distribution of species at risk of collision can influence how a site is developed. This distribution should include the airspace for flying species with respect to the rotor-swept zone. The abundance of a species and the spatial distribution of its habitat can be used to determine the relative risk of impact to species using the sites, and the absolute risk when compared to existing projects where similar information exists. Species abundance and habitat distribution can also be used in modeling risk factors.

Surveys for spatial distribution and relative abundance require coverage of the wind turbine sites and applicable site disturbance area, or a sample of the area using observational methods for the species of concern during the seasons of interest. As with presence/absence (see Tier 3, question 1, above) the methods used to determine distribution, abundance, and behavior may vary with the species and its ecology. Spatial distribution is determined by applying presence/absence or using surveys in a probabilistic manner over the entire area of interest.

Bird distribution, abundance, behavior and site use

Diurnal Avian Activity Surveys

The commonly used data collection methods for estimating the spatial distribution and relative abundance of diurnal birds includes counts of birds seen or heard at specific survey points (point count), along transects (transect surveys), and observational studies. Both methods result in estimates of bird use, which are assumed to be indices of abundance in the area surveyed. Absolute abundance is difficult to determine for most species and is not necessary to evaluate species risk. Depending on the characteristics of the area of interest and the bird species potentially affected by the project, additional pre-construction study methods may be necessary. Point counts or line transects should collect vertical as well as horizontal data to identify levels of activity within the rotor-swept zone.

Avian point counts should follow the general methodology described by Reynolds et al. (1980) for point counts within a fixed area, or the line transect survey similar to Schaffer and Johnson (2008), where all birds seen within a fixed distance of a line are counted. These methods are most useful for pre- and post-construction studies to quantify avian use of the project site by habitat, determine the presence of species of concern, and to provide a baseline for assessing displacement effects and habitat loss. Point counts for large birds (e.g., raptors) follow the same point count method described by Reynolds et al. (1980).

Point count plots, transects, and observational studies should allow for statistical extrapolation of data and be distributed throughout the area of interest using a probability sampling approach (e.g., systematic sample with a random start). For most projects, the area of interest is the area where wind turbines and permanent meteorological (met) towers are proposed or expected to be sited. Alternatively, the centers of the larger plots can be located at vantage points throughout the potential area being considered with the objective of covering most of the area of interest. Flight height should also be collected to focus estimates of use on activity occurring in the rotor-swept zone.

Sampling duration and frequency will be determined on a project-by-project basis and by the questions being addressed. The most important consideration for sampling frequency when estimating abundance is the amount of variation expected among survey dates and locations and the species of concern.

The use of comparable methods and metrics should allow data comparison from plot to plot within the area of interest and from site to site where similar data exist. The data should be collected so that avian activity can be estimated within the rotor-swept zone. Relating use to site characteristics requires that samples of use also measure site characteristics thought to influence use (i.e., covariates such as vegetation and topography) in relation to the location of use. The statistical relationship of use to these covariates can be used to predict occurrence in unsurveyed areas during the survey period and for the same areas in the future.

Surveys should be conducted at different intervals during the year to account for variation in expected bird activity with lower frequency during winter months if avian activity is low. Sampling frequency should also consider the episodic nature of activity during fall and spring migration. Standardized protocols for estimating avian abundance are well-established and should be consulted (e.g., Dettmers et al. 1999). If a more precise estimate of density is required for a particular species (e.g., when the goal is to determine densities of a special-status breeding bird species), the researcher will need more sophisticated sampling procedures, including estimates of detection probability.

Raptor Nest Searches

An estimate of raptor use of the project site is obtained through appropriate surveys, but if potential impacts to breeding raptors are a concern on a project, raptor nest searches are also recommended. These surveys provide information to predict risk to the local breeding population of raptors, for micro-siting decisions, and for developing an appropriate-sized non-disturbance buffer around nests. Surveys also provide baseline data for estimating impacts and determining mitigation requirements. A good source of information for raptor surveys and monitoring is Bird and Bildstein (2007).

Searches for raptor nests or raptor breeding territories on projects with potential for impacts to raptors should be conducted in suitable habitat during the breeding season. While there is no consensus on the recommended buffer zones around nest sites to avoid disturbance of most species (Sutter and Jones 1981), a nest search within at least one mile of the wind turbines and transmission lines, and other infrastructure should be conducted. However, larger nest search areas are needed for eagles, as explained in the Service's ECP Guidance.

Methods for these surveys are fairly common and will vary with the species, terrain, and vegetation within the survey area. The Service recommends that draft protocols be discussed with biologists from the lead agency, Service, state wildlife agency, and Tribes where they have jurisdiction. It may be useful to consult other scientifically credible information sources. At minimum, the protocols should contain the list of target raptor species for nest surveys and the appropriate search protocol for each site, including timing and number of surveys needed, search area, and search techniques.

Prairie Grouse and Sage Grouse Population Assessments

Sage grouse and prairie grouse merit special attention in this context for three reasons:

1. The scale and biotic nature of their habitat requirements uniquely position them as reliable indicators of impacts on, and needs of, a suite of species that depend on sage and

grassland habitats, which are among the nation's most diminished ecological communities (Vodehnal and Haufler 2007).

2. Their ranges and habitats are highly congruent with the nation's richest inland wind resources.
3. They are species for which some known impacts of anthropogenic features (e.g., tall structures, buildings, roads, transmission lines, wind energy facilities, etc.) have been documented.

Populations of prairie grouse and sage grouse generally are assessed by either lek counts (a count of the maximum number of males attending a lek) or lek surveys (classification of known leks as active or inactive) during the breeding season (e.g., Connelly et al. 2000). Methods for lek counts vary slightly by species but in general require repeated visits to known sites and a systematic search of all suitable habitat for leks, followed by repeated visits to active leks to estimate the number of grouse using them.

Recent research indicates that viable prairie grouse and sage grouse populations are dependent on suitable nesting and brood-rearing habitat (Connelly et al. 2000, Hagen et al. 2009). These habitats generally are associated with leks. Leks are the approximate centers of nesting and brood-rearing habitats (Connelly et al. 2000, but see Connelly et al. 1988; Becker et al. 2009,). High quality nesting and brood rearing habitats surrounding leks are critical to sustaining viable prairie grouse and sage grouse populations (Giesen and Connelly 1993, Hagen et al. 2004, Connelly et al. 2000). A population assessment study area should include nesting and brood rearing habitats that may extend several miles from leks. For example, greater and lesser prairie-chickens generally nest in suitable habitats within one to two miles of active leks (Hagen et al. 2004), whereas the average distances from nests to active leks of non-migratory sage grouse range from 0.7 to four miles (Connelly et al. 2000), and potentially much more for migratory populations (Connelly et al. 1988).

While surveying leks during the spring breeding season is the most common and convenient tool for monitoring population trends of prairie grouse and sage grouse, documenting available nesting and brood rearing habitat within and adjacent to the potentially affected area is recommended. Suitable nesting and brood rearing habitats can be mapped based on habitat requirements of individual species. The distribution and abundance of nesting and brood rearing habitats can be used to help in the assessment of adverse impacts of the proposed project to prairie grouse and sage grouse.

Mist-Netting for Birds

Mist-netting is not recommended as a method for assessing risk of wind development for birds. Mist-netting cannot generally be used to develop indices of relative bird abundance, nor does it provide an estimate of collision risk as mist-netting is not feasible at the heights of the rotor-swept zone and captures below that zone may not adequately reflect risk. Operating mist-nets requires considerable experience, as well as state and federal permits.

Occasionally mist-netting can help confirm the presence of rare species at documented fallout or migrant stopover sites near a proposed project. If mist-netting is to be used, the Service recommends that procedures for operating nets and collecting data be followed in accordance with Ralph et al. (1993).

Nocturnal and Crepuscular Bird Survey Methods

Additional studies using different methods should be conducted if characteristics of the project site and surrounding areas potentially pose a high risk of collision to night migrating songbirds and other nocturnal or crepuscular species. For most of their flight, songbirds and other nocturnal migrants are above the reach of wind turbines, but they pass through the altitudinal range of wind turbines during ascents and descents and may also fly closer to the ground during inclement weather (Able, 1970; Richardson, 2000). Factors affecting flight path, behavior, and "fall-out" locations of nocturnal migrants are reviewed elsewhere (e.g., Williams et al., 2001; Gauthreaux and Belser, 2003; Richardson, 2000; Mabee et al., 2006).

In general, pre-construction nocturnal studies are not recommended unless the site has features that might strongly concentrate nocturnal birds, such as along coastlines that are known to be migratory songbird corridors. Biologists knowledgeable about nocturnal bird migration and familiar with patterns of migratory stopovers in the region should assess the potential risks to nocturnal migrants at a proposed project site. No single method can adequately assess the spatial and temporal variation in nocturnal bird populations or the potential collision risk. Following nocturnal study methods in Kunz et al. (2007) is recommended to determine relative abundance, flight direction and flight altitude for assessing risk to migrating birds, if warranted. If areas of interest are within the range of nocturnal species of concern (e.g., marbled murrelet, northern spotted owl, Hawaiian petrel, Newell's shearwater), surveyors should use species-specific protocols recommended by state wildlife agencies, Tribes or Service to assess the species' potential presence in the area of interest.

In contrast to the diurnal avian survey techniques previously described, considerable variation and uncertainty exist on the optimal protocols for using acoustic monitoring devices, radar, and other techniques to evaluate species composition, relative abundance, flight height, and trajectory of nocturnal migrating birds. While an active area of research, the use of radar for determining passage rates, flight heights and flight directions of nocturnal migrating animals has yet to be shown as a good indicator of collision risk. Pre- and post-construction studies comparing radar monitoring results to estimates of bird and bat fatalities will be necessary to evaluate radar as a tool for predicting collision risk. Additional studies are also needed before making recommendations on the number of nights per season or the number of hours per night that are appropriate for radar studies of nocturnal bird migration (Mabee et al., 2006).

Bat survey methods

The Service recommends that all techniques discussed below be conducted by biologists trained in bat identification, equipment use, and the analysis and interpretation of data resulting from the design and conduct of the studies. Activities that involve capturing and handling bats may require permits from state and/or federal agencies.

Acoustic Monitoring

Acoustic monitoring provides information about bat presence and activity, as well as seasonal changes in species occurrence and use, but does not measure the number of individual bats or population density. The goal of acoustic monitoring is to provide a prediction of the potential risk of bat fatalities resulting from the construction and operation of a project. Our current state of knowledge about bat-wind turbine interactions, however, does not allow a quantitative link between pre-construction acoustic assessments of bat activity and operations fatalities. Discussions with experts, state wildlife trustee agencies, Tribes, and Service will be needed to determine whether acoustic monitoring is warranted at a proposed project site.

The predominance of bat fatalities detected to date are migratory species and acoustic monitoring should adequately cover periods of migration and periods of known high activity for other (i.e., non-migratory) species. Monitoring for a full year is recommended in areas where there is year round bat activity. Data on environmental variables such as temperature and wind speed should be collected concurrently with acoustic monitoring so these weather data can be used in the analysis of bat activity levels.

The number and distribution of sampling stations necessary to adequately estimate bat activity have not been well established but will depend, at least in part, on the size of the project area, variability within the project area, and a Tier 2 assessment of potential bat occurrence.

The number of detectors needed to achieve the desired level of precision will vary depending on the within-site variation (e.g., Arnett et al. 2006, Weller 2007, E.B. Arnett, Bat Conservation International, unpublished data). One frequently used method is to place acoustic detectors on existing met towers, approximately every two kilometers across the site where turbines are expected to be sited. Acoustic detectors should be placed at high positions (as high as practicable, based on tower height) on each met tower included in the sample to record bat activity at or near the rotor swept zone, the area of presumed greatest risk for bats. Developers should evaluate whether it would be cost effective to install detectors when met towers are first established on a site. Doing so might reduce the cost of installation later and might alleviate time delays to conduct such studies.

If sampling at met towers does not adequately cover the study area or provide sufficient replication, additional sampling stations can be established at low positions (~1.5-2 meters) at a sample of existing met towers and one or more mobile units (i.e., units that are moved to different locations throughout the study period) to increase coverage of the proposed project area. When practical and based on information from Tier 2, it may be appropriate to conduct some acoustic monitoring of features identified as potentially high bat use areas within the study area (e.g., bat roosts and caves) to determine use of such features.

There is growing interest in determining whether "low" position samples (~1.5-2 meters) can provide equal or greater correlation with bat fatalities than "high" position samples (described above) because this would substantially lower cost of this work. Developers could then install a greater number of detectors at lower cost resulting in improved estimates of bat activity and, potentially, improved qualitative estimates of risk to bats. This is a research question that is not expected to be addressed at a project.

Other bat survey techniques

Occasionally, other techniques may be needed to answer Tier 3 questions and complement the information from acoustic surveys. Kunz et al. (2007), NAS (2007), Kunz and Parsons (2009) provide comprehensive descriptions of bat survey techniques, including those identified below that are relevant for Tier 3 studies at wind energy facilities.

Roost Searches and Exit Counts

Pre-construction survey efforts may be recommended to determine whether known or likely bat roosts in mines, caves, bridges, buildings, or other potential roost sites occur within the project vicinity, and to confirm whether known or likely bat roosts are present and occupied by bats. If active roosts are detected, it may be appropriate to address questions about colony size and species composition of roosts. Exit counts and roost searches are two approaches to answering these questions, and Rainey (1995), Kunz and Parsons (2009), and Sherwin et al. (2009) are resources that describe options and approaches for these techniques. Roost searches should be performed cautiously because roosting bats are sensitive to human disturbance (Kunz et al. 1996). Known maternity and hibernation roosts should not be entered or otherwise disturbed unless authorized by state and/or federal wildlife agencies. Internal searches of abandoned mines or caves can be dangerous and should only be conducted by trained researchers. For mine survey protocol and guidelines for protection of bat roosts, see the appendices in Pierson et al. (1999). Exit surveys at known roosts generally should be limited to non-invasive observation using low-light binoculars and infrared video cameras.

Multiple surveys should be conducted to determine the presence or absence of bats in caves and mines, and the number of surveys needed will vary by species of bats, sex (maternity or bachelor colony) of bats, seasonality of use, and type of roost structure (e.g., caves or mines). For example, Sherwin et al. (2003) demonstrated that a minimum of three surveys are needed to determine the absence of large hibernating colonies of Townsend's big-eared bats (*Corynorhinus townsendii*) in mines (90 percent probability), while a minimum of nine surveys (during a single warm season) are necessary before a mine could be eliminated as a bachelor roost for this species (90 percent probability). An average of three surveys was needed before surveyed caves could be eliminated as bachelor roosts (90 percent probability). The Service recommends that decisions on level of effort follow discussion with relevant agencies and bat experts.

Activity Patterns

If active roosts are detected, it may be necessary to answer questions about behavior, movement patterns, and patterns of roost use for bat species of concern, or to further investigate habitat features that might attract bats and pose fatality risk. For some bat species, typically threatened, endangered, or state-listed species, radio telemetry or radar may be recommended to assess both the direction of movement as bats leave roosts, and the bats' use of the area being considered for development. Kunz et al. (2007) describe the use of telemetry, radar and other tools to evaluate use of roosts, activity patterns, and flight direction from roosts.

Mist-Netting for Bats

While mist-netting for bats is required in some situations by state agencies, Tribes, and the Service to determine the presence of threatened, endangered or other bat species of concern, mist-netting is not generally recommended for determining levels of activity or assessing risk of wind energy development to bats for the following reasons: 1) not all proposed or operational wind energy facilities offer conditions conducive to capturing bats, and often the number of suitable sampling points is minimal or not closely associated with the project location; 2) capture efforts often occur at water sources offsite or at nearby roosts and the results may not reflect species presence or use on the site where turbines are to be erected; and 3) mist-netting isn't feasible at the height of the rotor-swept zone, and captures below that zone may not adequately reflect risk of fatality. If mist-netting is employed, it is best used in combination with acoustic monitoring to inventory the species of bats present at a site.

White-Nose Syndrome

White-nose syndrome is a disease affecting hibernating bats. Named for the white fungus that appears on the muzzle and other body parts of hibernating bats, WNS is associated with extensive mortality of bats in eastern North America. All contractors and consultants hired by developers should employ the most current version of survey and handling protocols to avoid transmitting white-nose syndrome between bats.

Other wildlife

While the above guidance emphasizes the evaluation of potential impacts to birds and bats, Tier 1 and 2 evaluations may identify other species of concern. Developers are encouraged to assess adverse impacts potentially caused by development for those species most likely to be negatively affected by such development. Impacts to other species are primarily derived from potential habitat loss or displacement. The general guidance on the study design and methods for estimation of the distribution, relative abundance, and habitat use for birds is applicable to the study of other wildlife. References regarding monitoring for other wildlife are available in Appendix C. Nevertheless, most methods and metrics will be species-specific and developers are advised to work with the state, tribal, or federal agencies, or other credible experts, as appropriate, during problem formulation for Tier 3.

4. What are the potential risks of adverse impacts of the proposed wind energy project to individuals and local populations of species of concern and their habitats, and to limited plant communities or ecosystems? (In the case of rare or endangered species, what are the possible impacts to such species and their habitats?)

Methods used for estimating risk will vary with the species of concern. For example, estimating potential bird fatalities in Tier 3 may be accomplished by comparing exposure estimates (described earlier in estimates of bird use) at the proposed site with exposure estimates and fatalities at existing projects with similar characteristics (e.g., similar technology, landscape, and weather conditions). If models are used, they may provide an additional tool for estimating fatalities, and have been used in Australia (Organ and Meredith 2004), Europe (Chamberlin et al. 2006), and the United States (Madders and Whitfield 2006). As with other prediction tools, model predictions should be evaluated and compared with post-construction fatality data to validate the models. Models should be used as a subcomponent of a risk assessment based on the best available empirical data. A statistical model based on the relationship of pre-construction estimates of raptor abundance and post-construction raptor fatalities is described in Strickland et al. (in review) and promises to be a useful tool for risk assessment.

Collision risk to individual birds and bats at a particular wind energy facility may be the result of complex interactions among species distribution, relative abundance, behavior, weather conditions (e.g., wind, temperature) and site characteristics. Collision risk for an individual may be low regardless of abundance if its behavior does not place it within the rotor-swept zone. If individuals frequently occupy the rotor-swept zone but effectively avoid collisions, they are also at low risk of collision with a turbine (e.g., ravens). Alternatively, if the behavior of individuals frequently places them in the rotor-swept zone, and they do not actively avoid turbine blade strikes, they are at higher risk of collisions with turbines regardless of abundance. For a given species (e.g., red-tailed hawk), increased abundance increases the likelihood that individuals will be killed by turbine strikes, although the risk to individuals will remain about the same. The risk to a population increases as the proportion of individuals in the population at risk to collision increases.

At some projects, bat fatalities are higher than bird fatalities, but the exposure risk of bats at these facilities is not fully understood (National Research Council (NRC) 2007). Horn et al. (2008) and Cryan (2008) hypothesize that bats are attracted to turbines, which, if true, would further complicate estimation of exposure. Further research is required to determine if bats are attracted to turbines and if so, to evaluate 1) the influence on Tier 2 methods and predictions, and 2) if this increased individual risk translates into higher population-level impacts for bats.

The estimation of indirect impact risk requires an understanding of animal behavior in response to a project and its infrastructure, and a pre-construction estimate of presence/absence of species whose behavior would cause them to avoid areas in proximity to turbines, roads and other components of the project. The amount of habitat that is lost to indirect impacts will be a function of the sensitivity of individuals to the project and to the activity levels associated with the project's operations. The population-level significance of this indirect impact will depend on the amount of habitat available to the affected population. If the indirect impacts result in habitat fragmentation, then the risk to the demographic and genetic viability of the isolated animals is increased. Quantifying cause and effect may be very difficult, however.

5. How can developers mitigate identified significant adverse impacts?

Results of Tier 3 studies should provide a basis for identifying measures to mitigate significant adverse impacts predicted for species of concern. Information on wildlife use of the proposed area is most useful when designing a project to avoid or minimize significant adverse impacts. In cases of uncertainty with regard to impacts to species of concern, additional studies may be necessary to quantify significant adverse impacts and determine the need for mitigation of those impacts.

Chapter 7, Best Management Practices, and Chapter 8, Mitigation, outline measures that can be taken to mitigate impacts throughout all phases of a project.

The following discussion of prairie grouse and sage grouse as species of concern illustrates the uncertainty mentioned above by describing the present state of scientific knowledge relative to these species, which should be considered when designing mitigation measures. The extent of the impact of wind energy development on prairie grouse and sage grouse lekking activity (e.g., social structure, mating success, persistence) and the associated impacts on productivity (e.g., nesting, nest success, chick survival) is poorly understood (Arnett et al. 2007, NRC 2007, Manville 2004). However, recent published research documents that anthropogenic features (e.g., tall structures, buildings, roads, transmission lines) can adversely impact vital rates (e.g., nesting, nest success, lekking behavior) of lesser prairie-chickens (Pruett et al. 2009, Pitman et al. 2005, Hagen et al. 2009, Hagen et al. 2011) and greater prairie-chickens over long distances. Pitman et al. (2005) found that transmission lines reduced nesting of lesser prairie chicken by 90 percent out to a distance of 0.25 miles, improved roads at a distance of 0.25 miles, a house at 0.3 miles, and a power plant at >0.6 miles. Reduced nesting activity of lesser prairie chickens may extend farther, but Pitman et al. (2005) did not analyze their data for lower impacts (less than 90 percent reduction in nesting) of those anthropogenic features on lesser prairie chicken nesting activities at greater distances. Hagen et al. (2011) suggested that development within 1 to 1 ½ miles of active leks of prairie grouse may have significant adverse impacts on the affected grouse population. It is not unreasonable to infer that impacts from wind energy facilities may be similar to those from these other anthropogenic structures. Kansas State University, as part of the NWCC GS3C, is undertaking a multi-year telemetry study to evaluate the effects of a proposed wind-energy facility on displacement and demographic parameters (e.g., survival, nest success, brood success, fecundity) of greater prairie-chickens in Kansas.[4]

The distances over which anthropogenic activities impact sage grouse are greater than for prairie grouse. Based primarily on data documenting reduced fecundity (a combination of nesting, clutch size, nest success, juvenile survival, and other factors) in sage grouse populations near roads, transmissions lines, and areas of oil and gas development/production (Holloran 2005, Connelly et al. 2000), development within three to five miles (or more) of active sage grouse leks may have significant adverse impacts on the affected grouse population. Lyon and Anderson (2003) found that in habitats fragmented by natural gas development, only 26 percent of hens captured on disturbed leks nested within 1.8 miles of the lek of capture, whereas 91 percent of hens from undisturbed areas nested within the same area. Holloran (2005) found that active drilling within 3.1 miles of sage grouse lek reduced the number of breeding males by displacing adult males and reducing recruitment of juvenile males. The magnitudes and proximal causes (e.g., noise, height of structures, movement, human activity, etc.) of those impacts on vital rates in grouse populations are areas of much needed research (Becker et al. 2009). Data accumulated

[4] www.nationalwind.org

through such research may improve our understanding of the buffer distances necessary to avoid or minimize significant adverse impacts to prairie grouse and sage grouse populations.

When significant adverse impacts cannot be fully avoided or adequately minimized, some form of compensatory mitigation may be appropriate to address the loss of habitat value. For example, it may be possible to mitigate habitat loss or degradation for a species of concern by enhancing or restoring nearby habitat value comparable to that potentially influenced by the project.

6. Are there studies that should be initiated at this stage that would be continued in post-construction?

During Tier 3 problem formulation, it is necessary to identify the studies needed to address the Tier 3 questions. Consideration of how the resulting data may be used in conjunction with post-construction Tier 4 and 5 studies is also recommended. The design of post-construction impact or mitigation assessment studies will depend on the specific impact questions being addressed. Tier 3 predictions ~~of fatalities~~ will be evaluated using data from Tier 4 studies designed to estimate fatalities for species of concern and impacts to their habitat, including species of habitat fragmentation concern. Tier 3 studies may demonstrate the need for compensatory mitigation of significant adverse habitat impacts or for measures to avoid or minimize fatalities. Where Tier 3 studies indicate the potential for significant adverse direct and indirect impacts to habitat, Tier 4 studies will provide data that evaluate predictions of those impacts, and Tier 5 studies, if necessary, will provide data to evaluate the effect of those impacts on populations and the effectiveness of avoidance, minimization and mitigation measures. Evaluations of the impacts of a project on demographic parameters of local populations, habitat use, or some other parameter(s) are considered Tier 5 studies, and typically will require data on these parameters prior to as well as after construction of the project.

Study Design Issues

Specific study designs will vary from site to site and should be adjusted to the circumstances of individual projects. Study designs will depend on the types of questions, the specific project, and practical considerations. The most common practical considerations include the area being studied, the period of interest, the species of concern, potentially confounding variables, time available to conduct studies, project budget, and the magnitude of the anticipated impacts.

When collection of both pre- and post-construction data in the areas of interest and reference areas is possible, then the Before-After-Control-Impact (BACI) is the most statistically robust design. The BACI design is most like the classic manipulative experiment.[5] In the absence of a suitable reference area, the design is reduced to a Before-After (BA) analysis of effect where the differences between pre- and post-construction parameters of interest are assumed to be the result of the project, independent of other potential factors affecting the assessment area. With respect to BA studies, the key question is whether the observations taken immediately after the incident can reasonably be expected within the expected range for the system (Manly 2009). Reliable quantification of impact usually will include additional study components to limit variation and the confounding effects of natural factors that may change with time.

The developer's timeline for the development of a wind energy facility often does not allow for the collection of sufficient pre-construction data and/or identification of suitable reference areas to complete a BACI or BA study. Furthermore, alterations in land use or disturbance over the course of a multi-year BACI or BA study may complicate the analysis of study results. These design issues are discussed more fully under Tier 5 design considerations.

Tier 3 Decision Point

At the end of Tier 3, developers should coordinate with the Service to complete the Tier 3 decision process. The Service will provide written comments to a developer on study and project development plans that identify concerns and recommendations to resolve the concerns.

[5] In this context, such designs are not true experiments in that the treatments (project development and control) are not randomly assigned to an experimental unit, and there is often no true replication. Such constraints are not fatal flaws, but do limit statistical inferences of the results.

The developer and, when applicable, the permitting authority will make a decision regarding whether and how to develop the project. The decision point at the end of Tier 3 involves three potential outcomes:

1. Development of the site has a low probability of significant adverse impact based on existing and new information.

   There is little uncertainty regarding when and how development should proceed, and adequate information exists to satisfy any required permitting. The decision process proceeds to permitting, when required, and/or development, and post-construction monitoring.

2. Development of the site has a moderate to high probability of significant adverse impacts without proper measures being taken to mitigate those impacts. This outcome may be subdivided into two possible scenarios:

   a. There is certainty regarding how to develop the site to adequately mitigate significant adverse impacts. A decision to develop the site is made, conditional on the proper mitigation measures being adopted, with appropriate post-construction fatality and habitat studies (Tier 4).

   b. There is uncertainty regarding how to develop the site to adequately mitigate significant adverse impacts, or a permitting process requires additional information on potential significant adverse wildlife impacts before permitting future phases of the project. A decision to develop the site is made conditional on the proper mitigation measures being taken and with appropriate follow up post-construction studies (Tier 4 and 5).

3. Development of the site has a high probability of significant impact that cannot be satisfactorily mitigated.

Site development should be delayed until plans can be developed that satisfactorily avoid, minimize or provide compensatory mitigation for the significant adverse impacts. Alternatively, the site should be abandoned in favor of known sites with less potential for environmental impact, or the developer begins an evaluation of other sites or landscapes for more acceptable sites to develop.

Where pre-construction assessments are warranted to help assess risk to wildlife, the studies should be of sufficient duration and intensity to ensure adequate data are collected to accurately characterize wildlife use of the area. In ecological systems, resource quality and quantity can fluctuate rapidly. These fluctuations occur naturally, but human actions can significantly affect (i.e., increase or decrease) natural oscillations. Pre-construction monitoring and assessment of proposed wind energy sites are "snapshots in time," showing occurrence or no occurrence of a species or habitat at the specific time surveyed. Often due to prohibitive costs, assessments and surveys are conducted for very low percentages (e.g., less than 5 percent) of the available sample time in a given year, however, these data are used to support risk analyses over the projected life of a project (e.g., 30 years of operations).

To establish a trend in site use and conditions that incorporates annual and seasonal variation in meteorological conditions, biological factors, and other variables, pre-construction studies may need to occur over multiple years. However, the level of risk and the question of data requirements will be based on site sensitivity, affected species, and the availability of data from other sources. Accordingly, decisions regarding the studies recommended should consider information gathered during the previous tiers, variability within and between seasons, and years where variability is likely to substantially affect answers to the Tier 3 questions. These studies should also be designed to collect data during relevant breeding, feeding, sheltering, staging, or migration periods for each species being studied. Additionally, consideration for the frequency and intensity of pre-construction monitoring should be site-specific and determined through consultation with an expert authority based on their knowledge of the specific species, level of risk and other variables present at each individual site. Some tools have been developed for existing guidance to evaluate sites based on risk criteria.

Chapter 5

Tier 4 – Post-construction Studies to Estimate Impacts

Comment [UF&WS4]: FWS has significantly revised this Chapter. It now includes post-construction fatality monitoring and habitat studies.

Following the tiered decision process, the outcome of studies in Tiers 1, 2, and 3 will determine the duration and level of effort of post-construction studies.

Tier 4 post-construction studies are designed to assess whether predictions of fatality risk and direct and indirect impacts to habitat of species concern were correct. Fatality studies involve searching for bird and bat carcasses beneath turbines to estimate the number and species composition of fatalities (Tier 4a). Habitat studies involve application of GIS and use data collected in Tier 3 and Tier 4b and/or published information. Post-construction studies on direct and indirect impacts to habitat of species of concern, including species of habitat fragmentation concern need only be conducted if Tier 3 studies indicate the potential for significant adverse impacts.

1. Tier 4a – Fatality Studies

At this time, all projects should conduct at least one year of fatality studies. As data collected with consistent methods and metrics increases (see discussion below), it is possible that some future projects will not warrant fatality monitoring, but such a situation is rare with the present state of knowledge.

~~Fatality monitoring should be conducted at all wind energy projects.~~ Fatality monitoring should occur over all seasons of occupancy for the species being monitored, based on information produced in previous tiers. The number of seasons and total length of the monitoring may be determined separately for bats and birds, depending on the pre-construction risk assessment, results of Tier 3 studies and Tier 4 monitoring from comparable sites (see Glossary), and the results of first year fatality monitoring. Guidance on the relationship between these variables and monitoring for fatalities is provided in Table 2.

It may be appropriate to conduct monitoring using different durations and intervals depending on the species of concern. For example, if raptors occupy an area year-round, it may be appropriate to monitor for raptors throughout the year (12 months). It may be warranted to monitor for bats when they are active (spring, summer and fall or approximately eight months). It may be appropriate to increase the search frequency during the months bats are active and decrease the frequency during periods of inactivity. All fatality monitoring should include estimates of carcass removal and carcass detection bias likely to influence those rates.

Tier 4a Questions

Post-construction fatality monitoring should be designed to answer the following questions as appropriate for the individual project:

1. What are the bird and bat fatality rates for the project?
2. What are the fatality rates of species of concern?
3. How do the estimated fatality rates compare to the predicted fatality rates?
4. Do bird and bat fatalities vary within the project site in relation to site characteristics?
5. How do the fatality rates compare to the fatality rates from existing projects in similar landscapes with similar species composition and use?
6. What is the composition of fatalities in relation to migrating and resident birds and bats at the site?
7. Do fatality data suggest the need for measures to reduce impacts?

Tier 4a studies should be of sufficient statistical validity to address Tier 4a questions and enable determination of whether Tier 3 fatality predictions were correct. Fatality monitoring results also should allow comparisons with other sites, and provide a basis for determining if operational changes or mitigation measures at the site are appropriate. The Service encourages project operators to discuss Tier 4 studies with local, state, federal, and tribal wildlife agencies. The number of years of monitoring is based on outcomes of Tier 3 and Tier 4 studies and analysis of comparable Tier 4 data from other projects as indicated in Table 2. The Service may recommend multiple years of monitoring for projects located near a listed species or bald or golden eagle, or other situations, as appropriate.

Table 2. Decision Matrix for Post-construction Tier 4a Fatality Monitoring of Species of Concern.[6]

Risk as identified in Tier 3	Recommended Fatality Monitoring Duration and Effort	Possible outcomes of monitoring results
Tier 3 Studies indicate LOW risk	**Duration**: At least one year of fatality monitoring to estimate fatalities of birds and bats. Field assessments should be sufficient to confirm that risk to birds and/or bats is indeed "low."	1) Documented fatalities are approximately equal to or lower than predicted risk. No further fatality monitoring or mitigation is needed. 2) Fatalities are greater than predicted, but are not likely to be significant (i.e., unlikely to affect the long-term status of the population). If comparable fatality data at similar sites also supports that impacts are not likely to be high enough to affect population status, no further monitoring or mitigation is needed. If no comparable fatality data are available or such data indicates high risk, one additional year of fatality monitoring is recommended. If two years of fatality monitoring indicate levels of impacts that are not significant, no further fatality monitoring or mitigation is recommended. 3) Fatalities are greater than predicted and are likely to be significant OR Federally Endangered Species or BGEPA species are affected. Communication with the Service is recommended. Further efforts to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.
Tier 3 studies indicate MODERATE risk	**Duration**: Two or more years of fatality monitoring may be necessary. Field assessments should be sufficient to confirm that risk to birds and/or bats is indeed "moderate." Closely compare estimated effects to species to those determined from the risk assessment protocol(s).	1) Documented fatalities after the first two years are lower or not different than predicted and are not significant and no Federally Endangered Species or BGEPA species are affected - no further fatality monitoring or mitigation is needed. 2) Fatalities are greater than predicted and are likely to be significant OR Federally Endangered Species or BGEPA species are affected, communication with the Service is recommended. Further efforts to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.

[6] Ensure that survey protocols, and searcher efficiency and scavenger removal bias correction factors are the most reliable, robust, and up to date (after Huso 2009).

Tier 3 studies indicate HIGH risk	**Duration**: Three or more years of fatality monitoring may be necessary.	1) Documented fatalities during each year of fatality monitoring are less than predicted and are not likely to be significant, and no Federally Endangered Species or BGEPA species are affected – no further fatality monitoring or mitigation is needed. 2) Fatalities are equal to or greater than predicted and are likely to be significant - further efforts to reduce impacts are necessary; communication with the Service are recommended. Further efforts to address impacts to BGEPA or ESA species may be warranted, unless otherwise addressed in an ESA or BGEPA take permit.

Tier 4a Protocol Design Issues

The basic method of measuring fatality rates is the carcass search. Search protocols should be standardized to the greatest extent possible, especially for common objectives and species of concern, and they should include methods for adequately accounting for sampling biases (searcher efficiency and scavenger removal). However, some situations warrant exceptions to standardized protocol, and the responsibility of demonstrating that an exception is appropriate and applicable should be on the stakeholder attempting to justify increasing or decreasing the duration or intensity of operations monitoring.

Some general guidance is given below with regard to the following fatality search protocol design issues:

- Duration and frequency of monitoring
- Number of turbines to monitor
- Delineation of carcass search plots, transects, and habitat mapping
- General search protocol
- Field bias and error assessment
- Estimators of fatality

- More detailed descriptions and methods of fatality search protocols can be found in the California (California Energy Commission 2007) and Pennsylvania (Pennsylvania Game Commission 2007) state guidelines and in Kunz et al. (2007) and Smallwood (2007).
- Frequency of carcass searches

Frequency of carcass searches (search interval) may vary for birds and bats, and will vary depending on the questions to be answered, the species of concern, and their seasonal abundance at the project site. The carcass searching protocol should be adequate to answer applicable Tier 4 questions at an appropriate level of precision to make general conclusions about the project, and is not intended to provide highly precise measurements of fatalities. Except during low use times (e.g. winter months in northern states), the Service recommends that protocols be designed such that carcass searches occur at some turbines within the project area most days each week of the study.

The search interval is the interval between carcass searches at individual turbines, and this interval may be lengthened or shortened depending on the carcass removal rates. If the primary focus is on fatalities of large raptors, where carcass removal is typically low, then a longer interval between searches (e.g., 14-28 days) is sufficient. However, if the focus is on fatalities of bats and small birds and carcass removal is high, then a shorter search interval will be necessary.

There are situations in which studies of higher intensity (e.g., daily searches at individual turbines within the sample) may be appropriate. These would be considered only in Tier 5 studies or in research programs because the greater complexity and level of effort goes beyond that recommended for typical Tier 4 post construction monitoring. Tier 5 and research studies could include evaluation of specific measures that have been implemented to mitigate potential significant adverse impacts to species of concern identified during pre-construction studies.

<u>*Number of turbines to monitor*</u>

If available, data on variability among turbines from existing projects in similar conditions within the same region are recommended as a basis for determining needed sample size (see Morrison et al., 2008). If data are not available, the Service recommends that a sufficient number of turbines be selected via a systematic sample with a random start point. Sampling plans can be varied (e.g., rotating panels [McDonald 2003, Fuller 1999, Breidt and Fuller 1999, and Urquhart et al. 1998]) to increase efficiency as long as a probability sampling approach is used. If the project contains fewer than 10 turbines, the Service recommends that all turbines in the area of interest be searched unless otherwise agreed to by the permitting or wildlife resource agencies. When selecting turbines, the Service recommends that a systematic sample with a random start be used when selecting search plots to ensure interspersion among turbines. Stratification among different habitat types also is recommended to account for differences in fatality rates among different habitats (e.g., grass versus cropland or forest); a sufficient number of turbines should be sampled in each strata.

<u>*Delineation of carcass search plots, transects, and habitat mapping*</u>

Evidence suggests that greater than 80 percent of bat fatalities fall within half the maximum distance of turbine height to ground (Erickson 2003 a, b), and a minimum plot width of 120 meters from the turbine should be established at sample turbines. Plots will need to be larger for birds, with a width twice the turbine height to ground. Decisions regarding search plot size should be made in discussions with the Service, state wildlife agency, permitting agency and Tribes. It may be useful to consult other scientifically credible information sources.

The Service recommends that each search plot should be divided into oblong subplots or belt transects and that each subplot be searched. The objective is to find as many carcasses as possible so the width of the belt will vary depending on the ground cover and its influence on carcass visibility. In most situations, a search width of 6 meters should be adequate, but this may vary from 3-10 meters depending on ground cover.

Searchable area within the theoretical maximum plot size varies, and heavily vegetated areas (e.g., eastern mountains) often do not allow surveys to consistently extend to the maximum plot width. In other cases it may be preferable to search a portion of the maximum plot instead of the entire plot. For example, in some landscapes it may be impractical to search the entire plot because of the time required to do an effective search, even if it is accessible (e.g., croplands), and data from a probability sample of subplots within the maximum plot size can provide a reasonable estimate of fatalities. It is important to accurately delineate and map the area searched for each turbine to adjust fatality estimates based on the actual area searched. It may be advisable to establish habitat visibility classes in each plot to account for differential detectability, and to develop visibility classes for different landscapes (e.g., rocks, vegetation) within each search plot. For example, the Pennsylvania Game Commission (2007) identified four classes based on the percentage of bare ground.

The use of visibility classes requires that detection and removal biases be estimated for each class. Fatality estimates should be made for each class and summed for the total area sampled. Global positioning systems (GPS) are useful for accurately mapping the actual total area searched and area searched in each habitat visibility class, which can be used to adjust fatality estimates. The width of the belt or subplot searched may vary depending on the habitat and species of concern; the key is to determine actual searched area and area searched in each visibility class regardless of transect width. An adjustment may also be needed to take into account the density of fatalities as a function of the width of the search plot.

<u>General search protocol guidance</u>

Personnel trained in proper search techniques should look for bird and bat carcasses along transects or subplots within each plot and record and collect all carcasses located in the searchable areas. A developer should obtain a Special Purpose Salvage for Utilities-Wind permit to collect and possess bird carcasses. A complete search of the area should be accomplished and subplot size (e.g., transect width) should be adjusted to compensate for detectability differences in the search area. Subplots should be smaller when vegetation makes it difficult to detect carcasses; subplots can be wider in open terrain. Subplot width also can vary depending on the size of the species being looked for. For example, small species such as bats may require smaller subplots than larger species such as raptors.

Data to be recorded include date, start time, end time, observer, which turbine area was searched (including GPS coordinates) and weather data for each search. When a dead bat or bird is found, the searcher should place a flag near the carcass and continue the search. After searching the entire plot, the searcher returns to each carcass and records information on a fatality data sheet, including date, species, sex and age (when possible), observer name, turbine number, distance from turbine, azimuth from turbine (including GPS coordinates), habitat surrounding carcass, condition of carcass (entire, partial, scavenged), and estimated time of death (e.g., $\leq$1 day, 2 days). The recorded data will ultimately be housed in the FWS Office of Law Enforcement Bird Mortality Reporting System. A digital photograph of the carcass should be taken. Rubber gloves should be used to handle all carcasses to eliminate possible transmission of rabies or other diseases and to reduce possible human scent bias for carcasses later used in scavenger removal trials. Carcasses should be placed in a plastic bag and labeled. Fresh carcasses (those determined to have been killed the night immediately before a search) should be redistributed at random points on the same day for scavenging trials.

Field bias and error assessment

It has long been recognized that during searches conducted at wind turbines, actual fatalities are incompletely observed and that therefore carcass counts must be adjusted by some factor that accounts for imperfect detectability (Huso 2011). Important sources of bias and error include: 1) fatalities that occur on a highly periodic basis; 2) carcass removal by scavengers; 3) differences in searcher efficiency; 4) failure to account for the influence of site (e.g. vegetation) conditions in relation to carcass removal and searcher efficiency; and 5) fatalities or injured birds and bats that may land or move outside search plots.

Some fatalities may occur on a highly periodic basis creating a potential sampling error (number 1 above). The Service recommends that sampling be scheduled so that some turbines are searched most days and episodic events are more likely detected, regardless of the search interval. To address bias sources 2-4 above, it is strongly recommended that all fatality studies conduct carcass removal and searcher efficiency trials using accepted methods (Anderson 1999, Kunz et al. 2007, Arnett et al. 2007, NRC 2007, Strickland et al. 2011). Bias trials should be conducted throughout the entire study period and searchers should be unaware of which turbines are to be used or the number of carcasses placed beneath those turbines during trials. Carcasses or injured individuals may land or move outside the search plots (number 5 above). With respect to Tier 4a fatality estimates, this potential sampling error is considered to be small and can be assumed insignificant (Strickland et al. 2011).

Prior to a study's inception, a list of random turbine numbers and random azimuths and distances (in meters) from turbines should be generated for placement of each bat or bird used in bias trials. Data recorded for each trial carcass prior to placement should include date of placement, species, turbine number, distance and direction from turbine, and visibility class surrounding the carcass. Trial carcasses should be distributed as equally as possible among the different visibility classes throughout the study period and study area. Studies should attempt to avoid "over-seeding" any one turbine with carcasses by placing no more than one or two carcasses at any one time at a given turbine. Before placement, each carcass must be uniquely marked in a manner that does not cause additional attraction, and its location should be recorded. There is no agreed upon sample size for bias trials, though some state guidelines recommend from 50 - 200 carcasses (e.g., PGC 2007).

Estimators of fatality

If there were a direct relationship between the number of carcasses observed and the number killed, there would be no need to develop a complex estimator that adjusts observed counts for detectability, and observed counts could be used as a simple index of fatality (Huso 2011). But the relationship is not direct and raw carcass counts recorded using different search intervals and under different carcass removal rates and searcher efficiency rates are not directly comparable. It is strongly recommended that only the most contemporary equations for estimating fatality be used, as some original versions are now known to be extremely biased under many commonly encountered field conditions (Erickson et al. 2000b, Erickson et al. 2004, Johnson et al. 2003, Kerns and Kerlinger 2004, Fiedler et al. 2007, Kronner et al. 2007, Smallwood 2007, Huso 2011, Strickland et al. 2011).

Tier 4a Methods and Metrics

In addition to the monitoring protocol, the metrics used to estimate fatality rates must be selected with the Tier 4a questions and objectives in mind. Metrics considerations for each of the Tier 4a questions are discussed briefly below. Not all questions will be relevant for each project, and which questions apply would depend on Tier 3 outcomes.

1. What are the bird and bat fatality rates for the project?

The primary objective of fatality searches is to determine the overall estimated fatality rates for birds and bats for the project. These rates serve as the fundamental basis for all comparisons of fatalities, and if studies are designed appropriately they allow researchers to relate fatalities to site characteristics and environmental variables, and to evaluate mitigation measures. Several metrics are available for expressing fatality rates. Early studies reported fatality rates per turbine. However, this metric is somewhat misleading as turbine sizes and their risks to birds vary significantly (NRC 2007). Fatalities are frequently reported per nameplate capacity (i.e. MW), a metric that is easily calculated and better for comparing fatality rates among different sized turbines. Even with turbines of the same name plate capacity, the size of the rotor swept area may vary among manufacturers, and turbines at various sites may operate for different lengths of time and during different times of the day and seasons. With these considerations in mind, the Service recommends that fatality rates be expressed on a per turbine and per nameplate MW basis until a better metric becomes available.

2. What are the fatality rates of species of concern?

This analysis simply involves calculating fatalities per turbine of all species of concern at a site when sample sizes are sufficient to do so. These fatalities should be expressed on a per nameplate MW basis if comparing species fatality rates among projects.

3. How do the estimated fatality rates compare to the predicted fatality rates?

There are several ways that predictions can be assigned and later evaluated with actual fatality data. During the planning stages in Tier 2, predicted fatalities may be based on existing data at similar facilities in similar landscapes used by similar species. In this case, the assumption is that use is similar, and therefore that fatalities may be similar at the proposed facility. Alternatively, metrics derived from pre-construction assessments for an individual species or group of species – usually an index of activity or abundance at a proposed project – could be used in conjunction with use and fatality estimates from existing projects to develop a model for predicting fatalities at the proposed project site. Finally, physical models can be used to predict the probability of a bird of a particular size striking a turbine, and this probability, in conjunction with estimates of use and avoidance behavior, can be used to predict fatalities.

The most current equations for estimating fatality should be used to evaluate fatality predictions. Several statistical methods can be found in the revised Strickland et al. 2011 and used to evaluate fatality predictions. Metrics derived from Tier 3 pre-construction assessments may be correlated with fatality rates, and (using the project as the experimental unit), in Tier 5 studies it should be possible to determine if different preconstruction metrics can in fact accurately predict fatalities and, thus, risk.

4. Do bird and bat fatalities vary within the project site in relation to site characteristics?

Comparing fatality rates among facilities with similar characteristics is useful to determine patterns and broader landscape relationships, as is discussed in some detail above for predicting fatalities at a proposed project site. Fatality rates should be expressed on a per nameplate MW or some other standardized metric basis for comparison with other projects, and may be correlated with site characteristics – such as proximity to wetlands, riparian corridors, mountain-foothill interface, or other broader landscape features – using regression analysis. Comparing fatality rates from one project to fatality rates of other projects provides insight into whether a project has relatively high, moderate or low fatalities.

5. How do the fatality rates compare to the fatality rates from existing facilities in similar landscapes with similar species composition and use?

Turbine-specific fatality rates may be related to site characteristics such as proximity to water, forest edge, staging and roosting sites, known stop-over sites, or other key resources, and this relationship may be estimated using regression analysis. This information is particularly useful for evaluating micro-siting options when planning a future facility or, on a broader scale, in determining the location of the entire project.

6. What is the composition of fatalities in relation to migrating and resident birds and bats at the site?

The simplest way to address this question is to separate fatalities per turbine of known resident species (e.g., big brown bat, prairie horned lark) and those known to migrate long distances (e.g. hoary bat, red-eyed vireo). These data are useful in determining patterns of species composition of fatalities and possible mitigation measures directed at residents, migrants, or perhaps both, and can be used in assessing potential population effects.

7. Do fatality data suggest the need for measures to reduce impacts?

The Service recommends that the wind project operator[7] and the relevant agencies discuss the results from Tier 4 studies to determine whether these impacts are significant. If fatalities are considered significant, the wind project operator and the relevant agencies should develop a plan to mitigate the impacts.

2. Tier 4b – Assessing direct and indirect impacts of habitat loss, degradation, and fragmentation

Comment [UF&WS5]: This section on habitat impacts is new.

The purpose of Tier 4b studies is to **evaluate Tier 3 predictions of direct and indirect impacts to habitat and the potential for significant adverse impacts on species of concern as a result of these impacts**. Tier 4b studies should be conducted if Tier 3 studies indicate the presence of species of habitat fragmentation concern, or if Tier 3 studies indicate significant direct and indirect impacts to species of concern (see discussion below). Tier 4b studies should also inform project operators and the Service as to whether adaptive management and/or additional mitigation are necessary.

[7] In situations where a project operator was not the developer, the Service expects that obligations of the developer for adhering to the Guidelines transfer with the project.

Tier 4b studies should evaluate the following questions:

1. What are the effects of habitat loss, degradation, and fragmentation on species of concern, including species of habitat fragmentation concern?

2. Were any behavioral modifications or indirect impacts noted in regard to species of concern?

3. If significant adverse impacts were not predicted in Tier 3 because of loss, degradation, or fragmentation of habitat, but Tier 4b studies indicate such impacts may be occurring, a) can these impacts be mitigated and b) are Tier 5 studies necessary to evaluate the biological significance of these impacts?

The answers to these questions will be based on information estimating habitat loss, degradation, and fragmentation information collected in Tier 3, currently available demographic and genetic data, and studies initiated in Tier 3. As in the case of Tier 4a, the answers to these questions will determine the need to conduct Tier 5 studies.

Protocol Design Issues

Impacts to a species of concern resulting from the direct and indirect loss of habitat are important and must be considered when a wind project is being considered for development. Some species of concern are likely to occur at every proposed wind energy facility. This occurrence may range from a breeding population, to seasonal occupancy, such as a brief occurrence while migrating through the area. Consequently the level of concern regarding impacts due to direct and indirect loss of habitat will vary depending on the species and the impacts that occur.

If a breeding population of a species of habitat fragmentation concern occurs in the project area and Tier 3 studies indicate that fragmentation of their habitat is possible, these predictions should be evaluated following the guidance indicated in Table 3 using the protocols described in Tier 3. If the analysis of post-construction GIS data on direct and indirect habitat loss suggests that fragmentation is likely, then additional displacement studies and mitigation may be necessary. These studies would typically begin immediately and would be considered Tier 5 studies using design considerations illustrated by examples in Tier 5 below and from guidance in the scientific literature (e.g. Strickland et al. 2011).

Significant direct or indirect loss of habitat for a species of concern may occur without habitat fragmentation if project impacts result in the reduction of a habitat resource that potentially is limiting to the affected population. Impacts of this type include loss of use of breeding habitat or loss of a significant portion of the habitat of a Federally protected species. This would be evaluated by determining the amount of the resource that is lost and determining if this loss would potentially result in significant impacts to the affected population. Evaluation of potential significant impacts would occur in Tier 5 studies that measure the demographic response of the affected population.

The intention of the Guidelines is to focus industry and agency resources on the direct and indirect loss of habitat and limiting resources that potentially reduce the viability of a species of concern. Not all direct and indirect loss of a species' habitat will affect limiting resources for that species, and when habitat losses are minor or non-existent no further study is necessary.

1. What are the effects of habitat loss, degradation, and fragmentation on species of concern, including species of habitat fragmentation concern?

Predictions of impacts to species of concern from habitat loss, degradation, and fragmentation are made using GIS and demographic data collected in Tier 3 and/or published information under development assumptions provided by the developer. These assumptions should be evaluated in light of the actual development using GIS data collected during Tier 3 and updated after construction. Additional post-construction studies on impacts to species of concern due to direct and indirect impacts to habitat should only be conducted if Tier 4 studies indicate the potential for significant adverse impacts.

2. Were any behavioral modifications or indirect impacts noted in regard to affected species?

Evaluation of this question is based on the analysis of observed use of the area by species of concern prior to construction in comparison with observed use during operation. Observations and demographic data collected during Tier 3, and assessment of published information about the potential for displacement and demographic responses to habit impacts could be the basis for this analysis. If this analysis suggests that direct and/or indirect loss of habitat for a species of concern leads to behavioral modifications or displacement that are significant, further studies of these impacts in Tier 5 may be appropriate.

3. If significant adverse impacts were not predicted in Tier 3 because of loss, degradation, or fragmentation of habitat, but Tier 4b studies indicate such impacts may be occurring, a) can these impacts be mitigated and b) are Tier 5 studies necessary to evaluate the biological significance of these impacts?

When Tier 4b studies indicate significant impacts may be occurring, the developer may need to conduct an assessment of these impacts and what opportunities exist for additional mitigation. Evaluation of the effectiveness of mitigation is a Tier 5 study and should follow design considerations discussed in Tier 5 and from guidance in the scientific literature (e.g. Strickland et al. 2011).

Table 3. Decision framework to guide studies for minimizing impacts to habitat and species of habitat fragmentation (HF) concern. Level of effort for studies should be sufficient to answer all questions of interest. Refer to the relevant methods sections for Tier 2 Question 5 and Tier 3 Question 2 in the text for specific guidance on study protocols.

Outcomes of Tier 2	Outcomes of Tier 3	Outcomes of Tier 4b	Suggested Study/Mitigation Requirements
• No species of HF concern potentially present	• No further studies needed	• n/a	• n/a
• Species of HF concern potentially present	• No species of HF concern confirmed to be present	• No further studies needed	• n/a

	• Species of HF concern demonstrated to be present, but no significant impacts predicted	• Tier 4b studies confirm Tier 3 predictions	• No further studies or mitigation needed
		• Tier 4b studies indicate potentially significant impacts	• Tier 5 studies and mitigation may be needed
• Species of HF concern potentially present	• Species of HF concern demonstrated to be present; significant impacts predicted • Mitigation plan developed and implemented	• Tier 4b studies determine mitigation plan is effective; no significant impacts demonstrated	• No further studies or mitigation needed
		• Tier 4b studies determine mitigation plan is NOT effective; impacts potentially significant	• Further mitigation and, where appropriate, Tier 5 studies
• Plant community of concern is present	• Plant community of concern is present and adequate mitigation is possible	• Tier 4b studies determine mitigation plan is effective	• No further mitigation needed • Further mitigation is needed
	• Plant community of concern is present and cannot be adequately mitigated; project should be abandoned.	• Tier 4b studies determine mitigation plan is NOT effective; impacts potentially significant	

Chapter 6

Tier 5 – Other Post-construction Studies

Tier 5 studies will not be necessary for most wind energy projects. Tier 5 studies can be complex and time consuming. The Service anticipates that the tiered approach will steer projects away from sites where Tier 5 studies would be necessary.

When Tier 5 studies are conducted, they should be site-specific and intended to: 1) analyze factors associated with impacts in those cases in which Tier 4 analyses indicate they are potentially significant; 2) identify additional actions as warranted when mitigation measures implemented for a project are not adequate; and 3) assess demographic effects on local populations of species of concern including species of habitat fragmentation concern.

Tier 5 Questions

Tier 5 studies are intended to answer questions that fall in three major categories; answering yes to any of these questions might indicate a Tier 5 study is needed:

1. To the extent that the observed fatalities exceed anticipated fatalities, are those fatalities potentially having a significant adverse impact on local populations? Are observed direct and indirect impacts to habitat having a significant adverse impact on local populations?

For example, in the Tier 3 risk assessment, predictions of collision fatalities and habitat impacts (direct and indirect) are developed. Post-construction studies in Tier 4 evaluate the accuracy of those predictions by estimating impacts. If post-construction studies demonstrate potentially significant adverse impacts, Tier 5 studies may also be warranted and should be designed to understand observed versus predicted impacts.

2. Were habitat mitigation measures implemented in Tier 3(other than fee in lieu) not effective? If habitat restoration is conducted, it may be desirable to monitor the restoration efforts to determine if there is replacement of habitat conditions. Have measures undertaken to reduce collision fatalities been significantly less effective than anticipated?

Tier 4b studies can assess the effectiveness of measures taken to reduce direct and indirect habitat impacts as part of the project and to identify such alternative or additional measures as are necessary. For example, the project layout may be modified to avoid disturbance of grouse during the breeding season. Tier 4b studies would be designed to determine the effectiveness of these measures by evaluating prairie grouse behavior before and after construction. If these studies indicate that adverse direct and indirect impacts to habitat are higher than predicted, additional or alternative mitigation measures may need to be explored. The effectiveness of these additional measures would be evaluated using Tier 5 studies.

3. Are the estimated impacts of the proposed project likely to lead to population declines in the species of concern (other than federally-listed species)?

   Impacts of a project will have population level effects if the project causes a population decline in the species of concern.

   For non-listed species, this assessment will apply only to the local population.

Tier 5 studies may need to be conducted when:

1) Realized fatality levels for individual species of concern reach a level at which they are considered significant adverse impacts by the relevant agencies.

   For example, if Tier 4 fatality studies document that a particular turbine or set of turbines exhibits bird or bat collision fatality higher than predicted, adaptive management (as defined in Chapter 1) may be useful in evaluating alternative measures to avoid or minimize future fatalities at that turbine/turbine string.

2) There is the potential for significant fatality impacts or significant adverse impacts to habitat for species of concern, there is a need to assess the impacts more closely, and there is uncertainty over how these impacts will be mitigated.

3) Fatality and/or significant adverse habitat impacts suggest the potential for a reduction in the viability of an affected population, in which case studies on the potential for population impacts may be warranted.

4) A developer evaluates the effectiveness of a risk reduction measure before deciding to continue the measure permanently or whether to use the measure when implementing future phases of a project.

In the event additional turbines are proposed as an expansion of an existing project, results from Tier 4 and Tier 5 studies and the decision-making framework contained in the tiered approach can be used to determine whether the project should be expanded and whether additional information should be collected. It may also be necessary to evaluate whether additional measures are warranted to reduce significant adverse impacts to species.

Tier 5 Study Design Issues

As discussed in Chapter 4 Tier 3, Tier 5 studies will be highly variable and unique to the circumstances of the individual project, and therefore these Guidelines do not provide specific guidance on all potential approaches, but make some general statements about study design. Specific Tier 5 study designs will depend on the types of questions, the specific project, and practical considerations. The most common practical considerations include the area being studied, the time period of interest, the species of concern, potentially confounding variables, time available to conduct studies, project budget, and the magnitude of the anticipated impacts. When possible it is usually desirable to collect data before construction to address Tier 5 questions. Design considerations for these studies are including in Tier 3.

When pre-construction data are unavailable and/or a suitable reference area is lacking, the reference Control Impact Design (Morrison et al. 2008) is the recommended design. The lack of a suitable reference area also can be addressed using the Impact Gradient Design, when habitat and species use are homogenous in the assessment area prior to development. When applied both pre- and post-construction, the Impact Gradient Design is a suitable replacement for the classic BACI (Morrison et al. 2008).

In the study of habitat impacts, the resource selection function (RSF) study design (see Anderson et al 1999; Morrison et al. 2008; Manly et al. 2002) is a statistically robust design, either with or without pre-construction and reference data. Habitat selection is modeled as a function of characteristics measured on resource units and the use of those units by the animals of interest. The RSF allows the estimation of the probability of use as a function of the distance to various environmental features, including wind energy facilities, and thus provides a direct quantification of the magnitude of the displacement effect. RSF could be improved with pre-construction and reference area data. Nevertheless, it is a relatively powerful approach to documenting displacement or the effect of mitigation measures designed to reduce displacement even without those additional data.

Tier 5 Examples

As described earlier, Tier 5 studies will not be conducted at most projects, and the specific Tier 5 questions and methods for addressing these questions will depend on the individual project and the concerns raised during pre-construction studies and during operational phases. Rather than provide specific guidance on all potential approaches, these Guidelines offer the following case studies as examples of studies that have attempted to answer Tier 5 questions.

1. Habitat impacts - displacement and demographic impact studies

Studies to assess impacts may include quantifying species' habitat loss (e.g., acres of lost grassland habitat for grassland songbirds) and habitat modification. For example, an increase in edge may result in greater nest parasitism and nest predation. Assessing indirect impacts may include two important components: 1) indirect effects on wildlife resulting from displacement, due to disturbance, habitat fragmentation, loss, and alteration and 2) demographic effects that may occur at the local, regional or population-wide levels due to reduced nesting and breeding densities, increased isolation between habitat patches, and effects on behavior (e.g., stress, interruption, and modification). These factors can individually or cumulatively affect wildlife, although some species may be able to habituate to some or perhaps all habitat changes. Indirect impacts may be difficult to quantify but their effects may be significant (e.g., Stewart et al. 2007, Pearce-Higgins et al. 2008, Bright et al. 2008, Drewitt and Langston 2006, Robel et al. 2004, Pruett et al. 2009).

Example: in southwestern Pennsylvania, development of a project is proceeding at a site located within the range of a state-listed terrestrial species. Surveys were performed at habitat locations appropriate for use by the animal, including at control sites. Post-construction studies are planned at all locations to demonstrate any displacement effects resulting from the construction and operation of the project.

The Service recognizes that indirect impact studies may not be appropriate for most individual projects. Consideration should be given to developing collaborative research efforts with industry, government agencies, and NGOs to conduct studies to address indirect impacts.

Indirect impacts are considered potentially significant adverse threats to species such as prairie grouse (prairie chickens, sharp-tailed grouse), and sage grouse, and demographic studies may be necessary to determine the extent of these impacts and the need for mitigation.

Displacement studies may use any of the study designs describe earlier. The most scientifically robust study designs to estimate displacement effects are BACI, RSF, and impact gradient. RSF and impact gradient designs may not require specialized data gathering during Tier 3.

Telemetry studies that measure impacts of the project development on displacement, nesting, nest success, and survival of prairie grouse and sage grouse in different environments (e.g., tall grass, mixed grass, sandsage, sagebrush) will require spatial and temporal replication, undisturbed reference sites, and large sample sizes covering large areas. Examples of study designs and analyses used in the studies of other forms of energy development are presented in Holloran et al. (2005), Pitman et al. (2005), Robel et al. (2004), and Hagen et al. (2011). Anderson et al. (1999) provides a thorough discussion of the design, implementation, and analysis of these kinds of field studies and should be consulted when designing the BACI study.

Studies are being initiated to evaluate effects of wind energy development on greater sage grouse in Wyoming. In addition to measuring demographic patterns, these studies will use the RSF study design (see Sawyer et al. 2006) to estimate the probability of sage grouse use as a function of the distance to environmental features, including an existing and a proposed project.

In certain situations, such as for a proposed project site that is relatively small and in a more or less homogeneous landscape, an impact gradient design may be an appropriate means to assess avoidance of the wind energy facility by resident populations (Strickland et al., 2002). For example, Leddy et al. 1999 used the impact gradient design to evaluate grassland bird density as a function of the distance from wind turbines. Data were collected at various distances from turbines along transects.

This approach provides information on whether there is an effect, and may allow quantification of the gradient of the effect and the distance at which the displacement effect no longer exists – the assumption being that the data collected at distances beyond the influence of turbines are the reference data (Erickson et al., 2007). An impact gradient analysis could also involve measuring the number of breeding grassland birds counted at point count plots as a function of distance from the wind turbines (Johnson et al. 2000).

<u>Sound and Wildlife</u>

Turbine blades at normal operating speeds can generate levels of sound beyond ambient background levels. Construction and maintenance activities can also contribute to sound levels by affecting communication distance, an animal's ability to detect calls or danger, or to forage. Sound associated with developments can also cause behavioral and/or physiological effects, damage to hearing from acoustic over-exposure, and masking of communication signals and other biologically relevant sounds (Dooling and Popper 2007). Some birds are able to shift their vocalizations to reduce the masking effects of noise. However, when shifts don't occur or are insignificant, masking may prove detrimental to the health and survival of wildlife (Barber et al. 2010). Data suggest noise increases of 3 dB to 10 dB correspond to 30 percent to 90 percent reductions in alerting distances for wildlife, respectively (Barber et al. 2010).

The National Park Service has been investigating potential impacts to wildlife due to alterations in sound level and type. However, further research is needed to better understand this potential impact. Research may include: how wind facilities affect background sound levels; whether masking, disturbance, and acoustical fragmentation occur; and how turbine, construction, and maintenance sound levels can vary by topographic area.

2. Levels of fatality beyond those predicted

More intensive post-construction fatality studies may be used to determine relationships between fatalities and weather, wind speed or other covariates, which usually require daily carcass searches. Fatalities determined to have occurred the previous night can be correlated with that night's weather or turbine characteristics to establish important relationships that can then be used to evaluate the most effective times and conditions to implement measures to reduce collision fatality at the project.

3. Measures to address fatalities

The efficacy of operational modifications (e.g. changing turbine cut-in speed) of a project to reduce collision fatalities has only recently been evaluated (Arnett et al. 2009, Baerwald et al 2009). Operational modifications and other measures to address fatalities should be applied only at sites where collision fatalities are predicted or demonstrated to be high.

Tier 5 Studies and Research

The Service makes a distinction between Tier 5 studies focused on project-specific impacts and research (which is discussed earlier in the Guidelines). For example, developers may be encouraged to participate in collaborative studies (see earlier discussion of Research) or asked to conduct a study on an experimental mitigation technique, such as differences in turbine cut-in speed to reduce bat fatalities. Such techniques may show promise in mitigating the impacts of wind energy development to wildlife, but their broad applicability for mitigation purposes has not been demonstrated. Such techniques should not be routinely applied to projects, but application at appropriate sites will contribute to the breadth of knowledge regarding the efficacy of such measures in addressing collision fatalities. In addition, studies involving multiple sites and academic researchers can provide more robust research results, and such studies take more time and resources than are appropriately carried out by one developer at a single site. Examples below demonstrate collaborative research efforts to address displacement, operational modifications, and population level impacts.

1. Displacement Studies

The Service provides two examples below of ongoing studies to assess the effects of displacement related to wind energy facilities.

Kansas State University, as part of the NWCC Grassland Shrub-steppe Species Collaborative, is undertaking a multi-year research project to assess the effects of wind energy facilities on populations of greater prairie-chickens (GPCH) in Kansas. Initially the research was based on a Before/After Control/Impact (BACI) experimental design involving three replicated study sites in the Flint Hills and Smoky Hills of eastern Kansas. Each study site consisted of an impact area where a wind energy facility was proposed to be developed and a nearby reference area with similar rangeland characteristics where no development was planned. The research project is a coordinated field/laboratory effort, i.e., collecting telemetry and observational data from adult and juvenile GPCH in the field, and determining population genetic attributes of GPCH in the laboratory from blood samples of birds and the impact and reference areas. Detailed data on GPCH movements, demography, and population genetics were gathered from all three sites from 2007 to 2010. By late 2008, only one of the proposed wind energy facilities was developed (the Meridian Way Wind Farm in the Smoky Hills of Cloud County), and on-going research efforts are focused on that site. The revised BACI study design now will produce two years of pre-construction data (2007 and 2008), and three years of post-construction data (2009, 2010, and 2011) from a single wind energy facility site (impact area) and its reference area. Several hypotheses were formulated for testing to determine if wind energy facilities impacted GPCH populations, including but not limited to addressing issues relating to: lek attendance, avoidance of turbines and associated features, nest success and chick survival, habitat usage, adult mortality and survival, breeding behavior, and natal dispersal. A myriad of additional significant avenues are being pursued as a result of the rich database that has been developed for the GPCH during this research effort. GPCH reproductive data will be collected through the summer of 2011 whereas collection of data from transmitter-equipped GPCH will extend through the lekking season of 2012 to allow estimates of survival of GPCH over the 2011-2012 winter. At the conclusion of the study, the two years of pre-construction data and three years of post-construction data will be analyzed and submitted to peer-reviewed journals for publication.

Erickson et al. (2004) evaluated the displacement effect of a large wind energy facility in the Pacific Northwest. The study was conducted in a relatively homogeneous grassland landscape. Erickson et al. (2004) conducted surveys of breeding grassland birds along 300 meter transects perpendicular to strings of wind turbines. Surveys were conducted prior to construction and after commercial operation. The basic study design follows the Impact Gradient Design (Morrison et al. 2008) and in this application, conformed to a special case of BACI where areas at the distal end of each transect were considered controls (i.e., beyond the influence of the turbines). In this study, there is no attempt to census birds in the area, and observations per survey are used as an index of abundance. Additionally, the impact-gradient study design resulted in less effort than a BACI design with offsite control areas. Erickson et al. (2004) found that grassland passerines as a group, as well as grasshopper sparrows and western meadowlarks, showed reduced use in the first 50 meter segment nearest the turbine string. About half of the area within that segment, however, had disturbed vegetation and separation of behavior avoidance from physical loss of habitat in this portion of the area was impossible. Horned larks and savannah sparrows (*Passerculus sandwichensis*) appeared unaffected. The impact gradient design is best used when the study area is relatively small and homogeneous.

2. Operational Modifications to Reduce Collision Fatality

Arnett et al. (2009) conducted studies on the effectiveness of changing turbine cut-in speed on reducing bat fatality at wind turbines at the Casselman Wind Project in Somerset County, Pennsylvania. Their objectives were to: 1) determine the difference in bat fatalities at turbines with different cut-in-speeds relative to fully operational turbines, and 2) determine the economic costs of the experiment and estimated costs for the entire area of interest under different curtailment prescriptions and timeframes. Arnett et al. (2009) reported substantial reductions in bat fatalities with relatively modest power losses.

In Kenedy County, Texas, investigators are refining and testing a real-time curtailment protocol. The projects use an avian profiling radar system to detect approaching "flying vertebrates" (birds and bats), primarily during spring and fall bird and bat migrations. The blades automatically idle when risk reaches a certain level and weather conditions are particularly risky. Based on estimates of the number and timing of migrating raptors, feathering (real-time curtailment) experiments are underway in Tehuantepec, Mexico, where raptor migration through a mountain pass is extensive.

Other tools, such as thermal imaging (Horn et al. 2008) or acoustic detectors (Kunz et al. 2007), have been used to quantify post-construction bat activity in relation to weather and turbine characteristics for improving operational mitigation efforts. For example, at the Mountaineer project in 2003, Tier 4 studies (weekly searches at every turbine) demonstrated unanticipated and high levels of bat fatalities (Kerns and Kerlinger 2004). Daily searches were instituted in 2004 and revealed that fatalities were strongly associated with low-average-wind-speed nights, thus providing a basis for testing operational modifications (Arnett 2005, Arnett et al. 2008). The program also included behavioral observations using thermal imaging that demonstrated higher bat activity at lower wind speeds (Horn et al. 2008).

Studies are currently underway to design and test the efficacy of an acoustic deterrent device to reduce bat fatalities at wind facilities (E.B. Arnett, Bat Conservation International, under the auspices of BWEC). Prototypes of the device have been tested in the laboratory and in the field with some success. Spanjer (2006) tested the response of big brown bats (*Eptesicus fuscus*) to a prototype eight speaker deterrent emitting broadband white noise at frequencies from 12.5–112.5 kHz and found that during non-feeding trials, bats landed in the quadrant containing the device significantly less when it was broadcasting broadband noise. Spanjer (2006) also reported that during feeding trials, bats never successfully took a tethered mealworm when the device broadcast sound, but captured mealworms near the device in about 1/3 of trials when it was silent. Szewczak and Arnett (2006, 2007) tested the same acoustic deterrent in the field and found that when placed by the edge of a small pond where nightly bat activity was consistent, activity dropped significantly on nights when the deterrent was activated. Horn et al. (2007) tested the effectiveness of a larger, more powerful version of this deterrent device on reducing nightly bat activity and found mixed results. In 2009, a new prototype device was developed and tested at a project in Pennsylvania. Ten turbines were fitted with deterrent devices, daily fatality searches were conducted, and fatality estimates were compared with those from 15 turbines without deterrents (i.e., controls) to determine if bat fatalities were reduced. This experiment found that estimated bat fatalities per turbine were 20 to 53 percent lower at treatment turbines compared to controls. More experimentation is required. At the present time, there is not an operational deterrent available that has demonstrated effective reductions in bat kills (E. B. Arnett, Bat Conservation International, unpublished data).

3. Assessment of Population-level Impacts

The Altamont Pass Wind Resource Area (APWRA) has been the subject of intensive scrutiny because of avian fatalities, especially for raptors, in an area encompassing more than 5,000 wind turbines (e.g., Orloff and Flannery 1992; Smallwood and Thelander 2004, 2005). To assess population-level effects of long lived raptors, Hunt (2002) completed a four-year telemetry study of golden eagles at the APWRA and concluded that although all territories remain occupied, collision fatalities may reduce population productivity such that filling territories that become vacant may depend on floaters from the local population and/or immigration of eagles from other subpopulations to fill vacant territories. Hunt conducted follow-up surveys in 2005 (Hunt and Hunt 2006) and determined that all 58 territories occupied by eagle pairs in 2000 were occupied in 2005.

Chapter 7

Best Management Practices

Site Construction: Site Development and Construction Best Management Practices

During site planning and development, careful attention to reducing risk of adverse impacts to species of concern from wind energy projects, through careful site selection and facility design, is recommended. The following BMPs can assist a developer in the planning process to reduce potential impacts to species of concern. Use of these BMPs should ensure that the potentially adverse impacts to most species of concern and their habitats present at many project sites would be reduced, although compensatory mitigation may be appropriate at a project level to address significant site-specific concerns and pre-construction study results.

These BMPs will evolve over time as additional experience, learning, monitoring and research becomes available on how to best minimize wildlife and habitat impacts from wind energy projects. Service should work with the industry, stakeholders and states to evaluate, revise and update these BMPs on a periodic basis, and the Service should maintain a readily available publication of recommended, generally accepted best practices.

1. Minimize, to the extent practicable, the area disturbed by pre-construction site monitoring and testing activities and installations.
2. Avoid locating wind energy facilities in areas identified as having a demonstrated and unmitigatable high risk to birds and bats.
3. Use available data from state and federal agencies, and other sources (which could include maps or databases), that show the location of sensitive resources and the results of Tier 2 and/or 3 studies to establish the layout of roads, power lines, fences, and other infrastructure.
4. Minimize, to the maximum extent practicable, roads, power lines, fences, and other infrastructure associated with a wind development project. When fencing is necessary, construction should use wildlife compatible design standards.

5. Use native species when seeding or planting during restoration. Consult with appropriate state and federal agencies regarding native species to use for restoration.

6. To reduce avian collisions, place low and medium voltage connecting power lines associated with the wind energy development underground to the extent possible, unless burial of the lines is prohibitively expensive (e.g., where shallow bedrock exists) or where greater adverse impacts to biological resources would result:

    a. Overhead lines may be acceptable if sited away from high bird crossing locations, to the extent practicable, such as between roosting and feeding areas or between lakes, rivers, prairie grouse and sage grouse leks, and nesting habitats. To the extent practicable, the lines should be marked in accordance with Avian Power Line Interaction Committee (APLIC) collision guidelines.

    b. Overhead lines may be used when the lines parallel tree lines, employ bird flight diverters, or are otherwise screened so that collision risk is reduced.

    c. Above-ground low and medium voltage lines, transformers and conductors should follow the 2006 or most recent APLIC "Suggested Practices for Avian Protection on Power Lines."

7. Avoid guyed communication towers and permanent met towers at wind energy project sites. If guy wires are necessary, bird flight diverters or high visibility marking devices should be used.

8. Where permanent meteorological towers must be maintained on a project site, use the minimum number necessary.

9. Use construction and management practices to minimize activities that may attract prey and predators to the wind energy facility.

10. Employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights, to meet Federal Aviation Administration (FAA) requirements for visibility lighting of wind turbines, permanent met towers, and communication towers. Only a portion of the turbines within the wind project should be lighted, and all pilot warning lights should fire synchronously.

11. Keep lighting at both operation and maintenance facilities and substations located within half a mile of the turbines to the minimum required:
    a. Use lights with motion or heat sensors and switches to keep lights off when not required.
    b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.
    c. Minimize use of high-intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.
12. Establish non-disturbance buffer zones to protect sensitive habitats or areas of high risk for species of concern identified in pre-construction studies. Determine the extent of the buffer zone in consultation with the Service and state, local and tribal wildlife biologists, and land management agencies (e.g., U.S. Bureau of Land Management (BLM) and U.S. Forest Service (USFS)), or other credible experts as appropriate.
13. Locate turbines to avoid separating bird and bat species of concern from their daily roosting, feeding, or nesting sites if documented that the turbines' presence poses a risk to species.
14. Avoid impacts to hydrology and stream morphology, especially where federal or state-listed aquatic or riparian species may be involved. Use appropriate erosion control measures in construction and operation to eliminate or minimize runoff into water bodies.
15. When practical use tubular towers or best available technology to reduce ability of birds to perch and to reduce risk of collision.
16. After project construction, close roads not needed for site operations and restore these roadbeds to native vegetation.
17. Minimize the number and length of access roads; use existing roads when feasible.
18. Minimize impacts to wetlands and water resources by following all applicable provisions of the Clean Water Act (33 USC 1251-1387) and the Rivers and Harbors Act (33 USC 301 et seq.); for instance, by developing and implementing a storm water management plan and taking measures to reduce erosion and avoid delivery of road-generated sediment into streams and waters.

19. Reduce vehicle collision risk to wildlife by instructing project personnel to drive at appropriate speeds, be alert for wildlife, and use additional caution in low visibility conditions.

20. Instruct employees, contractors, and site visitors to avoid harassing or disturbing wildlife, particularly during reproductive seasons.

21. Reduce fire hazard from vehicles and human activities (instruct employees to use spark arrestors on power equipment, ensure that no metal parts are dragging from vehicles, use caution with open flame, cigarettes, etc.). Site development and operation plans should specifically address the risk of wildfire and provide appropriate cautions and measures to be taken in the event of a wildfire.

22. Follow federal and state measures for handling toxic substances to minimize danger to water and wildlife resources from spills. Facility operators should maintain Hazardous Materials Spill Kits on site and train personnel in the use of these.

23. Reduce the introduction and spread of invasive species by following applicable local policies for noxious weed control, cleaning vehicles and equipment arriving from areas with known invasive species issues, using locally sourced topsoil, and monitoring for and rapidly removing noxious weeds at least annually.

24. Use pest and weed control measures as specified by county or state requirements, or by applicable federal agency requirements (such as Integrated Pest Management) when federal policies apply.

25. Properly manage garbage and waste disposal on project sites to avoid creating attractive nuisances for wildlife by providing them with supplemental food. In some circumstances removing large animal carcasses (e.g., big game, domestic livestock, or feral animal) should also be considered.

Retrofitting, Repowering, and Decommissioning: Best Management Practices

As with project construction, these Guidelines offer BMPs for the retrofitting, repowering, and decommissioning phases of wind energy projects.

Retrofitting

Retrofitting is defined as replacing portions of existing wind turbines or project facilities so that at least part of the original turbine, tower, electrical infrastructure or foundation is being utilized. Retrofitting BMPs include:

1. Retrofitting of turbines should use installation techniques that minimize new site disturbance, soil erosion, and removal of vegetation of habitat value.
2. Retrofits should employ shielded, separated or insulated electrical conductors that minimize electrocution risk to avian wildlife per APLIC (2006).
3. Retrofit designs should prevent nests or bird perches from being established in or on the wind turbine or tower.
4. FAA visibility lighting of wind turbines should employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights.
5. Lighting at both operation and maintenance facilities and substations located within half a mile of the turbines should be kept to the minimum required:
    a. Use lights with motion or heat sensors and switches to keep lights off when not required.
    b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.
    c. Minimize use of high intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.
6. Remove wind turbines when they are no longer cost effective to retrofit.

Repowering

Repowering may include removal and replacement of turbines and associated infrastructure. BMPs include:

1. To the greatest extent practicable, existing roads, disturbed areas and turbine strings should be re-used in repower layouts.

2. Roads and facilities that are no longer needed should be demolished, removed, and their footprint stabilized and re-seeded with native plants appropriate for the soil conditions and adjacent habitat and of local seed sources where feasible, per landowner requirements and commitments.
3. Existing substations and ancillary facilities should be re-used in repowering projects to the extent practicable.
4. Existing overhead lines may be acceptable if located away from high bird crossing locations, such as between roosting and feeding areas, or between lakes, rivers and nesting areas. Overhead lines may be used when they parallel tree lines, employ bird flight diverters, or are otherwise screened so that collision risk is reduced.
5. Above-ground low and medium voltage lines, transformers and conductors should follow the 2006 or most recent APLIC "Suggested Practices for Avian Protection on Power Lines."
6. Guyed structures should be avoided. If use of guy wires is absolutely necessary, they should be treated with bird flight diverters or high visibility marking devices, or are located where known low bird use will occur.
7. FAA visibility lighting of wind turbines should employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights.
8. Lighting at both operation and maintenance facilities and substations located within ½ mile of the turbines should be kept to the minimum required.
    a. Use lights with motion or heat sensors and switches to keep lights off when not required.
    b. Lights should be hooded downward and directed to minimize horizontal and skyward illumination.
    c. Minimize use of high intensity lighting, steady-burning, or bright lights such as sodium vapor, quartz, halogen, or other bright spotlights.

Decommissioning

Decommissioning is the cessation of wind energy operations and removal of all associated equipment, roads, and other infrastructure. The land is then used for another activity. During decommissioning, contractors and facility operators should apply BMPs for road grading and native plant re-establishment to ensure that erosion and overland flows are managed to restore pre-construction landscape conditions. The facility operator, in conjunction with the landowner and state and federal wildlife agencies, should restore the natural hydrology and plant community to the greatest extent practical.

1. Decommissioning methods should minimize new site disturbance and removal of native vegetation, to the greatest extent practicable.
2. Foundations should be removed and covered with soil to allow adequate root penetration for native plants, and so that subsurface structures do not substantially disrupt ground water movements.
3. If topsoils are removed during decommissioning, they should be stockpiled and used as topsoil when restoring plant communities. Once decommissioning activity is complete, topsoils should be restored to assist in establishing and maintaining pre-construction native plant communities to the extent possible, consistent with landowner objectives.
4. Soil should be stabilized and re-vegetated with native plants appropriate for the soil conditions and adjacent habitat, and of local seed sources where feasible, consistent with landowner objectives.
5. Surface water flows should be restored to pre-disturbance conditions, including removal of stream crossings, roads, and pads, consistent with storm water management objectives and requirements.
6. Surveys should be conducted by qualified experts to detect invasive plants, and comprehensive approaches to controlling any detected plants should be implemented and maintained as long as necessary.
7. Overhead pole lines that are no longer needed should be removed.

8. After decommissioning, erosion control measures should be installed in all disturbance areas where potential for erosion exists, consistent with storm water management objectives and requirements.
9. Fencing should be removed unless the landowner will be utilizing the fence.
10. Petroleum product leaks and chemical releases should be remediated prior to completion of decommissioning.

Chapter 8

Mitigation

Mitigation is defined in this document as avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts, as determined through the tiered approach described in the recommended Guidelines. Several tools are available to determine appropriate mitigation, including the USFWS Mitigation Policy (USFWS Mitigation Policy, 46 FR 7656 (1981)). The USFWS policy provides a common basis for determining how and when to use different mitigation strategies, and facilitates earlier consideration of wildlife values in wind energy project planning.

The amount of compensation, if necessary, will depend on the effectiveness of any avoidance and minimization measures undertaken. If a proposed wind development is poorly sited with regard to wildlife effects, the most important mitigation opportunity is largely lost and the remaining options can be expensive, with substantially greater environmental effects. The Service will work with developers to report on the success of industry's mitigation efforts.

Ideally, project impact assessment is a cooperative effort involving the developer, the Service, tribes, local authorities, and state resource agencies. The Service does not expect developers to provide compensation for the same habitat loss more than once. But the Service, state resource agencies, tribes, local authorities, state and federal land management agencies may have different species or habitats of concern, according to their responsibilities and statutory authorities. Hence, one entity may seek mitigation for a different group of species or habitat than does another.

Compensation is most often appropriate for habitat loss under limited circumstances or for direct take of wildlife (e.g., Habitat Conservation Plans). In certain limited situations, compensation may be appropriate. Compensatory mitigation may involve contributing to a fund to protect habitat or otherwise support efforts to reduce existing impacts to species affected by a wind project. Developers should consult with the Service and state agency prior to initiating such an approach. When appropriate, developers should consider using adaptive management as discussed in Chapter 1 and throughout this document.

More typically, avoidance and minimization are used to offset direct take. However, E.O. 13186, which addresses responsibilities of federal agencies to protect migratory birds, includes a directive to federal agencies to restore and enhance the habitat of migratory birds as practicable. So for any wind projects with a federal nexus, E.O. 13186 provides a basis and a rationale for mitigating for the loss of migratory bird habitat that result from developing the project.

Regulations concerning eagle take permits in 50 CFR 22.26 and 50 CFR 22.27 may allow for compensation as part of permit issuance. Compensation may be a condition of permit issuance in cases of nest removal, disturbance or take resulting in mortality that will likely occur over several seasons, result in permanent abandonment of one or more breeding territories, have large scale impacts, occur at multiple locations, or otherwise contribute to cumulative negative effects. The draft ECP Guidance has additional information on the use of compensation for programmatic permits.

The ESA also has provisions that allow for compensation through the issuance of an Incidental Take Permit (ITP). Under the ESA, mitigation measures are determined on a case by case basis, and are based on the needs of the species and the types of effects anticipated. If a federal nexus exists, or if a developer chooses to seek an ITP under the ESA, then effects to listed species need to be evaluated through the Section 7 and/or Section 10 processes. If an ITP is requested, it and the associated HCP must provide for minimization and mitigation to the maximum extent practicable, in addition to meeting other necessary criteria for permit issuance. For further information about compensation under federal laws administered by the Service, see the Service's Habitat and Resource Conservation website http://www.fws.gov/habitatconservation.

In cases where adverse effects cannot be avoided or minimized, it may be possible to offset all, or a portion, of these effects through compensation. One approach for compensation is the Service Mitigation Policy, which describes steps for addressing habitat loss in detail and includes information on Resource Categories to assist in considering type and amount of compensation to offset losses of habitat.

Under the Service Mitigation Policy, the highest priority is for mitigation to occur on-site within the project planning area. The secondary priority is for the mitigation to occur off-site. Off-site mitigation should first occur in proximity to the planning area within the same ecological region and secondarily elsewhere within the same ecological region. Generally, the Service prefers on-site mitigation over off-site mitigation because this approach most directly addresses project impacts at the location where they actually occur. However, there may be individual cases where off-site mitigation could result in greater net benefits to affected species and habitats. Developers should work with the Service in comparing benefits among multiple alternatives.

Recommended measures may include on- or off-site habitat improvement, and may consist of in-kind or out-of-kind compensation. Compensatory measures may be project-specific, species-specific, or may be part of a mitigation banking approach. The Service recommends that the method for implementing compensation (e.g., fee-title acquisition, in-lieu fee, conservation easement, etc.) be determined as early in the process as possible.

In some cases, a project's effects cannot be forecast with precision. The developer and the agencies may be unable to make some mitigation decisions until post-construction data have been collected. If adverse effects have not been adequately addressed, additional mitigation for those adverse effects from operations may need to be implemented.

Mitigation measures implemented post-construction, whether in addition to those implemented pre-construction or whether they are new, are appropriate elements of the tiered approach. The general terms and funding commitments for future mitigation and the triggers or thresholds for implementing such compensation should be developed at the earliest possible stage in project development. Any mitigation implemented after a project is operational should be well defined, bounded, technically feasible, and commensurate with the project effects.

Some industries, such as the electric utilities, have developed operational and deterrent measures that when properly used can avoid or minimize "take" of migratory birds. Many of these measures to avoid collision and electrocution have been scientifically tested with publication in peer-reviewed, scientific journals. The Service encourages the wind industry to use these measures in siting, placing, and operating all power lines, including their distribution and grid-connecting transmission lines.

Chapter 9
Advancing Use, Cooperation and Effective Implementation

This chapter discusses a variety of policies and procedures that may affect the way wind project developers and the Service work with each other as well as with state and tribal governments and non-governmental organizations. The Service recommends that wind project developers work closely with field office staff for further elaboration of these policies and procedures.

Conflict Resolution

The Service and developers should attempt to resolve any issues arising from use of the Guidelines at the Field Office level. Deliberations should be in the context of the intent of the Guidelines and be based on the site-specific conditions and the best available data. However, if there is an issue that cannot be resolved within a timely manner at the field level, the developer and Service staff will coordinate to bring the matter up the chain of command in a stepwise manner.

Avian and Bat Protection Plan (ABPP)

A project-specific Avian and Bat Protection Plan (ABPP) is an example of a document that describes the steps a developer could take to apply these Guidelines to avoid and minimize effects to birds and bats, and any compensatory mitigation and address the post-construction monitoring efforts the developer intends to undertake. A stand-alone ABPP-type document may facilitate Service review. Typically, a project-specific ABPP will explain the analyses, studies, and reasoning that support progressing from one tier to the next in the tiered approach. A developer may prepare an ABPP in stages, over time, as analysis and studies are undertaken for each tier. It will also address the post-construction monitoring efforts for mortality and habitat effects, and may use many of the components suggested in the Suggested Practices for Avian

Protection on Power Lines (APLIC 2006). Any Service review of, or discussion with a developer, concerning its ABPP is advisory only, does not result in approval or disapproval of the ABPP by the Service, and does not constitute a federal agency action subject to the National Environmental Policy Act or other federal law applicable to such an action.

Project Interconnection Lines

The Guidelines are designed to address all elements of a wind energy facility, including the turbine string or array, access roads, ancillary buildings, and the above- and below-ground electrical lines which connect a project to the transmission system. The Service recommends that the project evaluation include consideration of the wildlife- and habitat-related impacts of these electrical lines, and that the developer include measures to reduce impacts of these lines, such as those outlined in the Suggested Practices for Avian Protection on Power Lines (APLIC 2006). The Guidelines are not designed to address transmission beyond the point of interconnection to the transmission system. The national grid and proposed smart grid system are beyond the scope of these Guidelines.

Confidentiality of Site Evaluation Process as Appropriate

Some aspects of the initial pre-construction risk assessment, including preliminary screening and site characterization, occur early in the development process, when land or other competitive issues limit developers' willingness to share information on projects with the public and competitors. Any consultation or coordination with agencies at this stage may include confidentiality agreements.

Collaborative Research

Much uncertainty remains about predicting risk and estimating impacts of wind energy development on wildlife. Thus there is a need for additional research to improve scientifically based decision-making when siting wind energy facilities, evaluating impacts on wildlife and habitats, and testing the efficacy of mitigation measures. More extensive studies are needed to further elucidate patterns and test hypotheses regarding possible solutions to wildlife and wind energy impacts.

It is in the interests of wind developers and wildlife agencies to improve these assessments to better avoid or minimize the impacts of wind energy development on wildlife and their habitats. Research can provide data on operational factors (e.g. wind speed, weather conditions) that are likely to result in fatalities. It could also include studies of cumulative impacts of multiple wind energy projects, or comparisons of different methods for assessing avian and bat activity relevant to predicting risk. Monitoring and research should be designed and conducted to ensure unbiased data collection that meets technical standards such as those used in peer review. Research projects may occur at the same time as project-specific Tier 4 and Tier 5 studies.

Research would usually result from collaborative efforts involving appropriate stakeholders, and is not the sole or primary responsibility of any developer. Research partnerships (e.g., Bats and Wind Energy Cooperative (BWEC)[8], Grassland and Shrub Steppe Species Collaborative (GS3C)[9]) involving diverse players will be helpful for generating common goals and objectives and adequate funding to conduct studies (Arnett and Haufler 2003). The National Wind Coordinating Collaborative (NWCC)[10], the American Wind Wildlife Institute (AWWI)[11], and the California Energy Commission (CEC)'s Public Interest Energy Research Program[12] all support research in this area.

Study sites and access will be necessary to design and implement research, and developers are encouraged to participate in these research efforts when possible. Subject to appropriations, the Service also should fund priority research and promote collaboration and information sharing among research efforts to advance science on wind energy-wildlife interactions, and to improve these Guidelines.

[8] www.batsandwind.org
[9] www.nationalwind.org
[10] www.nationalwind.org
[11] http://www.awwi.org
[12] http://www.energy.ca.gov/research

Service - State Coordination and Cooperation

The Service encourages states to increase compatibility between state guidelines and these voluntary guidelines, protocols, data collection methods, and recommendations relating to wildlife and wind energy. States that desire to adopt, or those that have formally adopted, wind energy siting, permitting, or environmental review regulations or guidelines are encouraged to cooperate with the Service to develop consistent state level guidelines. The Service may be available to confer, coordinate and share its expertise with interested states when a state lacks its own guidance or program to address wind energy-wildlife interactions. The Service will also use states' technical resources as much as possible and as appropriate.

The Service will explore establishing a voluntary state/federal program to advance cooperation and compatibility between the Service and interested state and local governments for coordinated review of projects under both federal and state wildlife laws. The Service, and interested states, will consider using the following tools to reach agreements to foster consistency in review of projects:

- Cooperation agreements with interested state governments.

- Joint agency reviews to reduce duplication and increase coordination in project review.

- A communication mechanism:
    - To share information about prospective projects
    - To coordinate project review
    - To ensure that state and federal regulatory processes, and/or mitigation requirements are being adequately addressed
    - To ensure that species of concern and their habitats are fully addressed

- Establishing consistent and predictable joint protocols, data collection methodologies, and study requirements to satisfy project review and permitting.

- Designating a Service management contact within each Regional Office to assist Field Offices working with states and local agencies to resolve significant wildlife-related issues that cannot be resolved at the field level.

- Cooperative state/federal/industry research agreements relating to wind energy -wildlife interactions.

The Service will explore opportunities to:

- Provide training to states.
- Foster development of a national geographic data base that identifies development-sensitive ecosystems and habitats.
- Support a national database for reporting of mortality data on a consistent basis.
- Establish national BMPs for wind energy development projects.
- Develop recommended guidance on study protocols, study techniques, and measures and metrics for use by all jurisdictions.
- Assist in identifying and obtaining funding for national research priorities.

Service - Tribal Consultation and Coordination

Federally-recognized Indian Tribes enjoy a unique government-to-government relationship with the United States. The United States Fish and Wildlife Service (Service) recognizes Indian tribal governments as the authoritative voice regarding the management of tribal lands and resources within the framework of applicable laws. It is important to recall that many tribal traditional lands and tribal rights extend beyond reservation lands.

The Service consults with Indian tribal governments under the authorities of Executive Order 13175 “Consultation and Coordination with Indian Tribal Governments” and supporting DOI and Service policies. To this end, when it is determined that federal actions and activities may affect a Tribe’s resources (including cultural resources), lands, rights, or ability to provide services to its members, the Service must, to the extent practicable, seek to engage the affected Tribe(s) in consultation and coordination.

Tribal Wind Energy Development on Reservation Lands:

Indian tribal governments have the authority to develop wind energy projects, permit their development, and establish relevant regulatory guidance within the framework of applicable laws.

The Service will provide technical assistance upon the request of Tribes that aim to establish regulatory guidance for wind energy development for lands under the Tribe's jurisdiction. Tribal governments are encouraged to strive for compatibility between their guidelines and these Guidelines.

Tribal Wind Energy Development on Lands that are not held in Trust:

Indian tribal governments may wish to develop wind energy projects on lands that are not held in trust status. In such cases, the Tribes should coordinate with agencies other than the Service. At the request of a Tribe, the Service may facilitate discussions with other regulatory organizations. The Service may also lend its expertise in these collaborative efforts to help determine the extent to which tribal resource management plans and priorities can be incorporated into established regulatory protocols.

Non-Tribal Wind Energy Development – Consultation with Indian Tribal Governments

When a non-Tribal wind energy project is proposed that may affect a Tribe's resources (including cultural resources), lands, rights, or ability to govern or provide services to its members, the Service should seek to engage the affected Tribe(s) in consultation and coordination as early as possible in the process. In siting a proposed project that has a Federal nexus, it is incumbent upon the regulatory agency to notify potentially affected Tribes of the proposed activity. If the Service or other federal agency determines that a project may affect a

Tribe(s), they should notify the Tribe(s) of the action at the earliest opportunity. At the request of a Tribe, the Service may facilitate and lend its expertise in collaborating with other organizations to help determine the extent to which tribal resource management plans and priorities can be incorporated into established regulatory protocols or project implementation. This process ideally should be agreed to by all involved parties.

In the consultative process, Tribes should be engaged as soon as possible when a decision may affect a Tribe(s). Decisions made that affect Indian Tribal governments without adequate Federal effort to engage Tribe(s) in consultation have been overturned by the courts. *See, e.g., Quechan Tribe v. U.S. Dep't of the Interior*, No. 10cv2241 LAB (CAB), 2010 WL 5113197 (S.D. Cal. Dec. 15, 2010). When a tribal government is consulted, it is neither required, nor expected that all of the Tribe's issues can be resolved in its favor. However, the Service must listen and may not arbitrarily dismiss concerns of the tribal government. Rather, the Service must seriously consider and respond to all tribal concerns. Regional Native American Liaisons are able to provide in-house guidance as to government-to-government consultation processes. (See *Section D. USFWS-State Coordination and Cooperation*, above).

Non-Governmental Organization Actions

If a specific project involves actions at the local, state, or federal level that provide opportunities for public participation, non-governmental organizations (NGOs) can provide meaningful contributions to the discussion of biological issues associated with that project, through the normal processes such as scoping, testimony at public meetings, and comment processes. In the absence of formal public process, there are many NGOs that have substantial scientific capabilities and may have resources that could contribute productively to the siting of wind energy projects. Several NGOs have made significant contributions to the understanding of the importance of particular geographic areas to wildlife in the United States. This work has benefited and continues to benefit from extensive research efforts and from associations with highly qualified biologists. NGO expertise can – as can scientific expertise in the academic or private consulting sectors – serve highly constructive purposes. These can include:

- Providing information to help identify environmentally sensitive areas, during the screening phases of site selection (Tiers 1 and 2, as described in this document)
- Providing feedback to developers and agencies with respect to specific sites and site and impact assessment efforts
- Helping developers and agencies design and implement mitigation or offset strategies
- Participating in the defining, assessing, funding, and implementation of research efforts in support of improved predictors of risk, impact assessments and effective responses
- Articulating challenges, concerns, and successes to diverse audiences

Non-Governmental Organization Conservation Lands

Implementation of these Guidelines by Service and other state agencies will recognize that lands owned and managed by non-government conservation organizations represent a significant investment that generally supports the mission of state and federal wildlife agencies. Many of these lands represent an investment of federal conservation funds, through partnerships between agencies and NGOs. These considerations merit extra care in the avoidance of wind energy development impacts to these lands. In order to exercise this care, the Service and allied agencies can coordinate and consult with NGOs that own lands or easements which might reasonably be impacted by a project under review.

Appendix A

Glossary

Comment [UF&WS6]: Definitions for red terms will be added. New terms are highlighted.

Accuracy – The agreement between a measurement and the true or correct value.

Adaptive management – An iterative decision process that promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. The term as used in the recommendations and the Guidelines specifically refers to “passive” adaptive management, in which alternative management activities are assessed, and the best option is designed, implemented, and evaluated.

Anthropogenic – Resulting from the influence of human beings on nature.

Area of interest – For most projects, the area where wind turbines and meteorological (met) towers are proposed or expected to be sited, and the area of potential impact.

Avian – Pertaining to or characteristic of birds.

Avoid – To not take an action or parts of an action to avert the potential effects of the action or parts thereof. First of three components of “mitigation,” as defined in Service Mitigation Policy. (*See* **mitigation**.)

Barotrauma - Involves tissue damage to air-containing structures caused by rapid or excessive pressure change; pulmonary barotrauma is lung damage due to expansion of air in the lungs that is not accommodated by exhalation (Baerwald et al 2009).

Before-after/control-impact (BACI) – A study design that involves comparisons of observational data, such as bird counts, before and after an environmental disturbance in a disturbed and undisturbed site. This study design allows a researcher to assess the effects of constructing and operating a wind turbine by comparing data from the “control” sites (before and undisturbed) with the “treatment” sites (after and disturbed).

Best management practices (BMPs) – Methods that have been determined by the stakeholders to be the most effective, practicable means of avoiding or minimizing significant adverse impacts to individual species, their habitats or an ecosystem, based on the best available information.

Buffer zone – A zone surrounding a resource designed to protect the resource from adverse impact, and/or a zone surrounding an existing or proposed wind energy project for the purposes of data collection and/or impact estimation.

Community-scale – Wind energy projects greater than 1 MW, but generally less than 20 MW, in name-plate capacity, that produce electricity for off-site use, often partially or totally owned by members of a local community or that have other demonstrated local benefits in terms of retail power costs, economic development, or grid issues.

Comparable site – A site similar to the project site with respect to topography, vegetation, and the species under consideration.

Compensatory mitigation – Replacement of project-induced losses to fish and wildlife resources. Substitution or offsetting of fish and wildlife resource losses with resources considered to be of equivalent biological value.

- **In-kind –** Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically and biologically the same or closely approximate to those lost.
- **Out-of-kind –** Providing or managing substitute resources to replace the value of the resources lost, where such substitute resources are physically or biologically different from those lost. This may include conservation or mitigation banking, research or other options.

Cost effective – Economical in terms of tangible benefits produced by money spent.

Covariate – Uncontrolled random variables that influence a response to a treatment or impact, but do not interact with any of the treatments or impacts being tested.

Critical habitat – For listed species, consists of the specific areas designated by rule making pursuant to Section 4 of the Endangered Species Act and displayed in 50 CFR § 17.11 and 17.12.

Cumulative impacts – *See* **impact**.

Curtailment – The act of limiting the supply of electricity to the grid during conditions when it would normally be supplied. This is usually accomplished by cutting-out the generator from the grid and/or feathering the turbine blades.

Cut-in Speed – The wind speed at which the generator is connected to the grid and producing electricity. It is important to note that turbine blades may rotate at full RPM in wind speeds below cut-in speed.

Displacement – The loss of habitat as result of an animal's behavioral avoidance of otherwise suitable habitat. Displacement may be short-term, during the construction phase of a project, temporary as a result of habituation, or long-term, for the life of the project.

Distributed wind – Small and mid-sized turbines between 1 kilowatt and 1 megawatt that are installed and produce electricity at the point of use to off-set all or a portion of on-site energy consumption.

Ecosystem – A system formed by the interaction of a community of organisms with their physical and chemical environment. All of the biotic elements (i.e., species, populations, and communities) and abiotic elements (i.e., land, air, water, energy) interacting in a given geographic area so that a flow of energy leads to a clearly defined trophic structure, biotic diversity, and material cycles. Service Mitigation Policy adopted definition from E. P. Odum 1971 *Fundamentals of Ecology.*

Endangered species – *See* **listed species**.

Extirpation – The species ceases to exist in a given location; the species still exists elsewhere.

Fatality – An individual instance of death.

Fatality rate – The ratio of the number of individual deaths to some parameter of interest such as megawatts of energy produced, the number of turbines in a wind project, the number of individuals exposed, etc., within a specified unit of time.

Feathering – Adjusting the angle of the rotor blade parallel to the wind, or turning the whole unit out of the wind, to slow or stop blade rotation.

Federal action agency – A department, bureau, agency or instrumentality of the United States which plans, constructs, operates or maintains a project, or which reviews, plans for or approves a permit, lease or license for projects, or manages federal lands.

Federally listed species – *See* **listed species**.

Footprint – The geographic area occupied by the actual infrastructure of a project such as wind turbines, access roads, substation, overhead and underground electrical lines, and buildings, and land cleared to construct the project.

G1 (Global Conservation Status Ranking) Critically Imperiled – At very high risk of extinction due to extreme rarity (often five or fewer populations), very steep declines, or other factors.

G2 (Global Conservation Status Ranking) Imperiled – At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors.

G3 (Global Conservation Status Ranking) Vulnerable – At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.

Guy wire – Wires used to secure wind turbines or meteorological towers that are not self-supporting.

Habitat – The area which provides direct support for a given species, including adequate food, water, space, and cover necessary for survival.

Habitat fragmentation – The separation of a block of habitat for a species into segments, such that the genetic or demographic viability of the populations surviving in the remaining habitat segments is reduced.

Impact – An effect or effects on natural resources and on the components, structures, and functioning of affected ecosystems.

- **Cumulative –** Changes in the environment caused by the aggregate of past, present and reasonably foreseeable future actions on a given resource or ecosystem.
- **Direct –** Effects on individual species and their habitats caused by the action, and occur at the same time and place.
- **Indirect impact –** Effects caused by the action that are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect impacts include displacement and changes in the demographics of bird and bat populations.

Infill – Add an additional phase to the existing project, or build a new project adjacent to existing projects.

In-kind compensatory mitigation – See **compensatory mitigation.**

Intact habitat – An expanse of habitat for a species or landscape scale feature, unbroken with respect to its value for the species or for society.

Intact landscape – Relatively undisturbed areas characterized by maintenance of most original ecological processes and by communities with most of their original native species still present.

Lattice design – A wind turbine support structure design characterized by horizontal or diagonal lattice of bars forming a tower rather than a single tubular support for the nacelle and rotor.

Lead agency – Agency that is responsible for federal or non-federal regulatory or environmental assessment actions.

Lek – A traditional site commonly used year after year by males of certain species of birds (e.g., greater and lesser prairie-chickens, sage and sharp-tailed grouse, and buff-breasted sandpiper), within which the males display communally to attract and compete for female mates, and where breeding occurs.

Listed species – Any species of fish, wildlife or plant that has been determined to be endangered or threatened under section 4 of the Endangered Species Act (50 CFR §402.02), or similarly designated by state law or rule.

Local population – A subdivision of a population of animals or plants of a particular species that is in relative proximity to a project.

Loss – As used in this document, a change in wildlife habitat due to human activities that is considered adverse and: 1) reduces the biological value of that habitat for species of concern; 2) reduces population numbers of species of concern; 3) increases population numbers of invasive or exotic species; or 4) reduces the human use of those species of concern.

Megawatt (MW) – A measurement of electricity-generating capacity equivalent to 1,000 kilowatts (kW), or 1,000,000 watts.

Migration – Regular movements of wildlife between their seasonal ranges necessary for completion of the species lifecycle.

Migration corridor – Migration routes and/or corridors are the relatively predictable pathways that a migratory species travel between seasonal ranges, usually breeding and wintering grounds.

Migration stopovers – Areas where congregations of birds assemble during migration, and supply high densities of food, such as wetlands and associated habitats.

Minimize – To reduce to the smallest practicable amount or degree.

Mitigation – (*Specific to these Guidelines)* Avoiding or minimizing significant adverse impacts, and when appropriate, compensating for unavoidable significant adverse impacts.

Monitoring – 1) A process of project oversight such as checking to see if activities were conducted as agreed or required; 2) making measurements of uncontrolled events at one or more points in space or time with space and time being the only experimental variable or treatment; 3) making measurements and evaluations through time that are done for a specific purpose, such as to check status and/or trends or the progress towards a management objective.

Mortality rate – Population death rate, typically expressed as the ratio of deaths per 100,000 individuals in the population per year (or some other time period).

Operational modification – Deliberate changes to wind energy project operating protocols, such as the wind speed at which turbines "cut in" or begin generating power, undertaken with the object of reducing collision fatalities.

Passerine – Describes birds that are members of the Order *Passeriformes*, typically called "songbirds."

Population – A demographically and genetically self-sustaining group of animals and/or plants of a particular species.

Practicable – Capable of being done or accomplished; feasible.

Prairie grouse – A group of gallinaceous birds, includes the greater prairie-chicken, the lesser prairie-chicken, and the sharp-tailed grouse, occurring in the broader Midwest region and much of Canada and Alaska.

Project area – The area that includes the project site as well as contiguous land that shares relevant characteristics.

Project commencement – The point in time when a developer begins its preliminary evaluation of a broad geographic area to assess the general ecological context of a potential site or sites for wind energy project(s). For example, this may include the time at which an option is acquired to secure real estate interests, an application for federal land use has been filed, or land has been purchased.

Project Site – The land that is included in the project where development occurs or is proposed to occur.

Project transmission lines – Electrical lines built and owned by a project developer.

Raptor – As defined by the American Ornithological Union, a group of predatory birds including hawks, eagles, falcons, osprey, kites, owls, vultures and the California condor.

Relative abundance – The number of organisms of a particular kind in comparison to the total number of organisms within a given area or community.

Risk – The likelihood that adverse effects may occur to individual animals or populations of species of concern, as a result of development and operation of a wind energy project. For detailed discussion of risk and risk assessment as used in this document see Chapter One - General Overview.

Rotor – The part of a wind turbine that interacts with wind to produce energy. Consists of the turbine's blades and the hub to which the blades attach.

Rotor-swept area – The area of the circle or volume of the sphere swept by the turbine blades.

Rotor-swept zone – The altitude within a wind energy project which is bounded by the upper and lower limits of the rotor-swept area and the spatial extent of the project.

S1 (Subnational Conservation Status Ranking) Critically Imperiled – Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.

S2 (Subnational Conservation Status Ranking) Imperiled – Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction**.**

S3 (Subnational Conservation Status Ranking) Vulnerable – Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation.

Sage grouse – A large gallinaceous bird living in the sage steppe areas of the intermountain west, includes the greater sage grouse and Gunnison's sage grouse.

Significant – For purposes of impacts to species of concern and their habitats, as used in these Guidelines, significance will be determined in the context of the degree to which each individual project affects the particular locality and region. The determination will focus on the degree to which the project is likely to affect the long-term status of the population(s) of the affected species of concern. Short-term, long-term, and cumulative effects are relevant.

Species of concern – For a particular wind energy project, any species which 1) is either a) listed as an endangered, threatened or candidate species under the Endangered Species Act, and subject to the Migratory Bird Treaty Act or Bald and Golden Eagle Protection Act; b) is designated by law, regulation, or other formal process for protection and/or management by the relevant agency or other authority; or c) has been shown to be significantly adversely affected by wind energy development, and 2) is determined to be possibly affected by the project.

Species of habitat fragmentation concern—Species of concern for which a relevant federal, state, tribal, and/or local agency has found that the genetic or demographic viability of these species is reduced by separation of their habitats into smaller blocks, thereby reducing connectivity, and that habitat fragmentation from a wind energy project may create significant barriers to genetic or demographic viability of the affected population.

String – A number of wind turbines oriented in close proximity to one another that are usually sited in a line, such as along a ridgeline.

Strobe – Light consisting of pulses that are high in intensity and short in duration.

Threatened species – *See* **listed species**.

Tubular design – A type of wind turbine support structure for the nacelle and rotor that is cylindrical rather than lattice.

Turbine height – The distance from the ground to the highest point reached by the tip of the blades of a wind turbine.

Utility-scale – Wind projects generally larger than 20 MW in nameplate generating capacity that sell electricity directly to utilities or into power markets on a wholesale basis.

Voltage (low and medium) – Low voltages are generally below 600 volts, medium voltages are commonly on distribution electrical lines, typically between 600 volts and 110 kV, and voltages above 110 kV are considered high voltages.

Wildlife – Birds, fishes, mammals, and all other classes of wild animals and all types of aquatic and land vegetation upon which wildlife is dependent.

Wildlife management plan – A document describing actions taken to identify resources that may be impacted by proposed development; measures to mitigate for any significant adverse impacts; any post-construction monitoring; and any other studies that may be carried out by the developer.

Wind turbine – A machine for converting the kinetic energy in wind into mechanical energy, which is then converted to electricity.

Comment [UF&WS7]: FWS will cross-reference the literature cited with citations throughout.

Appendix B

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Appendix C

Sources of Information Pertaining to Methods to Assess Impacts to Birds and Bats

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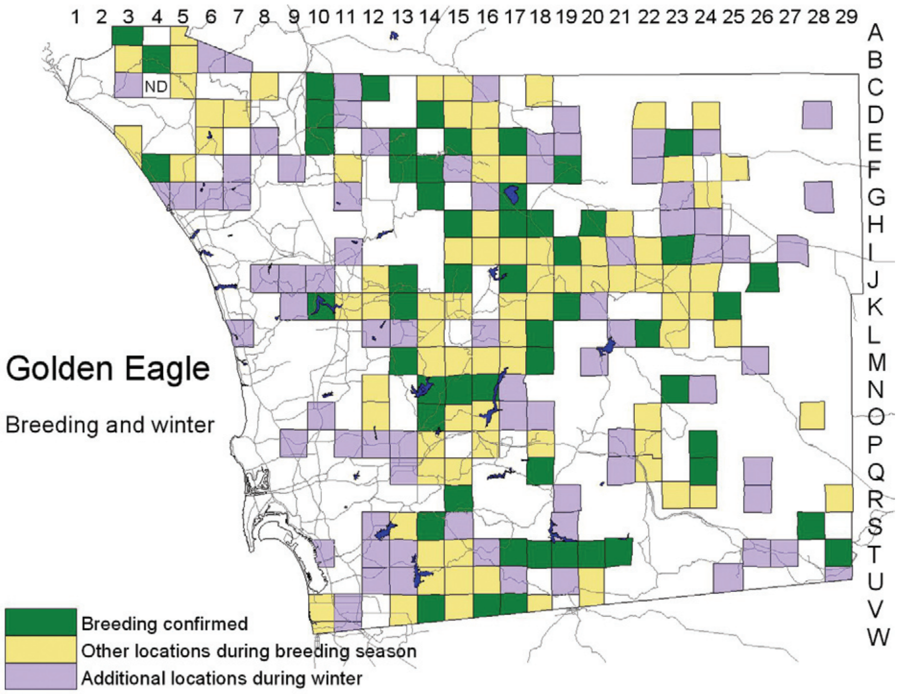
Golden Eagle *Aquila chrysaetos*

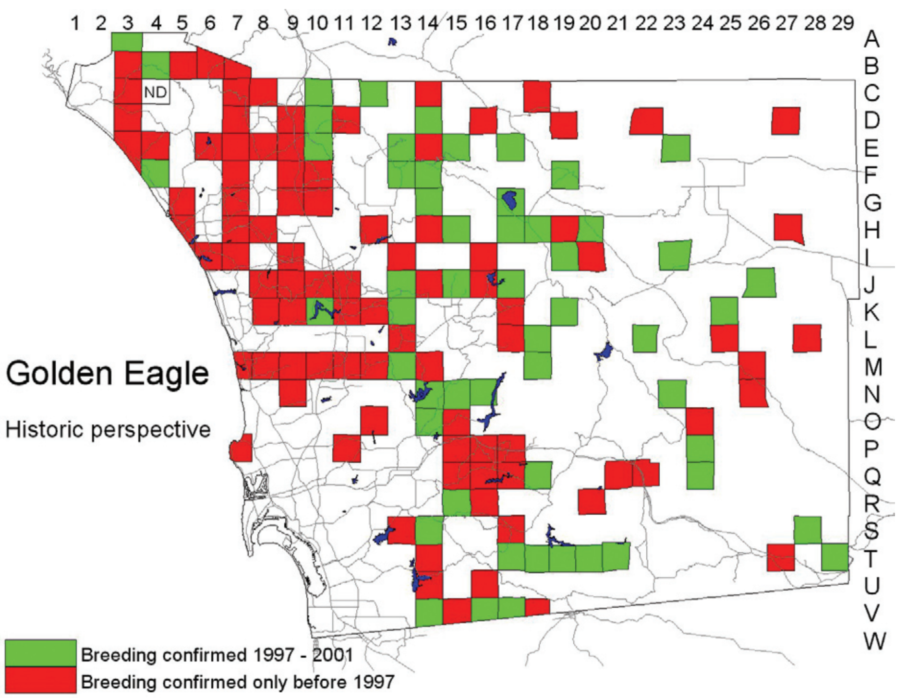
Photo by Anthony Mercieca

As a top predator, the Golden Eagle has the largest territory and the lowest population density of any San Diego County bird. Pairs remain in their territories year round, though the young disperse widely. Most pairs nest on cliff ledges, the rest in trees on steep slopes, hunting in nearby grassland, sage scrub, or broken chaparral. San Diego County's Golden Eagle population has dropped from an estimated 108 pairs at the beginning of the 20th century to about 53 pairs at the century's end, mainly as a result of urban development of foraging habitat. Many of the territories persisting at the beginning



of the 21st century lie near the edge of the urban growth front, a shadow over the future of the capstone of San Diego County's ecosystem.

Breeding distribution: The Golden Eagle's distribution in San Diego County is known better through history than that of any other bird, thanks to study by generations of San Diegans: James B. Dixon, John Colton, John Oakley, Thomas A. Scott, David Bittner, and their collaborators through the Wildlife Research Institute. Since 1988, Bittner and Oakley have organized a team of observers to monitor the county's nesting eagles annually and have checked some inaccessible nest sites via helicopter. This account is based largely on data kindly provided by Bittner.



From 1997 to 2001, about 50–55 pairs nested in the county. Fewer than 20 pairs fledged young each year, averaging 1.5 young per successful nest. Only four of these territories lie west of Interstate 15: three in Camp Pendleton, one around Lake Hodges (K10). Most of the remaining pairs nest within a band 20 to 25 miles wide through the foothills. In southern San Diego County, San Miguel Mountain (S13/S14) and Otay Mountain (U15/V14/V15) mark the western limit of the current breeding range.

In and along the edges of the Anza–Borrego Desert there are 10 known nest sites or clusters of nest sites, though some of these went unused during the entire atlas study, even following the wet winter of 1997–98. Only seven of these territories were active during the atlas period 1997–2001, and at most three were active in any given year. In some nests (D27, L28) new material was added but no eggs were laid; these squares are shown as occupied only before 1997. Since 1998, drought has suppressed numbers of the eagle's principal prey in the Anza–Borrego Desert, the black-tailed jackrabbit. Only two young eagles fledged in the Anza–Borrego Desert in 2003 (D. Bittner).

The Golden Eagle is absent from some surprisingly large yet little disturbed areas of San Diego County, such as Cuyamaca Mountains and the Campo Plateau between Lake Morena and Jacumba.

The map of the species' breeding distribution somewhat overrepresents its abundance. A few pairs straddle two atlas squares. Nesting in three squares (F19, M13, R15) has ceased since 1997.

Nesting: Scott (1985) found about 80% of San Diego County's Golden Eagle nests built on cliff ledges, 20% in trees, usually on steep slopes. A pair typically rotates among several nest sites, including both cliff and tree nests. Many of the cliff sites have been in regular use since the early 20th century and undoubtedly long before that. Though the giant stick nests are reused for years, the birds refurbish them annually. In San Diego County, fallen yucca leaves, with their tough fibers, are a common ingredient in the nest's lining (Dixon 1937, D. Bittner).

The Golden Eagle's schedule of nesting in San Diego County is also supported by abundant data. Nest building begins with the first heavy rain of fall (Dixon 1937). Copulation begins as early as 5 January (D. Bittner). Dates of 407 egg sets collected or observed from 1891 to 1957 range from 2 February to 26 April, except for one on 7 May and another on 16 June. The mean date is 4 March, standard deviation 17 days. Eggs laid after the first week of March, however, are probably replacement clutches (Dixon 1937). During his recent surveys, Bittner has found most eggs laid in mid February, most chicks hatching in late March or early April, and most young fledging in June. Occasionally, however, he encounters nestlings on dates suggesting they hatched from eggs laid in mid January (e.g., chicks five weeks old on 15 April 2004).

Migration: Once a Golden Eagle acquires a mate and a territory, it remains with them year round, except for occasional swapping (Kochert et al. 2002). Young birds, however, may disperse considerable distances: birds banded in San Diego County have been recovered in Ojai, Ventura County, in Apple Valley, San Bernardino County, in Utah, in the Grand Canyon, Arizona, and near Guadalajara in central Mexico (T. A. Scott, D. Bittner).

Winter: In spite of the mobility of immatures and nonterritorial adults, the nonbreeding distribution of the Golden Eagle in San Diego County does not differ greatly from the breeding distribution. In southern San Diego County a few birds often spread west to the Otay and Tijuana River valleys, accounting for the near regularity of the eagle on the San Diego Christmas bird count (noted on 16 of 20 counts 1983–2002). One on the fill north of the Sweetwater River mouth, National City (T10), 15 December 2001 (S. M. Wolf) was our only sighting during the atlas period of a Golden Eagle that must have flown several miles over developed areas. The count circles other than San Diego include at least one nesting territory. Our maximum winter count per atlas square per day was three, all within a few miles of nest sites.

Conservation: Following studies by Dixon (1937) and Scott (1985), David Bittner and John Oakley (pers. comm.) estimate the Golden Eagle population of San Diego County in 1900 at 108 pairs. It remained near 100 pairs until the rapid growth of the county's human population following World War II. In the 1970s, following the building of the interstate highways and the spread of avocado and citrus orchards along Interstate 15, the decline became precipitous. By 2004, the population had dropped to about 53 pairs, with some uncertainty because of a few territories straddling the county line and long vacancy of some territories in the Anza–Borrego Desert. Since 1988, the surveys organized by the Wildlife Research Institute have located about 15 previously unknown pairs in remote parts of the county, accounting for the variation from the estimate of 40–50 pairs reported by Unitt (1984) on the basis of studies by T. A. Scott (pers. comm.).

The eagles abandoned four territories just within the five-year atlas period, and the Wildlife Research Institute estimates that nine more are in imminent danger of abandonment. Without better planning for habitat conservation, the institute estimates the county's eagle population could be halved again by 2030.

The most important factor in this decrease has been urban sprawl covering former foraging habitat. From 1900 to 1936, when eagle territories still filled northwestern San Diego County, Dixon (1937) found the territories of 27 pairs in that region to range from 19 to 48 square miles and average 36 square miles. Thus the area needed to support the species is considerably greater than for any other San Diego County bird. The viability of territories that become isolated from the main block of the species' range is also questionable. Of the 27 territories mapped by Dixon (1937), only nine were occupied at the beginning of the 21st century.

Other factors affecting the eagle are human disturbance, especially rock climbing on nesting cliffs, but also shooting (both recreational and for military training on Camp Pendleton), and agriculture (avocado orchards planted near nest sites). Electrocution on power lines is now the biggest source of mortality: 37 of 55 dead eagles picked up in and near San Diego County 1988–2003 and reported to Bittner had been electrocuted. The Golden Eagle was less subject to poisoning by insecticides like DDT than other birds of prey but has suffered poisoning by scavenging prey killed by rodenticides. Three of the 55 dead birds recovered had been killed through such secondary poisoning. Ever more prolonged droughts could depress the population further, a factor Hoffman and Smith (2003) suggested as affecting raptors throughout the western United States.

Taxonomy: *Aquila c. canadensis* (Linnaeus, 1758) is the only subspecies of the Golden Eagle in North America.

The Wildlife Society

Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat

Technical Review 07–2
September 2007

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The Wildlife Society
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COVER: Wind turbines at the Maple Ridge Wind Farm in Lowville, New York (center): Ed Arnett, Bat Conservation International; Silver-haired bat (left): Merlin D. Tuttle, Bat Conservation International; Bluetit in spring (upper right); Greater prairie chicken (lower right): U.S. Geological Survey.

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Foreword

Presidents of The Wildlife Society occasionally appoint ad hoc committees to study and report on select conservation issues. The reports ordinarily appear as either a Technical Review or a Position Statement. Review papers present technical information, and position statements are based on these reviews. Preliminary versions of position statements are published for review and comment by Society members. Following the comment period, revision, and Council's approval, the statements are published as official positions of The Wildlife Society.

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Acknowledgments

We wish to thank past-President Richard Lancia and The Wildlife Society Council for appointing the Technical Review Committee on the Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat and addressing this important and growing issue. Tom Franklin, Jim Mosher, and Paul Racey reviewed a previous draft of this document. We also thank Laura Bies, Associate Director of Government Affairs for TWS, and TWS Council Technical Review Subcommittee Chair Gary Potts and Subcommittee members Tom Decker, Marti Kie, and Tom Ryder for their guidance and review of previous drafts. Bat Conservation International and TWS provided financial assistance and logistical support for the review, committee meetings, and publication.

Table of Contents

SYNOPSIS

Development of wind power offers promise of contributing to renewable energy portfolios to reduce greenhouse gas emissions from carbon-based sources, which contribute to accelerating climate change. This report summarizes information on the impacts of wind energy facilities on wildlife and wildlife habitat, including state and federal permitting processes, wildlife fatality, habitat loss and modification, animal displacement and fragmentation, offshore development, and issues surrounding monitoring and research methodology, including the use of technological tools.

Impacts of wind energy facilities on wildlife can be direct (e.g., fatality, reduced reproduction) or indirect (e.g., habitat loss, behavioral displacement). Although fatalities of many bird species have been documented at wind facilities, raptors have received the most attention. Turbine characteristics, turbine siting, and bird abundance appear to be important factors determining risk of raptor fatalities at wind energy facilities. In comparison with other sources of fatality (e.g., collision with buildings and communication towers, predation by domestic cats), wind turbines, at the current rate of development, appear to be a relatively minor source of passerine fatalities, but these fatalities are cumulative with other sources and their impact may become more pronounced over time. As turbine size increases and development expands into new areas with higher densities of birds, risk to birds could increase. Bat fatalities have been recorded either anecdotally or quantified at every wind facility where post-construction surveys have been conducted, worldwide, and reported fatalities are highest at wind facilities located on ridges in eastern deciduous forests in the United States. However, recent reports of high numbers of bats killed in open prairie in southern Alberta, Canada, and in mixed agriculture and forest land in New York raise concern about impacts to bats in other landscapes. Because bats are long-lived and have exceptionally low reproductive rates, population growth is relatively slow and their ability to recover from population declines is limited, increasing the risk of local extinctions. Given the projected growth of wind power generation, it is essential that future analysis of the impacts of wind energy development consider population effects for some species of bats and birds.

Often overlooked are impacts resulting from loss of habitat for wildlife due to construction, the footprint of the facility, and increased human access. Future development of transmission lines to facilitate wind generation will exacerbate the impacts of wind energy development on wildlife. Ultimately, the greatest impact to wildlife from habitat modification may be due to disturbance and avoidance of habitats in proximity to turbines and fragmentation of habitat for wide-ranging species. For example, habitat for many species of grassland birds in the Northern Great Plains has been dramatically reduced by land use changes, primarily agriculture, and further development of wind energy in undisturbed native and restored grasslands may result in further declines of these species.

Offshore wind facilities have been established throughout Europe, but few studies have been conducted to determine direct impacts on animals. A major concern with offshore developments in Europe has been loss of habitat from avoidance of turbines and the impact that boat and helicopter traffic to and from the wind development sites may cause with regard to animal behavior and movements, although little is known about such effects. Resident seabirds and rafting (resting) waterbirds appear to be less at risk than migrating birds, as they may adapt better to offshore wind facilities. The effects on marine mammals and bats are currently unknown. Although wind turbine/bird collision studies seem to indicate that onshore wind-generating facilities in those locations of the United States studied to date result in few fatalities compared with other sources of collision mortality, we cannot assume that similar impacts would occur among birds (or bats) using wind-generating sites established in unstudied areas such as coastal and offshore areas.

There is a dearth of information upon which to base decisions regarding siting of wind energy facilities, their impacts on wildlife, and possible mitigation strategies. With few exceptions, most work conducted to date at terrestrial facilities has been relatively short-term (e.g., one year or in some cases only one field season). Longer-term studies are required to elucidate patterns and develop predictive models for estimating fatalities and evaluating possible habitat fragmentation or other disturbance effects. The shortage of studies published in the scientific literature on wind-wildlife interactions is problematic and must be overcome to ensure the credibility of studies.

Potential mitigation measures exist and their effectiveness should be evaluated before mandated on a large scale. New mitigation measures are needed and effort must be focused on their development and evaluation. Mitigation measures can be patterned after other efforts that have been demonstrated to work. For example, conservation reserve program lands have replaced some habitat lost to grassland species as a result of agriculture.

Development of clean, renewable energy sources is an important goal, and wind power offers promise for contributing to renewable energy portfolios. However, given the projected development of wind energy, biologically significant cumulative impacts are possible for some species and may become more pronounced over time, unless solutions are found. Avoiding, minimizing, and mitigating harmful impacts to wildlife is an important element of "green energy" and developers of wind energy sources should cooperate with scientists and natural resource agency specialists in developing and testing methods to minimize harm to wildlife.

INTRODUCTION

Economically developed countries worldwide, most notably the United States, are highly dependent on fossil fuels to supply their energy needs. Conventional power generation from fossil fuels has a host of well-documented environmental impacts, globally the most notable being the emission of carbon dioxide (CO_2). The IPCC (2007) documents and projects significant and rapid world-wide changes in climate from increased atmospheric CO_2 concentrations, including rising temperatures, altered precipitation patterns, more severe extremes in droughts and floods, and rising sea levels. These changes in climate are already having significant impacts on flora and fauna (Parmesan 2006), which must adapt to changing environmental conditions (Inkley et al. 2004) if they are to survive.

Increasingly, the world is looking for alternatives for supplying energy. Alternatives frequently considered are nuclear, coal with CO_2 sequestration (i.e., capture and storage of CO_2 and other greenhouse gases that otherwise would be emitted into the atmosphere), conservation, and renewable energy. Conservation and energy-efficiency are perhaps the most cost-effective options, but they alone cannot fill the gap between growing demand for energy and available supply, while simultaneously reducing carbon emissions.

Wind has been used to commercially produce energy in North America since the early 1970s and currently is one of the fastest-growing forms of renewable energy worldwide (Figure 1), at a time of growing concern about the rising costs and long-term environmental impacts from the use of fossil fuels and nuclear power (McLeish 2002, Kunz et al. 2007a). Of the renewable energy technologies, wind-generated electricity is becoming cost-effective in many locations, and electrical utilities in the United States and Europe are increasingly turning to wind energy for new electricity supplies that are free of emissions and carbon. Wind turbines are able to generate electricity without many of the negative environmental impacts associated with other energy sources (e.g., air and water pollution, greenhouse gas emissions associated with global warming and climate change). The National Energy Modeling System (NEMS) model projects that the installed capacity of wind generators will grow to about 100,000 megawatts (MW) over the next 20 years and that these generators will displace approximately the equivalent of 69 million metric tons of carbon, while avoiding the installation of 17,000 MW of conventional generating capacity and saving energy consumers about $17.6 billion/year on energy costs.

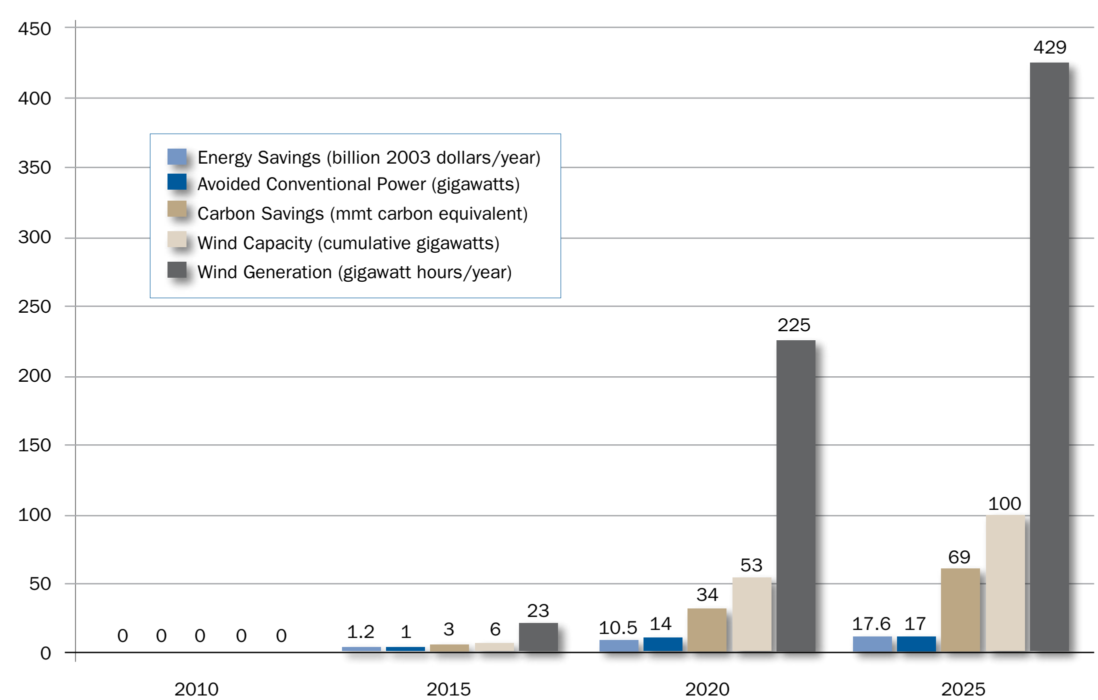
Some wind experts project that wind energy could ultimately contribute 20 percent of the United States' electrical energy needs, as Denmark has already achieved (Advanced Energy Initiative 2006). This would amount to about three times the installed capacity projected by the NEMS model, and while the various quantities in the figure do not scale linearly, the benefits would be roughly three times greater. Wind energy detractors, however, argue that while wind energy is growing exponentially in the United

States, fossil-fuel-burning power plants also continue to grow exponentially. Thus, while wind is producing more electricity, based on public demand, it is not replacing fossil fuels. Indeed, the proportion of fossil-fuels in the world's energy mix, currently at 86 percent, is not projected to change by 2030 (EIA 2007). Whether wind energy ever provides 20 percent of electricity in the United States will depend on many variables, not the least of which is connectivity to the power grid.

However, wind energy development is not environmentally neutral. Often overlooked are habitat impacts, both direct (e.g., resulting from turbine construction and increased human access) and indirect (e.g., habitat fragmentation and avoidance of habitats in proximity to turbines). Better known are fatalities of birds and bats that have been documented at wind facilities worldwide, including Australia (Hall and Richards 1972), the United States and Canada (e.g., Erickson et al. 2002, Johnson et al. 2002, 2003ab), and northern Europe (e.g., Ahlen 2003, Dürr and Bach 2004, Brinkman 2006). Raptor fatalities have been well documented in California (e.g., Orloff and Flannery 1992, Smallwood and Thelander 2004). Furthermore, recent reports of large numbers of bats being killed at wind energy facilities (e.g., Fiedler 2004, Kerns and Kerlinger 2004, Arnett 2005, Arnett et al. 2008) raise concerns about potential cumulative population-level impacts. Wildlife research related to wind energy has focused primarily on bird collisions with wind turbine blades, towers, support structures, and associated power lines (Erickson et al. 2001, Orloff and Flannery 1992). Wildlife advocates and experts have been slower to grasp other potential impacts of wind power development, such as bat fatalities and habitat effects.

This report summarizes information on the impacts of wind energy facilities on wildlife and wildlife

Figure 1. Projected growth and usage of wind energy in the U.S. through 2025, (National Renewable Energy Laboratory 2006).



habitat primarily at land-based facilities. We present information on world energy demands, wind energy development and technology, state and federal permitting processes, wildlife fatality, habitat loss (including modification, animal displacement, and fragmentation), offshore development, and issues surrounding monitoring and research methodology and use of technological tools. We also discuss information needs for siting wind energy facilities and the need to monitor wind energy impacts so that agency managers and biologists, researchers, decision makers, wind industry, and other stakeholders are sufficiently informed about impacts to help avoid, minimize, and mitigate impacts of wind energy facilities on wildlife and wildlife habitat.

FEDERAL AND STATE REGULATIONS AND PERMITTING

Federal resource and land management agencies, non-governmental organizations, contractors, developers, and utilities have dominated the discussion about wildlife interactions with wind energy facilities. Until recently, most state fish and wildlife agencies have not been deeply or proactively involved. This limited participation reflects a variety of factors, including more immediate management priorities, lack of fiscal and human resources, and the limited regulatory authority to apply wildlife considerations to these decisions. These facts notwithstanding, wind energy regulation in most of the United States is primarily the responsibility of state and local governments. First, most North American wind energy development has occurred and is occurring on private land (Government Accountability Office [GAO] 2005). Second, with the exception of federal trust species (Sullivan 2005), wildlife conservation in the United States lies within the exclusive jurisdictional authority of state fish and wildlife agencies (Baldwin vs. Fish and Game Commission of Montana 1978, Manville 2005). Federal jurisdiction over wildlife habitat is limited to sites located on federally owned lands, or where federal funding or federal permits are involved, or Critical Habitat designated under the federal Endangered Species Act. Several states have set up wind working groups to address issues and advise legislators and regulators about the potential impacts and benefits of wind development, including effects on wildlife resources.

Where wind projects are proposed for development in federal waters (generally > 3 NM [5.6 km], or for Texas, 3 leagues [~10.2 mi; 16.3 km]), the Interior Department's Minerals Management Service (MMS) now has jurisdictional authority. At this writing, MMS is developing an EIS review process under the National Environmental Policy Act. In Texas State waters, the Texas Lands Office retains siting authority. In the Great Lakes, the Army Corps of Engineers retains authority for offshore wind development.

Federal Regulatory Approaches

The primary federal laws that pertain to wind energy development, permitting, and impacts on wildlife include the MBTA (16 U.S.C. 703-712; MBTA), Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d; BGEPA), Endangered Species Act (16 U.S.C. 1531-1544; ESA), and the National Environmental Policy Act (16 U.S.C. 4371 et seq.; NEPA). Strict liability statutes under the MBTA and BGEPA, which lack a consultation process, require developers of wind energy on private and federally owned lands to perform within the spirit and the intent of these laws. Under the ESA, development of a Habitat Conservation Plan (Section 10) and subsequent acquisition of a "takings permit" are voluntary on the part of the developer, but any violation of the ESA is not. Other relevant aspects of facility development require compliance with federal laws and regulations such as the 404 b(1) of the Clean Water Act and use of aircraft warning lights, as required by the Federal Aviation Administration (FAA) under its current "obstruction marking and lighting" Advisory Circulars.

There currently is no oversight agency or commission tasked to review and regulate wind energy development on private lands, which complicates regulation among local, state, and federal governing bodies. How the federal government and specific federal agencies tasked to address issues related to wind development deal with wind siting, permitting, and development depends on a federal "nexus" or specific federal connection related to the proposed site. A federal nexus would include wind development 1) on federal lands or waters; 2) where federal funding has been provided to a project; 3) where a federal permit is involved; or 4) where there is a connection to a federal power grid, such as the Bonneville Power Authority (BPA) or the Western Area Power Administration (WAPA) transmission grids. While the federal production tax credit (currently $0.019/kilowatt [Kw] hour) is a tax-payer-financed subsidy, currently authorized through the end of 2008, it is not currently considered a federal nexus, has not yet been challenged in court, and thus does not require NEPA review. Where a commercial wind facility intends to connect to a federal power grid such as BPA or WAPA, the U.S. Department of Energy requires environmental review under NEPA. For wind development on private lands, where no federal permit or no federal funding is involved, no clear federal nexus presently exists. While NEPA typically evaluates proposed projects in terms of biological significance, ESA protects both individuals and populations, and strict liability statutes, such as the Migratory Bird Treaty Act, make it difficult for federal agencies to address only population impacts (Manville 2001, 2005).

To assist U.S. Fish and Wildlife Service (USFWS) staff, particularly those in the Service's 78 Ecological Services Field Offices whose task is to provide technical assistance to wind developers or their consultants, the Service developed interim voluntary land-based guidance to avoid or minimize impacts to wildlife and their habitats (found at www.fws.gov/habitatconservation/wind.pdf, May 13, 2003, Deputy Director's cover memo, and pp. 1–33, 52–55, released to the public on July 10, 2003). The voluntary guidance was intended to allow Field Offices to help wind developers avoid future take of migratory birds and federally listed threatened and endangered species, as well as minimally impact their habitats. The guidelines do this by making recommendations on the proper evaluation of potential sites; the proper location and design of wind turbines, and their associated infrastructures; and by suggesting pre- and post-construction research and monitoring to identify and assess risk and potential impacts to wildlife. While voluntary, the guidelines will remain in use until they are updated with recommendations from an advisory committee soon to convene.

State Regulatory Approaches

As of 2006, 11,603 MW of wind energy capacity was installed in the United States (Figure 2; U.S. Department of Energy 2006). Development is concentrated where adequate wind resources and transmission currently exist. At present, 16 states are without any wind power facilities (Alabama, Arizona, Arkansas, Connecticut, Delaware, Florida, Georgia, Indiana, Kentucky, Louisiana, Maryland, Mississippi, Nevada, North Carolina, South Carolina, and Virginia), although some have projects proposed or under development.

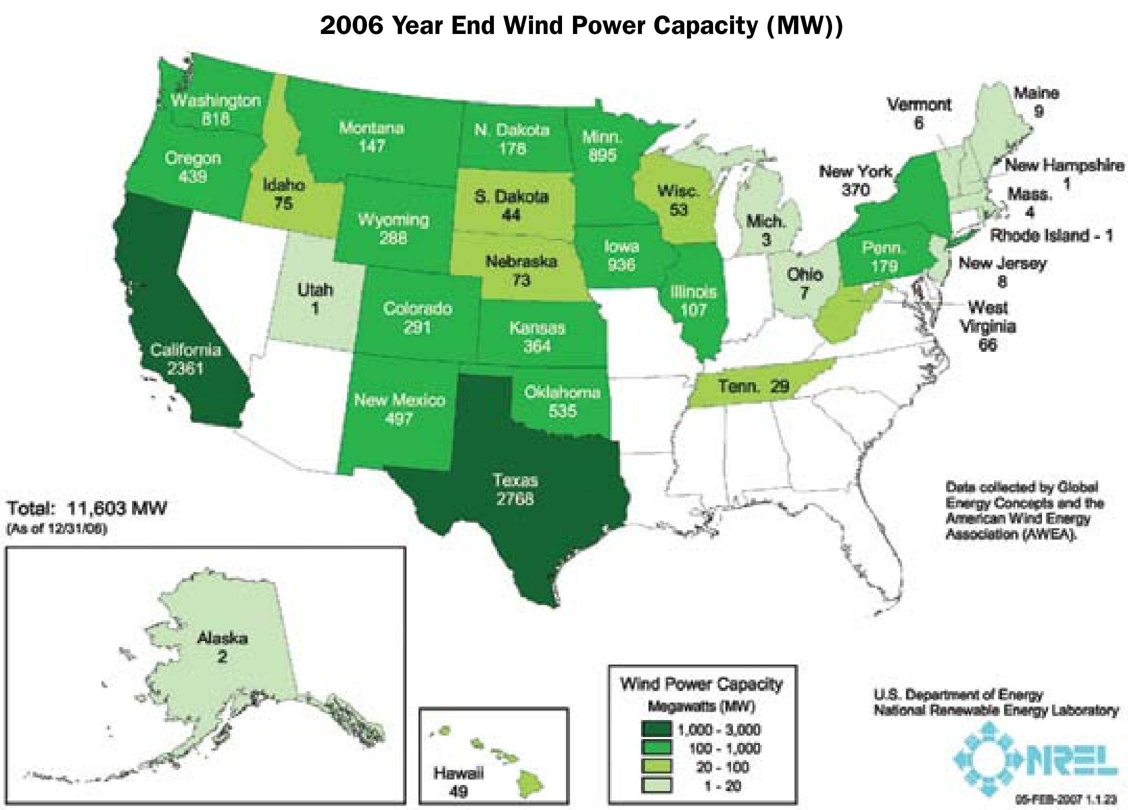
State fish and wildlife agency participation in wind energy development has varied from proactive involvement with clear regulatory guidance (e.g., Washington) to piecemeal reactive involvement with specific projects of special concern. With several notable exceptions, most states have statutes that can be applied (albeit indirectly) to regulate the siting, construction, and operation of wind energy facilities. These include industrial siting laws, zoning regulations, state environmental laws, and home-rule requirements at the local level (e.g., New York), among others. To date, state and local governments have used these authorities to encourage development rather than as a basis for litigation. Typically, state public service commissions, local or county planning commissions, zoning boards, and/or city councils are the permitting authorities for wind development projects (GAO 2005). Given this diversity, it is not surprising that there are considerable differences in the requirements imposed. Currently, several states (e.g., Vermont, Pennsylvania, and California) are in the process of developing state guidelines and regulations to address wind energy development (Stemler 2007).

More often than not, state fish and wildlife agencies lack regulatory authority to directly participate in the permitting of any type of development, and so instead rely on cooperating with the state regulating authority and federal partners, such as the Bureau of Land Management (BLM), to control when and where development occurs. This approach is only moderately effective because wildlife concerns are only one of a myriad of social, political, and economic inputs considered by decision-makers. State natural resource or environmental agencies, historic preservation boards, industrial development boards, public utility commissions, or siting boards often provide an additional level of oversight (in many cases, state authorities supersede local oversight). This involvement also varies among jurisdictions, reflecting the evolution of authorities in response to the growth of the industry. Pre-existing authorities to regulate development often are insufficient, ill-suited, or simply not applicable to wind energy projects. Compounding this difficulty, state and local governments sometimes lack the experience, staff, and capability necessary to adequately address the environmental impacts of wind energy development.

A critical point is that while many species potentially affected by wind energy development are under federal jurisdiction, others, such as prairie and sage grouse, mule deer, and bighorn sheep, are not, unless they become federally listed under the ESA. These species are managed by state fish and wildlife agencies, and, at least in the states that comprise major portions of their core habitat, the lack of regulatory authority compromises conservation and restoration objectives. Enhancing legislative authorities for state fish and wildlife agencies related to all forms of development, including wind energy, is the purview of the states involved.

A growing number of states have (or are developing) Renewable (Energy) Portfolio Standards (RPS) (Stemler 2007). In most cases, these are numerical targets requiring utilities to increase reliance on solar radiation, wind, water, and other renewable sources for electrical generation (American Wind Energy Association 1997). The Western Governors Association Clean and Diversified Energy Initiative for the West (WGA Proposed Policy Resolution 04-12, 2004) proposes to encourage development of RPS across the western United States. In 2001, 75 percent of wind power developed in the United States was in states with portfolio requirements. Some believe that RPS or purchase mandates are the most powerful tool that states can implement to promote renewable energy use (Bird et al. 2003). Unfortunately, RPS usually focus on benefits of renewable energy, with less attention to negative environmental impacts.

Figure 2. Installed wind capacity (megawatts; MW) in the United States as of 31 December 2006 (National Renewable Energy Laboratory; http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_installed_capacity.asp)



Washington Department of Fish and Wildlife Wind Power Guidelines

Among state fish and wildlife agencies, the Washington Department of Fish and Wildlife was the first to provide comprehensive guidelines for wind energy development (Washington Department of Fish and Wildlife 2003). These guidelines consist of three sections: (a) baseline and monitoring studies for wind projects, (b) wind project habitat mitigation, and (c) wind power alternative mitigation pilot program. The guidance applies to projects east of the Cascade Mountains in sage steppe habitats.

Baseline and monitoring studies for wind projects. Developers, in consultation with the agency, are required to collect information about potential environmental impacts. Site-specific components of the assessment include project size, availability of existing comparison baseline data, habitats affected, and the likelihood and timing of threatened, endangered species, and state-sensitive species occurring in the proposed project location. The guidance requires use of the best available evaluation protocols and communication of baseline and pre-construction study results to stakeholders (i.e., state agencies and other groups with an interest in the siting, construction, and operation of facilities).

Developers are required to conduct habitat mapping and report general vegetation and land cover types, habitats for wildlife species of concern, and the extent of noxious weeds at the development location. At least one raptor survey during the breeding season is required. If the occurrence of threatened, endangered, or state-sensitive species is likely, then monitoring within a 3.2 km buffer of the development location is recommended. At least one full season of general bird surveys is recommended during seasons of occurrence or for longer periods of time if avian use is high or if few data exist to indicate which seasons might be important. The guidelines also require state-of-the-art protocols that are reviewed and approved by the state wildlife agency.

The guidance recommends that developers use already disturbed lands (i.e., agricultural land, existing transmission corridors, established road systems), and it discourages the use of sites supporting high-value plant communities. It requires the use of tubular towers and discourages the use of guy wires either on turbine or associated meteorological towers. The guidance makes a series of recommendations with the intent of reducing impacts, including minimizing overhead power lines, minimizing lighting on turbines (to the extent permitted under Federal Aviation Administration [FAA] regulation), encouraging noxious weed control, and requiring a fire protection plan. The guidance requires that development locations be restored to (at least) pre-development conditions when turbines are decommissioned.

When a wind energy facility becomes operational, the guidance requires ongoing monitoring, the scope of which depends on size of the project and availability of data from similar projects. A Technical Advisory Committee reviews and evaluates mitigation actions (included as conditions of the permitting document) on a quarterly basis. Research studies are encouraged, but not as part of an operational monitoring plan.

Wind project habitat mitigation. The Washington guidance indicates that mitigations specified in permitting documents are considered to be entirely adequate, except for any subsequently identified impacts to threatened, endangered, and state-sensitive species. Developers are required to acquire and then manage replacement wildlife habitat for the life of the project, unless the development occurs on land with little or no wildlife habitat value (land under cultivation or otherwise developed or disturbed). The acquisition of replacement habitat is guided by five criteria: (1) replacement lands should be comparable to habitat disturbed by development; (2) replacement habitat should be given legal protection; (3) replacement habitat should be protected from degradation for the life of the project; (4) replacement habitat should be in the same geographic region as the project; (5) replacement habitat should be jointly agreed to by the developer and the Washington Department of Fish and Wildlife.

The area of replacement habitat varies depending on the value of the disturbed land. The ratio is 1:1 for habitat subject to imminent development, or to acquisition for grassland or CRP replacement. The ratio is 2:1 for sage steppe plant community replacement. When disturbance is temporary, the replacement ratios are 0.1:1 for habitats subject to imminent development and 0.5:1 for sage steppe plant community. Replacement habitats must be prepared and seeded, noxious weeds must be controlled, and the land otherwise protected from degradation.

Alternative mitigation pilot program. Developers can pay a median fee of $55.00/acre to the Washington Department of Fish and Wildlife. This cost is reviewed annually and may be adjusted by up to 25 percent to reflect current land values and/or the quality of the disturbed habitat. Funding obtained is used to purchase and manage high-value wildlife habitat in the same geographic region as the development project.

No RPS consider the potential impacts of renewable energies development on fish, wildlife, and their habitats. Revising existing standards to account for wildlife impacts and inclusion of guidelines in the permitting process would further strengthen agency participation and implementation of guidelines.

WILDLIFE COLLISION FATALITY AT WIND FACILITIES

Factors Influencing Estimation of Fatality Rates

Experimental designs and methods for conducting post-construction fatality searches are well established (e.g., Anderson et al. 1999, Morrison 1998, 2002). While the statistical properties for at least some common estimators have been evaluated and suggested to be unbiased under the assumptions of the simulations (Barnard 2000, W. P. Erickson, Western Ecosystems Technology, unpublished data), important sources of field sampling bias must be accounted for to correct estimates of fatality. Important sources of potential bias include 1) fatalities that occur sporadically; 2) carcass removal by scavengers; 3) searcher efficiency; 4) failure to account for the influence of site (e.g., vegetation) conditions (Wobeser and Wobeser 1992, Philibert et al. 1993, Anderson et al. 1999, Morrison 2002); and 5) fatalities or injured animals that may land or move outside the search plots.

Fatality searches usually are conducted on a systematic schedule of days (e.g., every 3, 7, or 14 days). Most estimators assume fatalities occur at uniformly distributed, independent random times between search days and apply an average daily rate of carcass removal expected during the study. However, if the distribution of fatalities is highly clustered, then estimates may be biased, especially if carcass removal rates are high. If most fatalities occur immediately after a search, those fatalities would have a longer time to be removed before the next search, resulting in higher scavenging rates than the average rate used in the estimates. This would lead to an underestimate of fatalities. On the other hand, if most fatalities occur before, but close to the next search, the fatality estimate may be an overestimate. The second source of bias in fatality estimation relates to assessing scavenging rates (also referred to as carcass removal). Most studies have used house sparrows as surrogates for small birds and bats during carcass removal trials, while using pigeons for medium-sized birds (Erickson et al. 2001, Morrison 2002). While the use of these surrogates may be reasonable for birds, past experiments assessing carcass removal may not be representative of scavenging on bats in the field when small birds are used as surrogates for bats (Kerns et al. 2005). Scavenging of both birds and bats should be expected to vary from site to site and among both macro-scale habitats (e.g., forests compared with grass pasture) and micro-scale vegetation conditions at any given turbine (e.g., bare ground compared with short grass). As scavengers learn of the presence of available carcasses, scavenging rates may significantly increase. A third source of bias relates to detectability: the rate by which searchers detect bird and bat carcasses. Searcher efficiency can be biased by many factors, including habitat, observer, condition of carcasses (e.g., decomposed remains compared with fresh, intact carcasses), weather, and lighting conditions. Searcher efficiency and carcass scavenging should be expected to vary considerably within and among different vegetation cover conditions (Wobeser and Wobeser 1992, Philibert et al. 1993, Anderson et al. 1999, Morrison 2002). Proportion of fatalities that land outside of search plots can be estimated by using the distribution of fatalities as a function of distance from turbines (Kerns et al. 2005). Bias associated with injured animals that leave search plots is difficult to quantify and has not been reported to date.

Below, we discuss patterns and estimates of fatalities reported for raptors, resident and migratory

Estimates of bird and bat fatality at wind facilities are conditioned on field sampling biases such as searcher efficiency which varies considerably with vegetative conditions. (Credit: Merlin D. Tuttle, Bat Conservation International) songbirds, other avian species, and bats, but caution that estimates are 1) conditioned upon the above described factors, 2) calculated differently for most studies reviewed and synthesized here, and 3) may be biased in relation to how the sources of field sampling bias were or were not accounted for.

Raptors

Early utility scale wind energy facilities, most of which were developed in California in the early 1980s, were planned, permitted, constructed, and operated with little consideration for potential impacts to birds (Anderson et al. 1999). Although fatalities of many bird species have been documented at wind facilities, raptors have received the most attention (e.g., Anderson et al. 1996a, 1996b, 1997, 2000; Anderson and Estep 1988, Estep 1989, Howell 1997, Howell and Noone 1992, Hunt 2002, Johnson et al. 2000a, 2000b, Martí 1994, Orloff and Flannery 1992, 1996, Thelander and Rugge 2000, Smallwood and Thelander 2004). In the United States, all raptors are protected under the MBTA and several species are protected by the ESA. Initial observations of dead raptors at the Altamont Pass Wind Resource Areas (APWRA) (Anderson and Estep 1988, Estep 1989, Orloff and Flannery 1992) triggered concern about possible impacts to birds from wind energy development from regulatory agencies, environmental groups, wildlife resource agencies, and wind and electric utility industries. Raptors occur in most areas with potential for wind energy development, but appear to differ in their susceptibility to collisions. Early fatality studies only reported carcasses discovered during planned searches of wind facilities and did not account for potential survey biases described above. Contemporary fatality estimates are based on extrapolation of the number of observed fatalities at surveyed turbines to the entire wind power facility, corrected for searcher efficiency and carcass removal.

Older generation turbines. Earlier studies on fatalities at wind facilities occurred in California because most wind power was produced by three California facilities (APWRA, San Gorgonio, and Tehachapi). APWRA currently has 5,000 to 5,400 turbines of various types and sizes and with an installed capacity of approximately 550 MW (~102 kw/turbine), San Gorgonio consists of approximately 3,000 turbines of various types and sizes with an installed capacity of approximately 615 MW (~205 kw/turbine), and Tehachapi Pass has approximately 3,700 turbines with an installed capacity of approximately 600 MW (~162 kw/turbine). While some replacement of smaller turbines with modern, much larger turbines has occurred (i.e., repowering), all three of these facilities are populated primarily with relatively small "old generation" turbines ranging from 40 to 300 kw, with the most common turbine rated at approximately 100 kw. The best wind sites located within each facility have a relatively high density of turbines. Turbine support structures are both lattice and tubular, all with abundant perching locations on the tower and nacelle. Additionally, all three facilities have above-ground transmission lines. Perching sites for raptors are ubiquitous within all three facilities, but particularly at APWRA. Vegetation communities differ among the sites, with San Gorgonio being the most arid and Tehachapi the most montane.

Widely publicized reports of avian fatalities at Altamont prompted considerable scrutiny of the problem (Orloff and Flannery 1992). Subsequent industry attempts to reduce fatalities at APWRA have not significantly reduced the problem, as suggested by recent results of avian fatality studies conducted by Smallwood and Thelander (2004). Notwithstanding, the turbines studied by Smallwood and Thelander ranged from 40 to 330 kw, and small sample sizes for turbines greater than 150 kw make extrapolation of fatality rates to all turbines in the AWPRA problematic. Nevertheless, Smallwood and Thelander (2004) extrapolated their results to the entire wind resource area and estimated that 881–1,300[1] raptors are killed by collision at APWRA each year. These estimates translate to 1.5–2.2 raptor fatalities/MW/year. Fatality estimates include 75 to 116 golden eagles, 209 to 300 red-tailed hawks *(Buteo jamaicensis)*, 73 to 333 American kestrels *(Falco sparverius)*, and 99 to 380 burrowing owls *(Athene cunicularia)*. The number of burrowing owls was particularly disconcerting given that it is classified as a species of special concern in California. Hunt (2002) completed a four-year telemetry study of golden eagles at APWRA and concluded that while the population is self-sustaining, fatalities resulting from wind power production were of concern because the population apparently depends on immigration of eagles from other subpopulations

[1]adjusted for scavenging and searcher efficiency from data at Oregon/Washington wind projects.

to fill vacant territories. A follow-up survey conducted in 2005, Hunt and Hunt (2006) reported on 58 territories in the APWRA and found that all territories occupied by eagle pairs in 2000 were also occupied in 2005. Early studies conducted at San Gorgonio documented relatively low raptor mortality (McCrary et al. 1983, 1984, 1986). More recent studies at San Gorgonio (Anderson et. al. 2005) and Tehachapi Pass (Anderson et al. 2004) also suggest lower raptor fatalities compared with APWRA. The unadjusted average per turbine and per MW raptor fatality rates, respectively, for these three sites are 0.006 and 0.03 for San Gorgonio, 0.04 and 0.20 for Tehachapi, and 0.1 and 1.23 for APWRA. Differences in fatality appear to be related to density of raptors on these facilities; APWRA has the highest density of raptors, presumably because of abundant prey (particularly small mammals), while San Gorgonio has the fewest raptors and Tehachapi Pass has intermediate densities of raptors (Anderson et al. 2004, 2005).

Newer generation wind facilities. Contemporary wind developments use a much different turbine than older facilities discussed above. In addition, many facilities have been constructed in areas with different land use than existing facilities in California. Results from 14 avian fatality studies, where surveys were conducted using a systematic survey process for a minimum of one year and scavenging and searcher efficiency biases were incorporated into estimates, indicate that combined mean fatality rate for these studies is 0.03 raptors per turbine and 0.04 raptors per MW (See Table 1 on page 47). Regional fatalities per MW were similar, ranging from 0.07 in the Pacific Northwest region to 0.02 in the East (Table 1). With the exception of two eastern facilities in forested habitats (68 MW; 7.5%), landuse/landcover is similar in all regions. Most of these facilities occur in agricultural areas (333 MW; 37%) including agriculture/grassland/Conservation Reserve Program (CRP) lands (438 MW; 48%), and the remainder occur in short grass prairie (68; 7.5%). Landscapes vary from mountains, plateaus, and ridges, to areas of low relief, but aside from size of rotor-swept area, all of these facilities had similar technology, including new generation turbines with lower rotational speeds (~15–27 rpm, but still with tip speeds exceeding 280 km/hr [175 mi/hr]), tubular towers, primarily underground transmission lines, FAA-recommended lighting, and few perching opportunities. Fatality search protocols varied, but all generally followed guidance in Anderson et al. (1999), although standard estimates of raptor use are not available for all 14 studies.

Two factors commonly associated with raptor collision risk are turbine type and bird abundance. Figure 3 illustrates the difference between raptor fatalities at older facilities in California and newer facilities in the United States outside of California. Fatality rates for older turbines are unadjusted for searcher detection and scavenger removal, while rates from the 14 sites with newer generation turbines are adjusted for these biases. Three of the four studies at older generation sites report higher fatality rates than at newer, larger turbine sites, even without bias adjustment. It is noteworthy that even though reported raptor fatalities are higher at older facilities, there is a rather dramatic difference among older facilities. Reported raptor fatalities at APWRA are higher than for Montezuma Hills (Howell 1997); fatalities are somewhat lower at Tehachapi (Anderson et al. 2004) and very few raptor fatalities are reported for San Gorgonio (Anderson et al. 2005). Because the three facilities have similar technology, this difference must be strongly influenced by other factors, most likely raptor abundance. The relationship of abundance and technology will be better addressed when it is possible to study old and new generation turbines in areas of varying raptor density. Three wind facilities in northern California, High Winds and Shiloh in Solano County and APWRA in Alameda County, may present such an opportunity when estimates of fatalities are published. Estimates of raptor use near the Solano County wind facilities are higher than the estimated use at APWRA. These estimates are based on numerous avian use studies conducted in both areas (e.g., Orloff and Flannery 1992, Smallwood and Thelander 2004). The Solano County sites have newer generation turbines and, with the exception of golden eagles, higher raptor use than APWRA.

Other factors such as site characteristics at wind facilities also may be important (Smallwood and Thelander 2004). Additionally, it is also possible that siting of individual turbines may relate to risk of collision and raptor fatalities. Orloff and Flannery (1992) concluded that raptor fatalities at APWRA were higher for turbine strings near canyons and at the end of row turbines. Smallwood and Thelander (2004) also concluded that fatalities were related to turbine site characteristics and position of turbines within a string. The implication of both studies is that turbine siting decisions during construction of a facility are important.

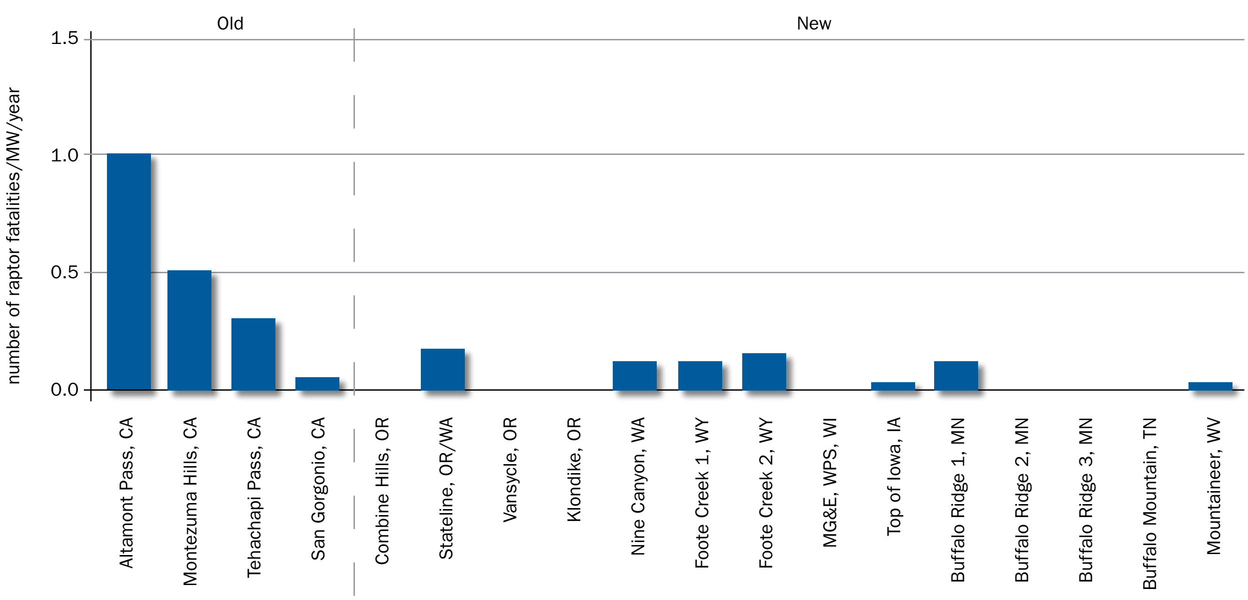
Resident and Migratory Passerines

The available data from wind facilities studied to date suggest that fatality of passerines from turbine blade strikes generally is not numerically significant at the population level (e.g., LGL Ltd. 1995, 1996, 2000; Nelson and Curry 1995; Osborn et al. 2000, Erickson et al. 2001, Strickland et al. 2001), but ill-sited facilities, particularly in areas where migrating birds are concentrated and in areas of abundance for rare species (e.g., listed songbirds, candidate species, and Birds of Conservation Concern), could constitute exceptions.

In a review of avian collisions reported in 31 studies at wind energy facilities, Erickson et al. (2001) reported that 78 percent of carcasses found at facilities outside of California were passerines that are protected under the MBTA. The balance of fatalities was waterfowl (5.3%), waterbirds (3.3%), shorebirds (0.7%), diurnal raptors (2.7%), owls (0.5%), gallinaceous (4.0%), other (2.7%), all protected under the MBTA, and non-protected birds (3.3%). Concerns have been raised by USFWS regarding fatalities at wind facilities of "Birds of Conservation Concern" (BCC) and birds whose populations have been declining based on Breeding Bird Survey (BBS) data. For example, 12 of 33 species reported retrieved were BCC and/or BBS declining from Buffalo Ridge, Minnesota (Johnson et al. 2002), seven of 19 species from northwestern Wisconsin (Howe et al. 2002), nine of 25 species from Mountaineer, West Virginia (Kerns and Kerlinger 2004), and eight of 24 species at Buffalo Mountain, Tennessee (Nicholson 2003).

Estimates of total passerine fatality vary considerably among studies conducted at 14 new generation facilities (see Table 1 on page 47), but fatalities per turbine and per MW are similar for all regions represented by these studies, although the two eastern sites studied suggest that more birds may be killed at wind facilities constructed on forested ridge tops in the East. The number of fatalities reported by in-

Figure 3. Fatality rates for raptors at four older generation turbines unadjusted for searcher efficiency and carcass removal bias (Smallwood and Thelander 2004, Howell 1997, Anderson et al. 2004, Anderson et al. 2005), and fatality rates adjusted for searcher efficiency and carcass removal at 14 wind projects (Erickson et al. 2000, 2003, 2004, Young et al. 2005, Johnson et al. 2003b, Young et al. 2003, Howe et al. 2002, Johnson et al. 2002, Jain 2005, Nicholson 2003, Kerns and Kerlinger 2004) with newer generation turbines.



dividual studies ranged from zero at the Searsburg, Vermont facility (Kerlinger 1997) to 11.7 birds/MW at Buffalo Mountain, Tennessee (Nicholson 2003). Most studies report that passerine fatalities occur throughout the facility, with no particular relationship to site characteristics.

Based on data from the 14 studies, it appears that approximately half the reported fatalities at new generation wind power facilities are nocturnally migrating birds, primarily passerines, and the other half are resident birds in the area. In reviewing the timing of fatalities at eight western and mid-western wind power facilities, it appears that fatalities of passerines occur in all months surveyed (e.g., Erickson et al. 2001, 2003a, 2004, Young et al. 2005, Johnson 2003a, Young et al. 2003, Howe et al. 2002, Johnson et al. 2002, Koford et al. 2004, Nicholson 2003, Kerns and Kerlinger 2004), although fatalities are most common from April through October. The timing of fatalities varies somewhat from site to site. For example, peak passerine fatalities occurred during spring migration at Buffalo Ridge, Minnesota (Johnson et al. 2002), and during fall migration at Stateline in Washington and Oregon (Erickson et al. 2004).

Vulnerability of birds colliding with wind turbines and associated infrastructures has not been thoroughly examined. Most fatalities at wind facilities are assumed to be from collisions with moving wind turbine blades, although there is no specific evidence suggesting that passerines do not occasionally collide with turbine support structures or stationary blades. Perhaps the most difficult task in interpreting breeding passerine fatalities is the estimation of exposure. The most common fatalities reported in western and mid-western wind power facilities are some of the more common species such as horned lark *(Eremophila alpestris)*, vesper sparrow *(Pooecetes gramineus)*, and bobolink *(Dolichonyx oryzivorus)*. These species perform aerial courtship displays that frequently take them high enough to enter the rotor-swept area of a turbine (Kerlinger and Dowdell 2003). In contrast, the western meadowlark *(Sturnella neglecta)*, also a common species, is frequently reported in fatality records, yet is not often seen flying at these altitudes. Also, corvids are a common group of birds observed flying near the rotor-swept area of turbines (e.g., Erickson et al. 2004, Smallwood and Thelander 2004), yet are seldom found during carcass surveys. Clearly, the role of abundance relative to exposure of birds to collisions with wind turbines is modified by behavior within and among species and likely varies across locations.

The estimation of exposure of nocturnal migrating passerines is even more problematic. Bird and bat "targets" identified by most radar systems currently cannot be distinguished, and not all targets are exposed to turbines because nocturnal migrating passerines are known to migrate at relatively high altitudes during favorable weather conditions, except during take-off and landing. Radar studies suggest there is a large amount of night-time variation in flight altitudes (e.g., Cooper et al. 1995), with targets averaging different altitudes among nights and at different times during each night. No doubt, some intra-night variation is due to birds landing and taking off at dawn and dusk, respectively. Kerlinger and Moore (1989) and Bruderer et al. (1995) concluded that atmospheric conditions affect choice of flight direction and flight height by migrating passerines. For example, Gauthreaux (1991) found that birds crossing the Gulf of Mexico appear to fly at altitudes at which favorable winds exist. Inclement weather has been identified as a contributing factor in avian collisions with other obstacles, including power lines, buildings, and communications towers (Estep 1989, Howe et al. 1995, Manville 2005). Johnson et al. (2002) estimated that as many as 51 of 55 collision fatalities discovered at the Buffalo Ridge wind facility may have occurred in association with inclement weather, such as thunderstorms, fog, and gusty winds. There is some concern that nocturnal migrating passerines may be compressed near the surface when cloud ceilings are low or when flying over high mountain ridges, increasing the risk of collisions with turbines. Estimating the effect of weather is problematic because marine radar is ineffective during rain events, but the association of avian fatalities at wind power facilities (e.g., Johnson et. al. 2002) and communications towers (Erickson et al. 2001, Manville 2005) with weather suggests this could be an issue. Recent radar evidence from studies in New York and Pennsylvania also shows that birds may vary their flight heights considerably, depending on weather conditions and landings/take-offs at stopover sites (ABR Inc. 2004).

The effect of topography on bird migration also is somewhat uncertain. It generally is assumed that nocturnal migrating passerines move in broad fronts and rarely respond to topography (Lowery and Newman 1966, Able 1970, Richardson 1972, Williams et al. 1977, Evans et al. 2007). However, Williams et al. (2001) cite work in Europe suggesting migrating birds respond to coastlines, river systems, and mountains (e.g., Eastwood 1967, Bruderer 1978, 1999; Bruderer and Jenni 1988). While bird response to coastlines and major rivers has been noted in North America (e.g., Richardson 1978), evidence is limited on response to major changes in topography (Seilman et al. 1981, McCrary et al. 1983). Mabee et al. (2006) reported that for 952 flight paths of targets approaching a high mountain ridge along the Allegheny Front in West Virginia, the vast majority (90.5%) did not alter their flight direction while crossing the ridge. The remaining targets either shifted their flight direction by at least 10 degrees (8.9%) while crossing the ridge or turned and did not cross the ridge (0.6%), both of which were considered reactions to the ridgeline. This study suggests that only those birds flying at relatively low levels above the ground respond to changes in topography.

Although FAA lighting has been associated with increased avian fatalities at communications towers and other tall structures (Manville 2001, 2005, Erickson et al. 2001, Longcore et al. 2005, Rich and Longcore 2005), there is no evidence suggesting a lighting effect for wind power-associated passerine fatalities (Erickson et al. 2001b, P. Kerlinger, Curry and Kerlinger LLC, unpublished data). While steady-burning, red incandescent L-810 lights appear to be the major bird attractant to communications towers (Gehring et al. 2006), lighting at wind turbines tends to be red strobe or red-blinking/pulsating incandescent lighting (USFWS 2007). At the Mountaineer facility in West Virginia, Kerns and Kerlinger (2004) reported the largest avian fatality event at a wind facility, when 33 passerines were discovered on May 23, 2002. These fatalities apparently occurred just prior to the survey during heavy fog conditions; all carcasses were located at a substation and three adjacent turbines. The substation was brightly lit with sodium vapor lights. Following the discovery of these fatalities, the bright lights were turned off and no further major mortality events were documented during surveys at this site through fall 2003 (Kern and Kerlinger 2004) or during six weeks in the summer and fall of 2004 (Kerns et al. 2005).

Wind facilities located on forest ridges in the eastern U.S. have the highest documented bat and passerine fatalities. (Credit: Merlin D. Tuttle, Bat Conservation International)

Other Avian Species

Fatality studies almost universally report very few fatalities of waterfowl, shorebirds, or gallinaceous birds, as previously noted by Erickson et al. (2001). Kerlinger (2002) speculated that the upland sandpiper *(Bartramia longicauda)* might be at low to moderate risk of colliding with turbines, because of its aerial courtship flight. It has been documented that grouse are susceptible to powerlines and other structures. Borell (1939) reported greater sage-grouse *(Centrocercus urophasianus)* mortalities from powerlines, and 4 percent to 14 percent of greater prairie-chicken *(Tympanuchus cupido)* deaths in Wisconsin resulted from powerline strikes (Toepfer 2003). Wolfe et al. (2003) found that collisions with structures, fences, and vehicles by radio-collared lesser prairie-chickens *(Tympanuchus pallidicinctus)* accounted for 42 percent of the total mortalities, from a total of 122 recovered carcasses. They speculated that collision deaths could be additive to other mortality factors. In a review of five wind facilities, Fernley and Lowther (2006) reported that 1) collision of medium to large species of geese with wind turbines is an extremely rare event (unadjusted rates of 0–4/year for the 5 sites reviewed), 2) there appears to be no relationship between observed collision fatality and number of goose flights per year, and 3) geese appear to be adept at avoiding wind turbines.

Bats

Recent surveys have reported large numbers of bat fatalities at some wind energy facilities, especially in the eastern United States (e.g., Fiedler 2004, Kerns and Kerlinger 2004, Arnett 2005) and, more recently, in Canada (Brown and Hamilton 2006b) and New York (Jain et al. 2007). Relatively large numbers of bat fatalities at wind facilities also have been reported in Europe (Ahlen 2003, Dürr and Bach 2004, Brinkmann 2006). Although bats collide with other tall anthropogenic structures, the frequency and number of fatalities reported in the literature (e.g., Avery and Clement 1972, Crawford and Baker 1981, Mumford and Whitaker 1982) are much lower than those for birds or for bat fatalities observed at wind turbines.

Migratory, tree-roosting species like the hoary bat (Lasiurus cinereus) are most frequently found killed at wind facilities in North America (Credit: Ed Arnett, Bat Conservation International)

Several plausible hypotheses relating to possible sources of attraction, density and distribution of prey, and sensory failure (i.e., echolocation), for example, have been proposed to explain why bats are killed by wind turbines (Arnett 2005, Kunz et al. 2007a).

Estimates of bat fatality from 21 studies located at 19 different facilities from five different regions in the United States and one province in Canada ranged from 0.9–53.3 bats/MW (See table 2 on page 48); Arnett et al. 2008). These estimates vary due in part to region of study, habitat conditions, sampling interval, and bias corrections used to adjust estimates. Currently, forested ridges in the eastern United States have the documented highest fatalities of bats reported in North America and are higher than estimates of bat fatality reported from European studies (Dürr and Bach 2004, Brinkmann 2006).

Johnson (2005) and Arnett et al. (2008) recently synthesized existing information on bat fatalities at wind facilities; here, we summarize key patterns they identified. Bat fatality appears to be higher during late summer and early fall when bats typically begin autumn migration (Griffin 1970, Cryan 2003, Fleming and Eby 2003). Johnson (2005) reported that approximately 90 percent of 1,628 documented bat fatalities, when the approximate date of the collision was reported, occurred from mid-July through the end of September, with over 50 percent occurring in August. Collision fatality appears to be low during spring migration, but few studies have been conducted during this time period. Migratory tree bats may follow different migration routes in the spring and fall (Cryan 2003), and behavioral differences between migrating bats in the spring and fall also may be related to mortality patterns (Johnson 2005). Rarely have studies been conducted simultaneously at multiple sites within a region to evaluate seasonal patterns between sites. In 2004, Kerns et al. (2005) conducted daily fatality searches at the Mountaineer and Meyersdale Wind Energy Centers in West Virginia and Pennsylvania, respectively, and found that the timing of bat fatalities over a six-week period at the two sites was highly correlated (r = 0.8). Although Kerns at al. (2005) found more male than female fatalities, the timing of fatality by sex was similar at both sites, as well. Additionally, timing of fatalities of hoary *(Lasiurus cinereus)* and eastern red bats *(Lasiurus borealis)* was positively correlated between the Meyersdale and Mountaineer sites. These findings suggest broader landscape, perhaps regional, patterns of activity and migratory movement that could be influenced by weather and prey abundance and availability.

Eleven of the 45 species of bats that occur in North America north of Mexico have been among fatalities reported at wind facilities (Johnson 2005). Ten species of bats have been reported killed by turbines in Europe (Dürr and Bach 2004). In most regional and individual studies, bat fatalities appear heavily skewed to migratory foliage roosting species that include the hoary bat, eastern red bats, and migratory tree-roosting silver-haired bats (*Lasionycteris noctivagans*; Johnson 2005, Kunz et al. 2007, Arnett et al. 2007). In Europe, migratory species also dominate fatalities (Dürr and Bach 2004). Fatalities of eastern pipistrelles *(Pipistrellus subflavus)* have been reported as high as 25.4 percent of total fatalities at facilities in the eastern United States (Kerns et al. 2005). No studies have been reported from wooded ridges in the western United States and few from the southwest (e.g., New Mexico, Texas), where different species of bats may be more susceptible in some areas (e.g., Brazilian free-tailed bats [*Tadarida brasiliensis*]). Interestingly, the only two investigations at wind facilities within the range of the Brazilian free-tailed bat report high proportions of fatalities of that species (31.4 and 85.6% in California [Kerlinger et al. 2006] and Oklahoma [Piorkowski 2006], respectively). To date, no fatalities of a threatened or endangered species of bat (e.g., Indiana bat [*Myotis sodalis*]) have been found at existing wind facilities, but continued development of wind facilities may pose risk to these species at other locations in the future.

Spatial patterns of bat fatality and relationships between weather and turbine variables are poorly understood. Fatalities appear to be distributed across most or all turbines at wind facilities, with no discernable pattern of collisions reported to date. Bats do not appear to strike the turbine mast, non-moving blades, or meteorological towers (Arnett 2005). Horn et al. (2008) observed bats through thermal imaging cameras attempting to and actually landing on stationary blades and investigating turbine masts. They also reported that seven out of eight observed collisions were between bats and turbine blades spinning at their maximum rotational speed of 17 rpm. Activity and fatality of bats, as with birds, do not appear to be influenced by FAA lighting (Arnett 2005, Arnett et al. 2008).

Bat activity and fatality appear to be higher on nights with relatively low wind speed. Kerns et al. (2005) reported that the majority of bats were killed on low wind nights when power production appeared insubstantial (low percentage of total possible capacity generation), but turbine blades were still moving, often times at or close to full operational speed (17 rpm). The proportion of 10 min intervals from 2000–0600 hr when wind speed was <4 m/sec was positively related to bat fatalities ($r = 0.561$, $p < 0.001$ at Mountaineer; $r = 0.624$, $p < 0.001$ at Meyersdale), whereas the reverse was true for proportion of the night when winds were >6 m/sec ($r = -0.634$, $p < 0.001$ at Mountaineer; $r = -0.66$, $p < 0.001$ at Meyersdale). Horn et al. (2008) found a negative relationship between the number of bat passes observed from infrared thermal images and average nightly wind speed at the Mountaineer facility, corroborating the finding of higher bat fatalities on low wind nights at this facility. In Germany, Brinkmann (2006) observed higher activity of bats via thermal imaging when wind speeds were between 3.5 and 7.5 m/s, but also observed some activity up to 10.9 m/s. At Buffalo Mountain, Tennessee, Fiedler (2004) found a negative relationship between bat fatality and wind speed and temperature and a positive relationship with wind direction. The positive relationship with wind direction indicated that the farther nightly wind direction was from the Southwest (the prevailing wind direction), the more likely a fatality event was to occur, perhaps due to more northerly winds associated with storm fronts and/or conditions that are conducive for bat migration (Fiedler 2004). Fiedler (2004) also suggested that the presence of more northerly winds during nights with fatality may be related to weather conditions conducive for bat migration, and that negative associations with the other three variables imply that fatality occurrence was more likely during cooler nights with calmer, less variable winds. Acoustic monitoring of bats at proposed wind facilities corroborates these findings and indicates that bat activity generally is higher on low wind nights (Reynolds 2006; Arnett et al. 2006). Studies in Europe also corroborate these findings (Brinkman 2006). These observed patterns offer promise toward predicting periods of high fatality and warrant further investigation at wind facilities worldwide to assess whether these findings represent predictable, annual patterns.

WILDLIFE HABITAT IMPACTS AND DISTURBANCE AT WIND FACILITIES

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. Wildlife habitat impacts can be considered direct (e.g., vegetation removal and/or modification and physical landscape alteration, direct habitat loss) or indirect (e.g., behavioral response to wind facilities, hereinafter referred to as displacement or attraction). Impacts may be short-term (e.g., during construction and continuing through the period required for habitat restoration) and long-term (e.g., surface disturbance and chronic displacement effects for the life of the project). Duration of habitat impacts vary depending on the species of interest, the area impacted by the wind facility (including number of turbines), turbine size, vegetation and topography of the site, and climatic conditions in a particular region, which influences vegetation. Road construction, turbine pad construction, construction staging areas, installation of electrical substations, housing for control facilities, and transmission lines connecting the wind facility to the power grid also are potential sources of negative habitat impacts. Presence of wind turbines can alter the landscape so as to change habitat use patterns of wildlife, thereby displacing wildlife from areas near turbines. It is possible that audible noise from wind turbines can impact wildlife, but these effects are largely unknown.

Below, we synthesize what is known about habitat impacts from the few studies that have been conducted, draw inference from a broader literature on habitat impacts, and hypothesize potential impacts of wind turbines on wildlife.

Habitat Loss and Fragmentation

Wind facilities can cover relatively large areas (e.g., several square kilometers), but have relatively low direct impact to the project area. The BLM Programmatic Environmental Impact Statement (BLM 2005) estimated 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. Information on actual habitat loss was estimated from a review of permitting documents for 17 existing facilities or those under construction. The facilities ranged in size from 34 turbines (50 MW) at the proposed Chautauqua, New York, facility to the San Gorgonio, California, wind facility including more than 4,000 turbines of a variety of sizes. The total area of estimated impact ranged from 434 ha at the Foote Creek, Wyoming, wind plant to only 6.5 ha for the 16 turbine Buffalo Mountain, Tennessee, wind facility. In general, direct loss of habitat is relatively small, with the maximum surface disturbance of approximately 1.2 ha/turbine during construction (BLM 2005). However, a careful examination of the estimated direct impacts for the 17 facilities gave unrealistic, underestimated ranges of per turbine estimates of impact. For example, per turbine estimates of the size of permanent footprints for 1.5 MW turbines ranges from 1.4 ha for the proposed 34-turbine Chautauqua facility to 0.4 ha/turbine for the 120-turbine Desert Claim project in Kittitas County, Washington. While there appears to be some economy of scale for site impacts, the largest variable in all projects was length of new road construction.

Short-term construction surface disturbance has been estimated to be as much as three times the long-term surface disturbance, although short-term impacts for 17 permitting documents reviewed suggest that approximately 1.6 times the number of hectares of the permanent project footprint were affected. Construction impacts primarily result from wide construction rights of way to accommodate large cranes and, in mountainous terrain, the wide turning radius required to accommodate trucks hauling turbine blades in excess of 40 m. In addition, construction staging and equipment storage areas may be temporary disturbances. The length of time required to reclaim a site will vary depending on climate, vegetation, and reclamation objective. For example, if the objective is to return the site to pre-disturbance condition, reclamation may be relatively rapid in grassland, on the order of 2 to 3 years, versus de-

The presence of wind turbines can alter the landscape and may change habitat use patterns, thereby displacing some species of wildlife from areas near turbines. (Credit: Ed Arnett, Bat Conservation International)

Wind facilities located in habitats modified by agriculture will have fewer habitat impacts relative to those developed in undisturbed habitats. (Credit: Ed Arnett, Bat Conservation International).

Aerial perspective of structural habitat fragmentation due to oil, gas, and wind energy development within sand sagebrush (Artemesia filifolia) rangelands, Oklahoma. (Credit: D. Wolfe, G. M. Sutton Avian Research Center).

cades in desert environments.

Ultimately, 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.

Habitat-Related Impacts on Birds

Grassland birds. Much attention regarding wind energy development and habitat fragmentation has focused on grassland birds for a number of reasons. First, North America's interior grassland habitats (tall, mixed, short, and sage) have steadily become more fragmented by a variety of human-induced influences (Samson and Knopf 1994, Knopf and Samson 1997). In many areas already fragmented by agriculture, the uncultivated grassland that remains exists on hilltops and in other locations that are difficult to plow but also have the greatest wind energy production potential (perhaps as much as 90 percent of the United States wind power potential [Weinberg and Williams 1990]). Second, among all bird groups, grassland birds have suffered population declines more consistently than any other suite of species, including Neotropical migrants (Droege and Sauer 1994), owing in part to the aforementioned habitat loss and fragmentation. Finally, of the three ecosystem types in the United States with greatest wind resources (Great Lakes, mountains, and grassland; Elliott et al. 1986), grassland habitats have the fewest logistical impediments to construction when transmission is available and currently have extensive wind energy development ongoing or planned (Weinberg and Williams 1990).

Relatively little work has been done to determine the effect of wind facilities on use of grasslands by birds. Here, we focus primarily on breeding birds, but recognize that it is likely that migrating and wintering birds may avoid wind facilities (Exo et al. 2003), although habitat for those activities is not suspected to be limiting or to influence population dynamics of grassland birds. In addition to the findings from studies of wind energy developments, we draw inferences from the larger body of literature on habitat fragmentation, which for grassland birds has grown considerably in the past decade (Johnson 2001).

Leddy et al. (1999) found that total breeding bird densities were lower in Conservation Reserve Program (CRP) fields with turbines compared with those without turbines in southwestern Minnesota. Moreover, densities of birds along transects increased with distance from turbines. While the extent of influence of turbines was uncertain, densities of birds were markedly lower within 80 m of the turbine string (Table 3; Leddy et al. 1999). Reduced avian use near turbines was attributed to avoidance of turbine noise and maintenance activities and reduced habitat effectiveness because of the presence of access roads and large gravel pads surrounding turbines (Leddy 1996; Johnson et al. 2000a). Other studies (e.g., Johnson et al. 2000b, Erickson et al. 2004) suggest that the area of influence of wind turbines is fairly small and that grassland birds occur in lower densities only within 100 m of a turbine. However, at a large wind facility at Buffalo Ridge, Minnesota, abundance of shorebirds, waterfowl, gallinaceous birds, woodpeckers, and several groups of passerines was significantly lower at survey plots with turbines compared with those without turbines (Johnson et al. 2000b). There were fewer differences in avian use as a function of distance from turbines, however, suggesting that the area of reduced use was limited primarily to those areas within 100 m of turbines (Johnson et al. 2000b). Some proportion of these displacement effects likely resulted from direct loss of habitat near the turbine from concrete pads and associated roads. These results are similar to those of Osborn et al. (2000), who reported that birds at Buffalo Ridge avoided flying in areas with turbines. Preliminary results from the Stateline (Oregon-Washington) wind facility suggest a fairly small-scale impact of the wind facility on grassland nesting passerines, with a large part of the impact related to direct loss of habitat from turbine pads and roads, and temporary disturbance of habitat between turbines and road shoulders (Erickson et al. 2004). Horned larks appeared least affected, with some suggestion of displacement for grasshopper sparrows *(Ammodramus savannarum),* although sample sizes were limited.

Research on habitat fragmentation has demonstrated that several species of grassland birds are area-sensitive, prefer larger patches of grassland, and tend to avoid trees. Area-sensitivity in grassland birds was reviewed by Johnson (2001); 13 species have been reported to favor larger patches of grassland in one or more studies. Other studies have reported an avoidance of trees by certain grassland bird species. Many of the studies refer to an avoidance of "edge," but edges in most studies consisted of woody vegetation. Seven grassland bird species have been shown to be edge-averse (Johnson 2001). Based on the available information, it is probable that some disturbance or displacement effects may occur to the grassland/shrub-steppe avian species occupying a site. The extent of these effects and their significance is unknown and hard to predict but could range from zero to several hundred meters.

Raptors. Development of wind turbines near raptor nests may result in indirect and direct impacts; however, the only report of avoidance of wind facilities by raptors occurred at Buffalo Ridge, where raptor nest density on 261 km^2 of land surrounding a wind facility was 5.94/100 km^2, yet no nests were present in the 32 km^2 wind facility itself, even though habitat was similar (Usgaard et al. 1997). Similar numbers of raptor nests were found before and after construction of Phase 1 of the Montezuma Hills, California, wind plant (Howell and Noone 1992). A pair of golden eagles *(Aquila chrysaetos)* successfully nested 0.8 km from the Foote Creek Rim, Wyoming, wind facility for three different years after it became operational (Johnson et al. 2000b), and a Swainson's hawk *(Buteo swainsoni)* nested within 0.8 km of a small wind plant in Oregon (Johnson et al. 2003a). In a survey to evaluate changes in nesting territory occupancy, Hunt and Hunt (2006) found that all 58 territories occupied by eagle pairs at APWRA in 2000 also were occupied in 2005.

Prairie grouse. Prairie grouse, which exhibit high site fidelity and require extensive grasslands, sagebrush, and open horizons (Giesen 1998, Fuhlendorf et al. 2002), may be especially vulnerable to wind energy development. Serious population declines and the fact that prairie grouse distributions intersect with some of the continent's most prime wind generation regions (Weinberg and Williams 1990) compound the concern. Leks, the traditional courtship display grounds of greater sage-grouse, Gunnison's sage-grouse *(Centrocercus minimus)*, sharp-tailed grouse *(Tympanuchus phasianellus)*, lesser prairie-chicken, and greater prairie-chicken, are consistently located on elevated or flat grassland sites with few vertical obstructions (Flock 2002). Several studies indicate that prairie grouse strongly avoid certain anthropogenic features (e.g., roads, buildings, powerlines), resulting in sizable areas of habitat rendered less suitable (Braun et al. 2002, Robel et al. 2004, Pitman et al. 2005). Robel et al. (2004) observed mean avoidance buffers (mean distances based on 90% avoidance by 187 nesting hens) of 397 m (se = 70) from transmission lines, 93 m (se = 25) from oil or gas wellheads, 1,371 m (se = 65) from buildings, 336 m (se = 51) from center pivot irrigation fields, and 859 m (se = 44) from either side of improved roads (32 m (se = 15) from unimproved roads). Robel (2002) predicted that utility-scale (1.5 MW) wind turbines would create an approximate 1,600 m radius avoidance zone for greater prairie-chicken nesting and brood-rearing activities. Based on this estimate, they projected that a proposed 100 MW wind facility in the Flint Hills, Kansas, would render 6,070–7,280 ha of very good to excellent tallgrass prairie habitat unsuitable for nesting and brood-rearing purposes; the actual size of this proposed project was roughly half this area.

The widespread expansion of wind energy development, as is proposed in many ecologically intact areas of the Great Plains, could threaten already sensitive and declining species. The lesser prairie-chicken may best illustrate this onerous potential. The remaining habitat of this species overlaps almost entirely with areas identified as prime for wind generation in Oklahoma. If wind energy development expands into unbroken native and restored grasslands of the five states the species inhabits, increased negative impacts could be expected. 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; Woodward et al. 2001, Fuhlendorf et al. 2002). Patten et al. (2005) suggested that landscape fragmentation would result in an expansion of home range size for greater prairie-chickens, likely resulting in decreased survivorship due to predation, collisions, and increased energy expenditures.

Other avian species. Estimated size of the mountain plover *(Charadrius montanus)*[2] population at the Foote Creek Rim wind facility declined from 1995 to 1999 during the wind facility construction period (1998 to 2000). It is not known if plovers were simply displaced from the rim because of construction activity or if the population declined, but declines recorded at a reference area and in other regional populations (southeast Wyoming – northeast Colorado) suggest a larger species-wide or regional phenomena coincidental to observations at Foote Creek Rim. In Europe, some species appear unaffected by the presence of wind turbines (Winkelman 1990), while certain waterfowl, shorebird, and songbird species are known to avoid turbines (e.g., European golden plovers [*Pluvialis apricaria*] and northern lapwings [*Vanellus vanellus*; Pederson and Poulsen 1991], Eurasian curlews [*Numenius arquata*; Winkelman 1990]). Spaans et al. (1998) suggested variable levels of disturbance for feeding and roosting birds and concluded that with the exception of lapwings, black-tailed godwits *(Limosa limosa)*, and redshanks *(Tringa tetanus)*, many species used areas for breeding that were close (within 100 m) to the wind facilities. Displacement effects of up to 600 m from wind turbines (reduced densities) have been recorded for some waterfowl species (e.g., pink-footed goose [*Anser brachyrhunchus*]; and European white-fronted goose [*Anser albifrons albifrons*]; Spaans et al. 1998). Larsen and Madsen (2000) found that avoidance distance of pink-footed geese from wind farms with turbines in lines and in clusters were estimated to be 100 m and 200 m, respectively. Low estimated waterfowl mortality at these sites 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. In Iowa, primary foraging habitat for geese (corn fields) is very common surrounding wind facilities, and no large-scale displacement of Canada geese *(Branta canadensis)* was apparent based on counts and behavior observations of geese in areas with and without turbines (Koford and Jain 2004).

David Young (Western Ecosystems Technology) studied mountain plovers at the Foote Creek Rim wind facility from 1995–1999. Declines of this species were reported at the wind facility, a reference area, and for other regional populations in southeast Wyoming and northeast Colorado, suggesting broader species-wide or regional phenomena coincidental to observations at Foote Creek Rim. (Credit: Fritz Knopf)

[2]The U.S. Fish and Wildlife Service proposed listing mountain plover as a threatened species under the Endangered Species Act in February 1999 (USFWS 1999). Prior to this time, mountain plover had been included on the USFWS list of candidate species. In 2003, the USFWS found that listing mountain plover as threatened was not warranted and withdrew the proposed rule, stating that the threats to the species as identified are not as significant as earlier believed, and the plover is now not designated as a candidate species.

Habitat-Related Impacts on Bats

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. Studies also have suggested that many species use linear landscape elements, such as those created by roads built through forest, for successful foraging or commuting (Grindal 1996, Russo et al. 2002, Patriquin and Barclay 2003), echo-orientation (Verboom et al. 1999) and protection from predators or wind (Verboom and Huitema 1997). Forest edge effects created by clearing also may be favorable to insect congregations and a bat's ability to capture them in flight (Verboom and Spoelstra 1999). Both local populations of bats as well as migrants making stopovers may be similarly attracted to these areas. However, the removal of roost trees would be detrimental to bats. Disturbance to tree- and crevice-roosting bats from wind turbines is completely unknown. It is not likely that noise generated by turbines influences roosting bats, but no empirical data exist to support or refute this contention. Increased human activity at wind facilities could disturb roosting bats, but, again, no data exist.

Habitat-Related Impacts on Large Mammals

Direct evidence of impacts on large mammals generally is lacking, and inferences are indirect based on disturbance from other anthropogenic sources. At western wind facilities located in native range, the species of concern are usually elk *(Cervus elaphis)*, mule deer *(Odocoileus hemionus)*, and pronghorn *(Antelocapra americanus)*. In the Midwest and eastern United States and Canada, white-tailed deer *(Odocoileus virginianus)* and black bear *(Ursus americanus)* may be impacted by development of wind energy. Deficiencies in quality and/or quantity of habitat can lead to population declines. During the 9- to 12-month period of construction at a wind facility, it is expected that large mammals will be temporarily displaced from the site due to the influx of humans and heavy construction equipment and associated disturbance (e.g., blasting). Construction is rarely performed during winter, thus minimizing construction disturbance to wintering ungulates. Following completion of a project, disturbance levels from construction equipment and humans diminish, and the primary disturbances will be associated with operations and maintenance personnel, occasional vehicular traffic, and presence of turbines and other facilities.

Direct loss of habitat for large mammals resulting from wind development has been documented in several states, although these losses generally encompassed habitat in adequate supply and, to date, have not been considered important. The impacts of habitat loss and fragmentation are greatest when habitat is in short supply. Roads associated with energy development also may fragment otherwise continuous patches of suitable habitat, effectively decreasing the amount of winter range, for example, available for ungulates. Fragmentation of habitat also may limit the ability of ungulate populations to move throughout winter range as conditions change, causing animals to utilize less suitable habitat (Brown 1992). At the Foote Creek Rim facility in Wyoming, pronghorn observed during raptor use surveys were recorded year-round before and after construction (Johnson et. al. 2000) and results indicated no reduction in use of the immediate area. A recent study regarding interactions of a transplanted elk population with an operating wind facility found no evidence that turbines had significant impact on elk use of the surrounding area (Walter et al. 2004). There is concern that development of wind power in the northeastern United States on forested ridge tops, in stands of mast-producing hardwoods, and in wetlands will have a negative impact on black bears. In the state's wind policy, the Vermont wildlife agency expresses this concern, but notes that negative impacts have not yet been documented. Perhaps the greatest potential for impact is disturbance of denning black bears. In a review of the literature on den site selection, Linnell et al. (2000) found that black bears generally select dens 1–2 km from human activity (roads, habitation, industrial activity) and seemed to tolerate most activities that occurred >1 km from the den. Activity <1 km and especially within 200 m caused variable responses, including den abandonment. While the loss of a single den site may not lead to deleterious effects, den abandonment can lead to increased cub mortality (Linnell et al. 2000).

While the footprint of wind facilities is relatively small, if the facilities are placed in critical habitat areas, the direct loss of habitat would be a negative for large mammals. Additionally, studies on the impacts of oil and gas developments on ungulates suggest shifts in use, avoidance of roads, and potential declines in reproduction and abundance (Van Dyke and Klein 1996, Sawyer et al. 2006). Studies of mule deer and elk in Oregon suggest that habitat selection and movements may be altered by roads, primarily because of the associated human activities (Johnson et al. 2000, Wisdom et al. 2004). Large mammals may avoid wind facilities to some extent, depending on the level of human activity. These impacts could be negative and perhaps biologically significant if facilities are placed in the wrong locations, particularly if the affected area is considered a critical resource whose loss would limit the populations.

Habitat-Related Impacts on Other Wildlife

Virtually nothing is known about habitat-related impacts on other species of wildlife, including reptiles, amphibians, forest carnivores, and small mammals. In a study addressing the influence of audible noise from turbines on predator strategies employed by California ground squirrels *(Spermophilus beecheyi)* at Altamont Pass, Rabin et al. (2006) reported that this species may be able to cope with noise from wind turbines through behavioral modifications in a predatory context. While inferences about potential habitat impacts from wind facilities on other wildlife could be drawn from data on other sources of disturbance, more studies would be useful for understanding and mitigating these potential impacts for other species.

OFFSHORE WILDLIFE—WIND ISSUES

Interest is high in establishing wind-generating facilities along portions of the Atlantic Coast, Lower Gulf Coast (LGC) of Texas, and the Great Lakes. Terrain offshore (coastal shelf) in these areas is shallow for a relatively long distance from shore, which permits placement of towers into the bottom substrate with existing technology. The first major wind-energy development proposed for the Atlantic Coast is located in Nantucket Sound, Massachusetts (Cape Wind Project). This project met with opposition from several groups, including those concerned with potential impacts to local fauna and the lack of studies on the movements of birds through the project area. In 2005, the State of Texas began steps for permitting the first commercial offshore wind-energy development, planned for a location off Galveston Island.

Although studies seem to indicate that wind facilities in some locations of the United States have a minor impact on birds compared to other sources of collision mortality, one cannot assume that similar impacts would occur among birds using wind-generating sites established offshore. As with land-based wind development, offshore development must also address cumulative impacts to birds, bats, and marine resources.

Offshore Bird Movements and Behavior

Three migratory bird corridors converge immediately north of Corpus Christi, Texas, effectively funneling tens of millions of birds along the LGC to wintering grounds in south Texas and Latin America. Over 200 species of birds migrate along the LGC in Texas annually and several federally threatened or endangered species are included among these. The largest numbers of migrating birds cross the Gulf of Mexico from the northern Texas coast, eastward to the Florida panhandle (Figure 4). Crossing the Gulf represents the shortest route to extreme southeast Mexico for some migrants, while birds migrating along the LGC tend to follow the coastline because of its primary north-south orientation, rendering crossing the Gulf relatively less important (Figure 4, route 5; Lincoln et al. 1998).

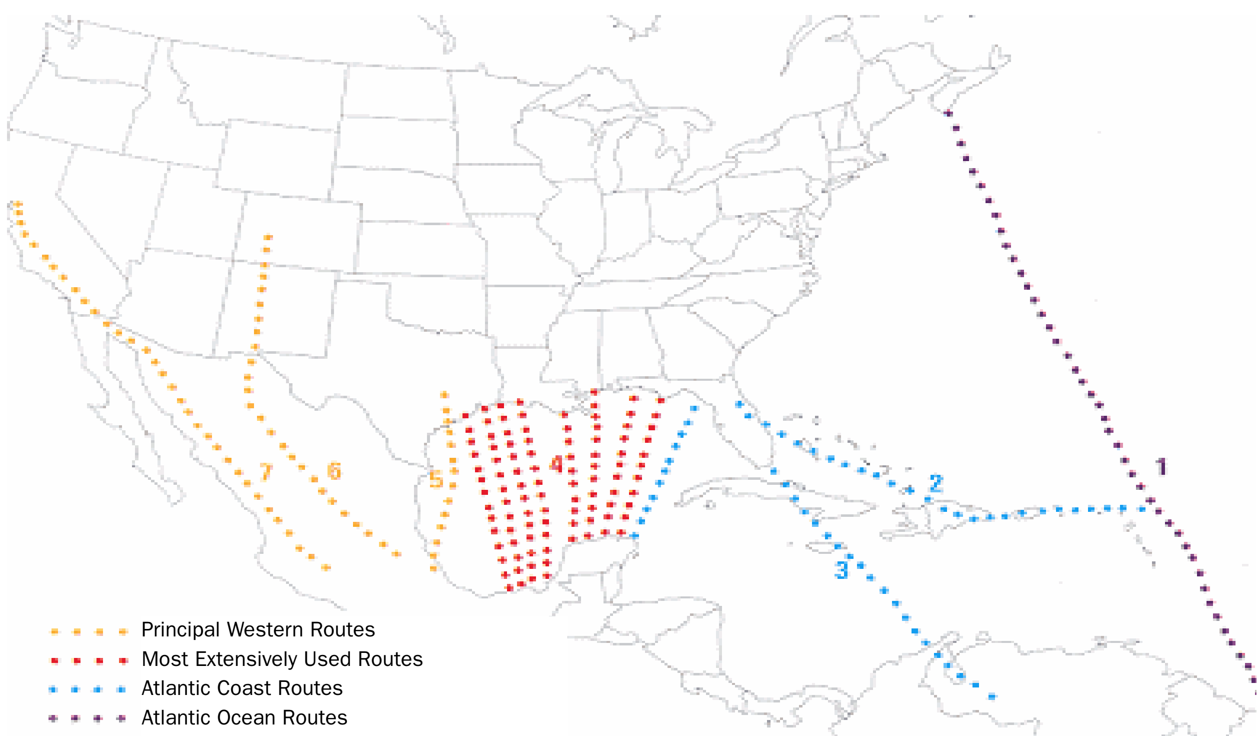
One of the most important components of avian migration strategies is their use of local habitats for resting and refueling while en route. In light of the absence of natural islands or other terrestrial habitats in the Gulf of Mexico, it seems inevitable that the installation of thousands of artificial islands in the northern Gulf must affect migrants in some fashion. However, few systematic studies have examined the influence of Gulf oil platforms on trans-Gulf migrating birds. From 1998–2000, Russell (2005) studied the ecology of trans-Gulf migration and the influence of platforms and showed that most spring trans-Gulf migration detected by radar occurred between 25 March and 24 May, but very large flights (>25 million migrants) occurred only in the three-week period from 22 April to 13 May. Waterfowl and herons peaked by early

April and shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April. Theoretical analyses of radar data yielded total seasonal estimates of 316 million trans-Gulf migrants in spring 1998 and 147 million trans-Gulf migrants in spring 1999. Radar-observed spring migration was characterized by a series of pulses and tended to be "all-or-nothing"; that is, either significant trans-Gulf migration was evident on radar or else it was essentially entirely absent. Dramatic hiatuses in radar-observed migration were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf (Russell 2005). Studies such as that of Russell (2005) indicate that potential exists for interactions between a substantial number of migrant birds and offshore and near-shore wind turbines.

Although Neotropical migrant birds do pass offshore along the Atlantic Coast (Figure 4), the magnitude of migration is small relative to that along the Gulf Coast. Concern along the Atlantic Coast is focused more on potential impacts to waterbirds such as gulls, terns, waterfowl, and other species that make regular movements in near-shore areas. There are many "Important Bird Areas," locations that harbor a high number of birds or species of special concern (e.g., Federally designated Birds of Conservation Concern and Federally listed threatened or endangered birds), along the eastern seaboard. Although areas where birds migrate through or concentrate seasonal activities are generally known, the specific timing, routes, and altitudes of movement within and between resting and foraging areas and altitudes that migrants use are poorly known, and such information is needed to conduct assessments of the potential risk of to birds from offshore wind developments.

Consequently, impacts of a wind-generating facility located on the LGC and Atlantic Coast could be different from each other and also different than those located at other sites throughout the United States simply because the behavior, abundance and diversity of birds that migrate or reside on any wind-generating facility site may be much different than at inland facilities. Russell (2005) found that migrants would sometimes arrive at certain oil platforms

Figure 4. Primary migratory routes of birds (from Lincoln et al. 1998).



shortly after nightfall and proceed to circle those platforms for variable periods ranging from minutes to hours. The numbers of birds involved varied from a single individual to many hundreds of migrants and, while a wide variety of species was recorded in circulations, herons, shorebirds, swallows, and warblers were most common. This behavior, if repeated around offshore wind turbines, could raise the risk of collision with the tower or the blade. Russell (2005) concluded that this circling behavior was related to attraction of the birds to platform lights. Many offshore developments have proposed turbine-tower combinations that are near or exceed 160 m in total height, making them highly visible from several km away. In some locations, aircraft warning lights may be required by the FAA, which adds another dimension to visual considerations.

Offshore Impacts on Habitat and Animal Movements

Offshore wind facilities have been established throughout Europe, but few studies have been conducted to determine impact on animals. Most of these developments are small relative to onshore developments (although larger projects are being planned). Some disruption in bird flight patterns has been noted in Europe, although additional study is needed. However, there does not appear to be disruption in fish movements or populations (Morrison 2006). The effects on marine mammals warrant study and clarification, especially since most great whales are federally listed. A major concern with offshore developments relates to impacts on animal behavior and movement from boat and helicopter traffic to and from the wind development that could extend far outside the boundaries of the turbines.

European Studies

More than 280 studies have been conducted relating environmental and human effects from offshore wind installations in Europe. There have been, however, concerns about the adequacy of these studies because most projects had few turbines (less than 10), did not employ rigorous study design, and were not peer-reviewed. To address uncertainty from past studies, two major projects were developed: Concerted Action for the Offshore Wind Energy in Europe (CA-OWEE) and Concerted Action for the Deployment of Offshore Wind (COD). In 2005, COD compiled available studies in a searchable electronic database and summarized its findings in a final report: "The COD work on the establishment of an environmental body of experience has brought an important overview of the present state of knowledge in this up-to-now unknown field" (COD 2005, 2).[3] Two Greenpeace International reports summarized environmental impact assessment studies in Europe prepared by Deutsches Windenergie Institute (2000) and Deutsche WindGuard GmbH (2005), respectively.[4]

These reports suggest that major risks from offshore wind turbines to sea birds and resting birds are:

- Permanent loss of habitat due to displacement;
- Collisions with the turbines; and
- Barrier effects, including fragmentation of the ecological habitat network (e.g., breeding or feeding areas).

Of these, collisions and disturbance were considered primary impacts on sea birds and resting birds, although these groups may be at less risk than migrating birds, as they may adapt better to offshore wind facilities (COD 2005). Large offshore wind facilities may diminish foraging and resting conditions and so assessment of cumulative effects is needed. Thus far, risks of habitat loss and barrier effects for birds have not been quantitatively estimated. Avoidance behavior of birds is significant in evaluating these risks; species-specific avoidance behavior and overall availability of suitable areas are important considerations when evaluating impacts.

Collisions of birds with wind turbines at offshore wind facilities, in most cases, are only a minor problem (but with exceptions in some poorly sited land-based facilities [Greenpeace International 2000, section 5.3.3]). Quantitative risk estimates for collision risks are difficult to obtain due to the fact that impacts are highly site-dependent, inadequate data exist on bird migration routes and flight behavior

[3]See the CA-OWEE and COD reports and database at www.offshorewindenergy.org. See the summary in "COD, Principal Findings 2003-2005," prepared by SenterNovem in the Netherlands, as part of a series highlighting the potential for innovative non-nuclear energy technologies.

[4]See "Offshore Wind: Implementing a New Powerhouse for Europe; Grid Connection, Environmental Impact, Assessment, Political Framework," 4 April 2005, WindGuard GmbH, commissioned by Greenpeace, at http://www.greenpeace.org/international/press/reports/offshore-wind-implementing-a and "North Sea Offshore Wind—A Powerhouse for Europe; Technical Possibilities and Ecological Consideration," 2000.

(Exo et al. 2003), impacts vary for different bird species, measurements address only found bird corpses, and results thus far are often contradictory between studies (Desholm and Kahlert 2005). Winkelman (1994) provides an overview of research carried out in Europe with special emphasis on results of the two most in-depth studies (Winkelman 1992, parts 1-4). At 108 sites, 303 dead birds were found, of which at least 41 percent were proven collision deaths. Of 14 collisions visually observed, 43 percent were caused by birds swept down by the wake behind a rotor, 36 percent by a rotor, and 21 percent unknown. The author states that total numbers likely to be killed per 1,000 MW of wind power capacity are low relative to other human-related causes of death. Because fewer birds probably collided with the middle row of wind turbines, Winkelman (1992) suggested that a cluster formation of turbines may cause fewer impacts than a line formation. Lighting of wind turbines was believed to be harmful rather than beneficial, particularly when weather and visibility are bad (Winkelman 1992, 1994). Still, a number of studies conducted thus far at offshore facilities suggest little or no impact on bird life (COD 2001). A recent study of 1.5 million migrating seabirds from Swedish wind facilities in Kalmarsund concluded that fatality risk to passing seabirds was only one in 100,000 (Eriksson and Petersson 2005). In Denmark, radar studies indicate that migrating birds avoid flying through the Nysted wind facility. These studies reveal that 35 percent of the birds fly through the area at baseline, but only 9 percent after construction. Monitoring at the operating Horns Rev wind facility in Denmark found that, "…most bird species generally exhibit an avoidance reduction to the wind turbines, which reduces the probability of collisions" (Elsam Engineering and ENERGI E2 2005). From the European point of view, in most circumstances disturbance and habitat loss are thought to be of much more importance than bird mortality, although the consequences on populations remain unknown.

Winkelman (1994) also summarized findings on disturbance and effect of turbines on flight behavior, which were investigated in most studies. Up to a 95 percent reduction in bird numbers has been shown to occur in the disturbance zones (250–500 m from the nearest turbines). Winkelman (1985) studied the possible danger to birds of medium-sized wind turbines (tower height 10–30 m) situated on six small wind facilities located along or near the Dutch coast and reported that diurnal migrants seemed to respond more to operating turbines than did local birds. An average of 13 percent of migrating flocks and 5 percent of local flights showed a change in flight behavior that could be attributed to the turbines during this study, suggesting that local birds may habituate to wind turbines. Fox and Nilsson (2005) summarized results from offshore radar studies in Denmark and Sweden, respectively, and reported marked seaduck avoidance of existing wind facilities ("Offshore and Nearshore Wind Development, and Impacts to Sea Ducks and Other Waterbirds," 2nd N. Am. Sea Duck Conference, Annapolis, MD, 2005; results on USGS-Patuxent Wildlife Research Area website). Winkelman (1990) studied behavior of birds approaching wind turbines during day and night conditions and found that 92 percent of birds approached the rotor without any hesitation during the day compared to 43 percent at night. During high-use nights, Winkelman (1990) found that 56 percent to 70 percent of the birds passed at rotor height (21–50 m) and more birds collided with the rotor at night and twilight than during the day. Of 51 birds recorded trying to cross the rotor area during twilight and total darkness, 14 (28%) collided while only one of 14 birds (7%) collided, during the day. Based on the number of birds passing at rotor height and the proportion of birds colliding, Winkelman (1990) estimated 1 out of 76 birds passing the towers at night was expected to collide with turbines when the facility was fully operational.

Following Winkelman's (1994) review, Exo et al. (2003) reviewed the status of offshore wind-energy developments and research on birds in Europe and noted that European seas are internationally important for a number of breeding and resting seabird populations that are subject to special protection status. Moreover, every year tens of millions of birds cross the North Sea and the Baltic Sea on migration. They concluded the erection of offshore wind turbines may affect birds as follows: (1) risk of collision; (2) short-term habitat loss during construction; (3) long-term habitat loss due to disturbance by turbines, including disturbances from boating activities in connection with maintenance; (4) formation of barriers on migration routes; and (5) disconnection of ecological units, such as between roosting and feeding sites. These researchers also stated it was vital that all potential construction sites are considered as part of an integral assessment framework, so that cumulative effects can be fully taken into account. They concluded, however, that making these assessments was hindered by a lack of good data on migration routes and flight behavior of many of the relevant bird species. They added that, based on experience gained from studies at inland wind facilities and at the near-shore sites where environmental impact assessments are currently under way, marine wind facilities could have a significant adverse effect on resident seabirds and other coastal birds as well as migrants. Moreover, the potential impacts may be considerably higher offshore than onshore. Disturbance and barrier effects probably constitute the highest conflict potential (Exo et al. 2003). While further studies are needed to better define the risks, precautionary measures to reduce and mitigate such risks exist. For example, careful siting of wind facilities away from bird migratory paths, bird habitats, and large concentrations of species at higher risk is possible.

ISSUES REGARDING STUDIES ON WIND ENERGY AND WILDLIFE

The location of a wind facility can be critically important based on its known, suspected, or potential impacts on wildlife and their habitats. By performing risk evaluations and pre-construction monitoring, potential impacts could be predicted and potentially avoided or mitigated. Post-construction evaluations, in turn, can validate (or negate) hypotheses, conclusions, and assumptions reached from risk evaluations and pre-construction monitoring performed before the project is actually built. Post-construction monitoring also provides data allowing “mid-course corrections” to respond to problems discovered by monitoring through subsequent use of deterrents (although no deterrents of proven effectiveness are currently available), mitigation, or alternative actions and can assist in the permitting and design of future facilities.

Peer Review and Publication

Currently, few studies of wildlife interactions with wind turbines have been published in refereed scientific journals, although this trend is changing. Most reports on wind-wildlife relationships have entered the “gray literature” and appear on the Internet, possibly accompanied by archived paper copies. Many others are retained by wind energy companies as proprietary material not available to outside parties, including regulatory agencies. We believe that peer review lends some credibility to “gray literature” even if a document is never published as a stand-alone paper in a scientific journal, but strongly encourage publication in journals. Peer review is an integral component of scientific research and publishing and an important means of ensuring sound information (The Wildlifer May-June 2006). The shortage of scientific publication on wind-wildlife interactions (GAO 2005, Kunz et al. 2007a) must be overcome to place the problem on a base of solid science.

Study Design and Duration

Investigations of wind turbine and wildlife interactions and impacts are relatively recent and there is a dearth of information upon which to base decisions. With few exceptions, most work conducted to date has been short-term (e.g., only one field season) and the frequency of study (e.g., both season length and time into the night at which research is conducted) also may be inadequate. Longer-term studies are required to elucidate patterns, better estimate fatality, and develop predictive models to estimate the risk of fatalities and evaluate possible habitat fragmentation or other disturbance effects. As one example, birds may continue to occupy habitats suddenly rendered unsuitable because of some “inertia” (Wiens et al. 1986). If that occurs, an unsuitable site will continue to support birds for several years, and a short-term evaluation will not identify effects of the treatment. Another example: some disturbance to the vegetation caused by construction might induce short-term effects that will diminish over time. For these reasons, it is desirable to monitor wind facilities for several years after construction. Years need not always be consecutive, although conducting studies in alternate years may pose budgeting difficulties. The British Government, for example, requires three to five years of post-construction monitoring on offshore projects constructed on Crown lands (DEFRA 2005).

Because randomization of "treatments" (installation of wind turbines) is not feasible, true experimentation is impossible. Before-After, Control-Impact (BACI) studies are the next best approach (Stewart-Oaten et al. 1986, Smith 2002), along with impact gradient studies in some cases (e.g., where habitats are homogeneous or where before data are unavailable). Some guidelines for conducting such studies have been developed recently (Anderson et al. 1999, Erickson et al. 2005), but these need to be modified to accommodate each particular site. Acquiring data on wildlife use at a site before construction begins is essential to account for variation in populations among sites. Collecting site-specific pre-construction data can be complicated when exact locations of wind turbines are not identified or divulged far enough in advance of construction to allow time to design and conduct monitoring. Data from reference sites without wind turbines improves understanding of potential cause and effect relationships, particularly where variation among years is common, such as in grassland bird populations, for example. In some situations, however, it is difficult to find sites that are similar in location, topography, vegetation, and land use, and which themselves are not sites of wind turbines.

Metrics and methods guidance document. Anderson et al. (1999) prepared a document for the National Wind Coordinating Committee (see www.nwcc.org) titled "Studying Wind Energy/Bird Interactions: a Guidance Document:Metrics and Methods for Determining or Monitoring Potential Impacts on Birds at Existing and Proposed Wind Energy Sites." This document contains detailed standardized metrics and methods for performing various studies, observations, and evaluations of the impact of wind energy facilities on wildlife. Anderson et al. (1999) present efficient, cost-effective study designs intended to produce similar types of data for comparison among projects, which could potentially reduce the need for detailed surveys or research at other proposed projects in the future. Specifically, the Metrics and Methods Document identifies four levels of surveys, which at the time the document was published were designed primarily for avian studies. They include:

1) "Site evaluation," where information is collected from existing sources including local expertise, literature searches, natural resource databases, lists of state and federally listed species and critical habitats, reconnaissance surveys of the site, vegetation mapping, and an assessment if information available is sufficient to make a defensible determination to build or not build at the site. These "evaluations" generally are not highly rigorous, as they are typically used to screen sites, although they may need to be if federally or state-listed species are present, or species susceptible to collisions or disturbance are present.

2) "Level 1 studies" include pre-permitting baseline studies, risk assessment studies, and monitoring studies designed to detect relatively large effects of operating wind facilities on wildlife. A BACI Design may also be used as part of a "level 1 study" since it may help answer the question, "did the average difference in abundance between the [control] area(s) and the wind plant area change after the construction and operation?" (Anderson et al. 1999:25). Meta-analysis, an approach to combining statistical results from several independent studies all dealing with the same issue, is also suggested as a tool for "level 1 studies."

3) "Level 2 studies" involve detailed studies of one or more populations, manipulative studies designed to determine mechanisms involved in fatality and risk, the quantification of risk to populations, and the evaluation of risk-reduction management practices.

4) "Risk-reduction studies" attempt to assess attributable risk versus preventable risk to avian populations; review suggestions for measuring risk; include counts for bird utilization, mortality, scavenger removal, and observer bias; and review the challenges addressing indirect interactions affecting "habitat" and "vegetation type."

In addition to research protocols suggested in the Metrics and Methods document, regulatory agencies also examine and may recommend other protocols (e.g., "best management practices" suggested by the BLM, suggestions from the Government of Great Britain in its regulatory offshore wind development [DEFRA 2005]), and specific recommendations from USFWS in its voluntary guidance to avoid and minimize impacts to wildlife and habitats [USFWS 2003]).

Inconsistent Methodology and Implementation

One problem with site review and evaluation is inconsistent implementation of procedures to assess impact and risk, and to perform pre-, during- and post-construction evaluation and monitoring. Some assessments are performed at minimal levels of evaluation while others at sites with an apparent comparable level of risk are performed in much more rigorous, scientifically valid ways. Use of standardized protocols to address specific questions would improve comparability of studies and credibility of efforts. Consistency would greatly assist regulatory agencies during decision making in regard to statutory trust responsibilities. However, state permitting processes vary widely in regard to environmental requirements, thus potentially hindering consistent development of objectives and implementation of methodologies. On private lands or where no federal nexus exists, federal agencies can only suggest which protocols might be used and to what extent.

Assessing the overall impact of a wind project is prudent and such broad assessments should include potential impacts such as collision mortality, indirect impacts from reduced nesting and breeding densities, habitat and site abandonment, loss of refugia, displacement to less-suitable habitats, effects on behavior of wildlife, changes in resource availability, disturbance, avoidance, fragmentation, and an assessment of cumulative impact. Unfortunately, indirect effects often are very difficult to predict. Inadequate or no impact assessments are problematic. For example, "risk assessments" performed for bats at Buffalo Mountain, Tennessee, Mountaineer, West Virginia, and Meyersdale, Pennsylvania, did not identify high risk (at least to non-federally listed bats; e.g., hoary and red bats), but later were documented to have the highest bat kills ever recorded at a wind facility (Arnett et al. 2008). While no formal "risk assessment" process was conducted at APWRA, California, USFWS biologists and other agency biologists and managers advised proponents in the late 1980s and early 1990s of potential problems, but these concerns have not been successfully addressed even though high levels of raptor mortality have been documented. Pre-construction estimation of such events and potential impacts requires more extensive study at both existing and proposed wind facilities. These broader assessments, while daunting, will be critical for understanding not only the potential impacts, but also development of solutions.

Technological Tools for Studying Wind-Wildlife Interactions

Numerous technological tools exist for conducting pre-construction assessments and predicting both direct and indirect impacts of wind facilities on wildlife (see Anderson et al. 1999 and Kunz et al. 2007b for detailed reviews). Here, we focus on remote sensing technologies that employ radar, thermal infrared imaging, and acoustic detection, but also recognize that other techniques exist to study wind-wildlife interactions (e.g., night vision, mist-netting, radio telemetry). No single method can be used unambiguously for assessing temporal and spatial variation in natural populations or the impacts of wind turbines on bats and nocturnally active birds. Employing a combination of techniques, including night vision observations, reflectance and thermal infrared imaging, marine radar, NEXRAD Doppler radar, and captures can contribute most toward understanding how bats and birds may be impacted by wind energy developments (Kunz et al. 2007b). Each device or method has its own strengths, limitations, and biases and it is essential for field researchers to understand these limitations and ensure that the fundamentals of study design and sampling (e.g., Anderson et al. 1999, Morrison et al. 2001) are employed and sufficient data are gathered to address the question of interest.

Radar is a broadly-applicable technique for observing flying animals (most radar systems are unable to distinguish individual "targets" or differentiate between birds and bats and insects) and is a widely used tool during pre-construction assessments at proposed wind facilities. Recent reviews by Bruderer (1997a, b), Diehl (2005), and Larkin (2005), as well as the classic text by Eastwood (1967), describe how various kinds of radar operate and their use in wildlife research and monitoring. With regard to wind energy facilities, radar has a role in broad-scale surveys of migratory and roosting movements of flying animals, pre-construction monitoring of proposed sites for wind facilities, and post-construction observation of the behavior of flying animals approaching fields of wind turbines and around individual turbines, and for estimating exposure for use in the analysis of bird and bat fatalities. Appropriate use of radar occupies a prominent position in the available tools because it can report the three-dimensional position of echo-producing objects ("targets"), operates day and night, can detect flying biota beyond the range of most other techniques, can be used freely in conjunction with other techniques such as light- and infrared-based observation, and does not affect the behavior of the animals being observed (Bruderer 1999).

Some kinds of radar data are relatively inexpensive to acquire. The long reach of the equipment and continuous, perhaps even unattended, operation appear ideal for quick surveys of the airborne biota. In the present climate favoring installing wind turbines quickly and the scarcity of funding for research on the machines' effects on wildlife, radar offers a powerful tool, yet decision-makers may be asked to accept radar data out of context and inappropriately. Those considering using radar should be aware of three possibly critical deficiencies:

- **Height (geometry).** Flying animals significantly above or below the rotor-swept area of turbines are probably in little danger. Therefore, surveys of local and migrating flying animals must document how they are distributed vertically. No radar can provide accurate height information at long range, and marine radar mounted in the conventional fashion cannot provide accurate height information.
- **Metal rotor blades.** Radar cannot be used to observe flying animals close to large, metal-containing, moving objects such as blades of wind turbines. "Close" is defined in terms of the resolution (pulse volume) of the radar when sited near a wind turbine. This disadvantage may be unimportant when studying only animals approaching a wind facility or a turbine rather than actually interacting with turbine blades.
- **Distinguishing targets.** A migrating bat may be orders of magnitude more vulnerable to wind turbines than a bird flying nearby, but the flying mammal and bird may present identical-appearing and -moving echoes on most radars. Even the mass of flying animals is only loosely related to body size (Vaughn 1985). This is part of a larger problem of detection bias that includes bias as a function of distance, interaction of targets (e.g., interpretation of intersecting targets), the determination of the actual space sampled by the radar, and the effect of weather and topography. Ongoing research is attempting to use optical techniques to provide taxonomic information when radar is being used.

Thermal Infrared (TI) cameras sense metabolic heat emitted by animals in flight, producing a clear image against the cooler sky and landscape without need for artificial illumination that may disturb normal behavior (Kunz et al. 2007b). Digital images are captured at variable rates up to 100 frames per second and recorded to disk, thus achieving high temporal detail for extended periods. TI may be useful for post-construction research. Horn et al. 2008 demonstrated that bats were more frequently observed in the vicinity of sampled turbines on forested mountain ridges during periods of low wind. Bats were observed striking various regions along the blade, approaching non-moving blades, and investigating the structure with repeated fly-bys, sometimes briefly alighting or landing on them. Small size and portability facilitate use of TI in the field, but monitoring turbines is challenged by finding a compromise between viewable area and resolution. A station may consist of a single high-resolution camera or an array of several lower-resolution cameras to achieve the same resolving power and viewable area. Multiple cameras with large field-of-view can be positioned close to turbines, improving image clarity and, during later analysis, permitting stereo estimation of distances and 3D reconstruction of flight paths. Collection of TI images currently is limited by availability of equipment, the need for large amounts of data storage, and costs of equipment and analysis of data.

Acoustic monitoring allows researchers to detect and record various calls of echolocating bats and vocalizing birds that can be used to assess relative activity and identify species or groups of species, which applies to both pre- and post-construction studies. Acoustic methods have several limitations. Detection is only possible when birds are calling or bats are echolocating within the range of the detectors, and factors influencing detection probability remain poorly understood. The method can only be used to indicate presence, but not absence. Pre-construction monitoring of vocalizations to identify sites with high levels of bird and bat activity or use by sensitive species prior to construction may be valuable in assessment of site-specific risks of turbine construction to birds and bats (Kunz et al. 2007b). A key assumption is that pre-construction activity, as estimated through vocalizations, is correlated with post-construction bird and bat mortality, yet we are currently unaware of any study linking pre-construction monitoring data with post-construction fatality, although such efforts are under way (e.g., Arnett et al. 2006). Acoustic detectors often are used in the field without a thorough understanding of underlying assumptions and limitations or standardized protocols (Hayes 2000, Weller and Zabel 2002, Gannon et al. 2003). Although echolocation calls are reliably distinguishable from other sounds (e.g., bird, arthropod, wind, mechanical), the ability to distinguish species of bats varies with taxon, location, type of equipment, and quality of recording, and may be challenging. Estimating amount of activity of those bats echolocating is straightforward, but estimating abundance requires differentiation between multiple passes of a single bat and multiple bats making single passes and is not usually possible.

RESEARCH NEEDS

Along with providing a framework for development of more robust experimental field design, use of accepted standardized protocols will greatly enhance researchers' ability to compare and analyze data among studies from various facilities. More important than interpreting results from individual studies is the search for consistent patterns ("metareplication," sensu Johnson 2002). What patterns are consistent, and what variation in patterns occurs among species, habitat types, and geographic locations? The effect of changing technologies (e.g., bigger turbines) on bird and bat fatalities should be investigated. Predictions of future impacts will necessarily be based on today's technology, but it is important that we understand how changing technology may affect those predictions. There also is the need to determine effectiveness of mitigation measures currently in use (e.g., turbine placement) and develop and evaluate new mitigation measures. It is important that a better understanding of the influence of wind facilities on wildlife and their habitats be sought and, to that end, studies should be undertaken at wind facilities and reference sites both before and after construction. Short-term studies may not identify potentially deleterious impacts of wind facilities or efficacy of mitigation. Longer-term and broader assessments of cumulative impacts and potential mitigation strategies are clearly warranted. The dearth of available information regarding impacts of wind development on wildlife creates uncertainty that should be addressed in an adaptive management context (Walters 1986, Walters and Holling 1990) until proven solutions to wildlife fatalities and habitat-related impacts are found. As new information becomes available, data should be used to trigger adjustments to mitigation strategies that reduce impacts on wildlife. Decision-making frameworks will be required to establish what data are required and how they will be used to establish triggers and thresholds for adjusting strategies for mitigating wildlife impacts.

Based on our review, we offer the following suggestions for priority research needed to elucidate patterns of fatality, evaluate the context and biological and population implications, determine risk to predict future impacts, develop mitigation strategies, and assess efficacy of methods and tools used to study impacts of wind energy development on wildlife and their habitats. Our suggestions are not exhaustive, but reflect our view of high-priority needs to advance our knowledge and develop effective mitigation strategies for the responsible development of wind energy.

Birds and Bats

Numerous questions require further and immediate investigation to advance the understanding of bird and bat fatalities at wind turbines, develop solutions for existing facilities, and aid with assessing risk at future wind facilities. First there needs to be a better synthesis of existing information. A priority research need for existing wind facilities is an estimate of impacts, both fatalities and habitat-related impacts for facilities located in unstudied or new locations (e.g., eastern mountains, the Southwest, coastal, offshore). 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. 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. Additional priority research, recommended by Arnett (2005), Arnett et al. (2008), and Kunz et al. (2007a) includes: 1) conducting extensive post-construction fatality searches for a "full season" of bat movement and activity (e.g., April through November in northern latitudes) at facilities encompassing a diversity of surrounding habitat characteristics to fully elucidate temporal patterns of fatality; 2) further investigating relationships between passage of storm fronts, weather conditions (e.g., wind speed, temperature), turbine blade movement, and bat fatality to determine predictability of periods of highest fatality; 3) 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; and 4) comparing different methods and tools (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. It is also important to develop and verify models that allow prediction of impacts to individuals and populations of both birds and bats.

Habitat Loss, Fragmentation, and Disturbance

Two critical questions concerning habitat-related impacts remain unanswered and center on 1) the extent to which strings of wind turbines effectively fragment grassland habitat, and 2) how inferences about avoidance of trees and tall anthropogenic structures by birds transfer to avoidance of wind turbines. There is a need to determine relationships of small scale (e.g., habitat disturbance) versus large-scale habitat impacts (e.g., habitat fragmentation needs investigation) on wildlife. It is important to quantify and predict not only changes in habitat structure, but also displacement impacts, particularly on forest-dwelling and shrub-steppe/grassland birds (e.g. prairie grouse). Furthermore, development of roads for construction and maintenance may have important consequences; this issue is especially a concern in the West, which does not have as extensive networks of roads as in the Midwest. Future development of transmission lines to facilitate wind generation will undoubtedly have broad-ranging impacts on wildlife and their habitats that should be investigated as well. Likewise, potential mitigation of habitat disturbance from wind energy development, particularly in grassland habitats, through restoration of other nearby areas, should be investigated.

Habitat and Prey Density Management

Habitat modification to reduce prey densities has been discussed as a possible avian risk-reduction technique. Directly reducing prey (e.g., rodents) populations within the vicinity of wind turbines might reduce high-risk foraging activities by raptors. Suggested methods include county-sponsored abatement programs, reduced grazing intensities, and re-vegetation with higher-stature plants that pocket gophers and ground squirrels tend to avoid. The effects of widespread vegetation and/or rodent control programs would have to consider the effects on the overall demographics of the affected population as well as effects on other wildlife, such as protected species and special-status species like the San Joaquin kit fox *(Vulpes macrotis mutica)*, burrowing owl, and badger *(Taxidea taxus)*. There also may be impacts on other non-target rodent species such as kangaroo rats *(Dipodomys spp.)* and pocket mice *(Perognathus spp.)*, which have special status in some states. Research is needed to evaluate reductions in fatality relative to these management techniques.

Curtailment Experiments

Decreasing operation time of problem turbines or entire facilities has been suggested as a risk-reduction measure and recently was mandated at APWRA. Studies have reported that a large proportion of bat fatalities occur on nights with low winds and relatively low levels of power production (Feidler 2004, Arnett 2005, Brinkman 2006). 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. Thus, critical shutdown times could be predictable and implemented seasonally (e.g., during migration periods) or based on inclement weather or nighttime periods when visibility is reduced. 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. While the results from studies at APWRA, and studies just begun at Tehuantepec, Mexico, are not yet available, these datasets should provide important new information about the effects of seasonal shutdowns and turbine "feathering" (i.e., changing blade pitch to make turbines inoperative). Related research is ongoing in Europe and Canada and is anticipated in the United States beginning in 2008.

Alerting and Deterring Mechanisms

There currently is no effective alerting or deterring mechanism that has been proven to effectively reduce fatality of birds or bats. Laboratory tests suggest that some blade painting schemes may increase a bird's ability to see turbine blades (Hodos 2003), but these painting schemes have not been field-tested. Young et al. (2002) field tested the effect of painting turbines and blades with a UV gel coat, theoretically to increase a bird's ability to see the structures. However, field tests showed no difference in fatalities between treatment and control turbines. Although no research has been conducted on auditory deterrents to birds approaching wind turbines, audible devices to scare or warn birds have been used at airports, television towers, utility poles, and oil spills, yet most studies of auditory warning devices have found that birds become habituated to these devices. Birds do not hear as well as humans (Dooling 2002) and minor modifications to the acoustic signature of a turbine blade could make blades more audible to birds, while at the same time making no measurable contribution to overall noise level. 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. At present there is no research under way that tests the effects of auditory deterrents on birds and, because of the low likelihood of developing a successful application, none is planned for the foreseeable future.

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 of such devices at an operating facility that will include measures of fatality reduction as well as behavioral responses of bats. If such deterrents can be built and prove effective, long-term monitoring would be required at multiple sites to elucidate and justify effectiveness and determine whether bats habituate over time. Furthermore, a deterrent for bats will probably need to nullify or counteract the hypothetical attraction of some bats to wind turbines. Simply making turbines more easily perceived by bats may have no effect or could increase the hypothesized attraction. Although devices or procedures to repel bats from wind turbines may be discovered by trial and error, it is almost certain that an effective deterrent will emerge only after further basic research in the field permits us to understand the mechanism of attraction of bats to turbines (Larkin 2006).

Offshore

The priority research objective is to quantify seasonal occurrence, abundance, use, and location of birds along the Lower Gulf and Atlantic coasts. Specifically, research should focus on three major areas. First, the location, magnitude, and timing of movements of bats and birds during spring and fall migration need to be determined. It appears that a substantial number of passerines and other non-raptorial birds move along the LGC during migration, likely staying close to the coastline and along the near-shore area. Such behavior could increase risk for these species relative to direct flights out over the Gulf.

Second, identification of locations where species of concern and threatened or endangered species (bats and birds) occur during breeding and nonbreeding periods is warranted. Finally, a method for estimating fatalities at existing and planned wind facilities offshore will be required to understand impacts and develop mitigation strategies; retrieving dead birds and bats at sea will be a considerable challenge.

Cumulative Effects

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. A meta-analysis, for example, conducted by Stewart et al. (2004) of bird mortality studies performed worldwide, suggests that impacts of wind facilities on bird abundance may become more pronounced over time, indicating that short-term abundance studies do not provide robust indicators of the potentially deleterious impacts of wind facilities on bird abundance. Broader assessments of the cumulative impacts for both birds and bats clearly are warranted. We also must consider the context of wildlife mortality at wind facilities in relation to other natural and anthropocentric sources of mortality, and determine if mortality from wind development is additive or compensatory.

RECOMMENDATIONS

This review identified several areas in need of immediate improvement to establish a scientific basis for decision-making, provide more rigorous and consistent requirements during permitting of wind facilities, and develop effective mitigation strategies to reduce or eliminate impacts on wildlife and their habitats from wind energy development. The following recommendations should help managers and decision-makers meet the challenges of developing wind energy responsibly.

1. Improve state agency involvement and consistency for requirements and regulation. Coordination among states and their agencies responsible for wildlife and energy development will be critical to ensure consistency in permitting requirements, research efforts, and acceptable mitigation, especially for species of migratory wildlife. Focused leadership among the states, for example, by the Western Governor's Association, would be one approach to gain acceptance of principles and guidelines for wind energy development. The Association of Fish and Wildlife Agencies could provide a useful facilitative role and has initiated dialogue with state, federal, and industry stakeholders to help reach these goals.

2. Renewable Portfolio Standards. A Renewable Portfolio Standard (RPS) is a state-level policy mandating a state to generate a percentage of its electricity from renewable sources, including wind energy. The standards usually focus on benefits of renewable energy, and currently no RPS considers the potential impacts of renewable energy's development on fish and wildlife and their habitats. Revising existing standards to account for wildlife impacts and the inclusion of this language and mitigation measures in new standards could lead to a more balanced and accurate presentation in the RPS.

3. Develop federal and state guidelines. State permitting processes vary widely in regard to environmental requirements, thus potentially hindering consistent development of objectives and implementation of methodologies. Developing consistent guidelines for siting, monitoring, and mitigation strategies among states and federal agencies would assist developers with compliance with relevant laws and regulations and establish standards for conducting site-specific, scientifically sound and consistent pre- and post-construction evaluations, using comparable methods as much as is feasible. Such consistency would greatly assist regulatory agencies during decision-making in regard to statutory trust responsibilities. Inclusion of guidelines in the permitting process would further strengthen agency participation and implementation of guidelines.

4. Avoid siting wind facilities in high-risk areas. A primary goal of wind energy development should be to avoid high-risk sites that are determined based on the best science available. Criteria and standards for high-risk sites need to be established for different groups of species and any designated "critical habitats" on a state-by-state or regional basis, and developers of wind energy should be required to avoid impacts to these areas. Examples may include locations important to threatened or endangered species or in large, contiguous areas of unfragmented native habitat. Siting wind facilities in areas where habitat is of poor quality and/or already fragmented, for example (see sidebar on Washington State guidelines), will likely result in fewer habitat-related impacts, although these sites should be monitored to determine collision impacts.

5. Reduce fragmentation and habitat effects. Developers should attempt to reduce habitat impacts by using existing roads when possible, limiting construction of new roads, and restoring disturbed areas to minimize impact from a facility's footprints. While clearing and perhaps maintaining low vegetation density will be important for post-construction surveys, habitat rehabilitation should be planned for disturbed areas after monitoring has been completed. On- and off-site habitat mitigation may be necessary to reduce habitat-related impacts.

6. Conduct priority research. Immediate research is needed to develop a solid scientific basis for decision-making when siting wind facilities, evaluating their impacts on wildlife and habitats, and testing efficacy of mitigation measures. More extensive pre- and post-construction surveys are needed to further elucidate patterns and test hypotheses regarding possible solutions. Monitoring and research should be designed and conducted to ensure unbiased data collection that meets peer review and legal standards (Kunz et al. 2007a). Research partnerships (e.g., Arnett and Haufler 2003, Bats and Wind Energy Cooperative [www.batcon.org], Grassland and Shrub Steppe Species Cooperative [www.nwcc.org]) among diverse players will be helpful for generating common goals and objectives and adequate funding to conduct studies.

7. Evaluate pre-construction assessments and predicted impacts. Prior to construction, industry, federal and state agencies, and others should conduct studies to determine what, if any, environmental risk would be posed by a planned wind facility. Resulting assessments are used in the permitting process and elsewhere. Rarely, however, is the quality of those assessments evaluated. Linking pre-construction assessments to post-construction monitoring is fundamental to assessing risk of a facility. Such comparisons are needed and would not only inform the pre-construction assessment process, but also provide valuable information about the environmental risks of wind facilities.

8. Conduct more consistent, longer-term studies. Most "research" conducted in association with wind development is short-term, and there appears to be little follow-up to determine if predictions from research are accurate. Long-term studies clearly are needed to address many questions on impacts of wind energy development on wildlife. Use of standardized protocols to address specific questions would improve comparability of studies and credibility of efforts. Consistency across data collection efforts, post-construction evaluations, and access to resulting data will be critical for conducting meta-analyses so that consistent effects, even if they are small, could be detected.

9. Develop and evaluate habitat-related mitigation strategies. All too often, mitigation measures have been generally required without adequate evaluation. Strategies for mitigating habitat impacts associated with wind facilities should be developed and evaluated. Effective mitigation measures should then be employed.

10. Employ principles of adaptive management. Operations and mitigation strategies should be adjusted as new information becomes available, following the principles of adaptive management (Walters 1986, Walters and Holling 1990). For example, future permitting requirements and guidelines should clearly define monitoring standards, mitigation measures (e.g., curtailment), and how data will be used to trigger adjustments to operations to mitigate impacts on wildlife. Strategies should be adjusted as new information becomes available.

11. Conduct regional assessments and forecasting of cumulative land-use and impacts from energy development. Given 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.

12. Improve public education, information exchange, and participation. There is an immediate need to better educate the public and decision-makers regarding the full range of trade-offs and benefits regarding all forms of energy, including wind energy development. Impacts on wildlife and their habitat must be integrated into the political dialogue so that all tradeoffs can be considered during decision-making. Maintaining relationships with private landowners and communicating the importance of conservation efforts and their benefits will be critical toward developing wind energy responsibly. ■

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Table 1. Avian fatality rates from new generation wind facilities where standardized fatality monitoring was conducted.

	Project Size		Turbine Characteristics			Raptor Fatality Rates		All Bird Fatality Rates		Source
	#	#	RD	RSA		#/	#/	#/	#/	
Wind Project	turbines	MW	(m)	m^2	MW	turbine	MW	turbine	MW	
Pacific Northwest										
Stateline, OR/WA	454	300	47	1735	0.66	0.06	0.09	1.93	2.92	Erickson et al. 2004
Vansycle, OR	38	25	47	1735	0.66	0.00	0.00	0.63	0.95	Erickson et al 2000
Combine Hills, OR	41	41	61	2961	1.00	0.00	0.00	2.56	2.56	Young et al. 2005
Klondike, OR	16	24	65	3318	1.50	0.00	0.00	1.42	0.95	Johnson 2003
Nine Canyon, WA	37	48	62	3019	1.30	0.07	0.05	3.59	2.76	Erickson et al. 2003
Overall	586	438	56	2554	1.02	0.03	0.03	2.03	2.03	
Weighted averages	586	438	49	1945	0.808	0.05	0.07	1.98	2.65	
Rocky Mountain										
Foote Creek Rim, WY Phase I	72	43	42	1385	0.60	0.03	0.05	1.50	2.50	Young et al. 2001
Foote Creek Rim, WY Phase II	33	25	44	1521	0.75	0.04	0.06	1.49	1.99	Young et al. 2002
Totals or simple averages	105	68	43	1453	0.675	0.04	0.05	1.50	2.24	
Totals or weighted averages	105	68	43	1428	0.655	0.03	0.05	1.50	2.31	
Upper Midwest										
Wisconsin	31	20	47	1735	0.66	0.00	0.00	1.30	1.97	Howe et al. 2002
Buffalo Ridge Phase I	73	22	33	855	0.30	0.01	0.04	0.98	3.27	Johnson et al. 2002
Buffalo Ridge Phase II	143	107	48	1810	0.75	0.00	0.00	2.27	3.03	Johnson et al. 2002
Buffalo Ridge, MN Phase III	139	104	48	1810	0.75	0.00	0.00	4.45	5.93	Johnson et al. 2002
Top of Iowa	89	80	52	2124	0.90	0.01	0.01	1.29	1.44	Koford et al. 2004
Totals or simple averages	475	333.96	46	1667	0.67	0.00	0.01	2.06	3.13	
Totals or weighted averages	475	333.96	46	1717	0.53	0.00	0.00	2.22	3.50	
East										
Buffalo Mountain, TN	3	2	47	1735	0.66	0.00	0.00	7.70	11.67	Nicholson 2003
Mountaineer, WV	44	66	72	4072	1.50	0.03	0.02	4.04	2.69	Kerns and Kerlinger 2004
Totals or simple averages	47	68	60	2903	1.08	0.02	0.01	5.87	7.18	
Overall (weighted average)	47	68	70	3922	1.45	0.03	0.02	4.27	2.96	

Table 2. Estimates of bat fatalities at wind facilities in North America (modified from Arnett et al. 2007).

Study Area Location	Estimated Fatality/Turbine	Estimated Fatality/MW	Source
Canada			
Castle River, AB	0.5	0.8	Brown and Hamilton 2002
McBride Lake, AB	0.5	0.7	Brown and Hamilton 2006a
Summerview, AB	18.5	10.6	Brown and Hamilton 2006b
Eastern U.S.			
Buffalo Mt, TN (Phase 1) [a]	20.8	31.5	Nicholson 2003, Fiedler 2004
Buffalo Mt, TN (Phase 2, 0.66 MW) [a]	35.2	53.3	Fiedler et al. 2007
Buffalo Mt, TN (Phase 2, 1.8 MW) [b]	69.6	38.7	Fiedler et al. 2007
Maple Ridge, NY	24.5	14.9	Jain et al. 2007
Meyersdale, PA	23	15.3	Arnett 2005
Mountaineer, WV (2003)	48	32	Kerns and Kerlinger 2004
Mountaineer, WV (2004)	38	25.3	Arnett 2005
Rocky Mountains U.S.			
Foote Ck. Rim, WY	1.3	2.0	Young et al. 2003
Pacific Northwest U.S.			
Highwinds, CA	3.4	1.9	Kerlinger et al. 2006
Klondike, OR	1.2	0.8	Johnson et al. 2003b
Stateline, OR/WA	1.1	1.7	Erickson et al. 2003b, 2004
Vansycle, OR	0.7	1.1	Erickson et al. 2001
Nine Canyon, WA	3.2	2.5	Erickson et al. 2003a
Midwestern U.S.			
Buffalo Ridge, MN Phase 1) [c]	0.1	0.3	Johnson et al. 2003a
Buffalo Ridge, MN (Phase 2) [d]	2.0	2.7	Johnson et al. 2003a, 2004
Buffalo Ridge, MN (Phase 3) [e]	2.1	2.7	Johnson et al. 2004
Lincoln, WI	4.3	6.5	Howe et al. 2002
Top of Iowa	7.8	8.7	Jain 2005
South-central U.S.			
Woodward, OK [f]	1.2	0.8	Piorkowski 2006

[a]Estimated bats killed by 3 Vestas V47 0.66 megawatt turbines.
[b]Estimated bats killed by 15 Vestas V80, 1.8 megawatt turbines.
[c]Estimated bats killed by 73 Kenetech 33 0.33 megawatt turbines based on 4 years of data.
[d]Estimated bats killed by 143 Zond 0.75 megawatt turbines based on 4 years of data.
[e]Estimated bats killed by 138 Zond 0.75 megawatt turbines based on 3 years of data.
[f]Estimated average over eight surveys in two years.

Table 3. Densities of male grassland birds (all species combined) in Conservation Reserve Program fields along transects at various distances from strings of wind turbines, and at a control site, in southwestern Minnesota (from Leddy et al. 1999).

Distance from turbine string (m)	Mean density of males (per 100 ha)
0 m	58.2
40 m	66.0
80 m	128.0
180 m	261.0
Control	312.5

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