Scientific Review of *California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development*

(California Energy Commission, October 2007)

Prepared for
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1. Executive Summary

Objectives of the Review

The *California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development* (Guidelines) was completed by the California Energy Commission and the California Department of Fish and Game in October 2007. The Guidelines were developed to address coexisting and sometimes conflicting objectives to encourage wind development in the state while minimizing and mitigating harm to birds and bats. The stated objectives of the Guidelines are to provide information and protocols for assessing, evaluating, and determining the effects of wind energy projects on bird and bat species and to develop and recommend impact avoidance, minimization, and mitigation measures. The Guidelines describe methods of assessing bird and bat impacts associated with wind projects in California. The Guidelines assert that the state of knowledge about bird and bat interaction is reflected in the document, and that ongoing and future research will refine, expand, and alter this knowledge (p. 4).

Coupled with development of the Guidelines, the California Energy Commission's Public Interest Energy Research (PIER) Program has an objective to support further research that will increase the accuracy of the methods and metrics of assessing and mitigating potential impacts to birds and bats from wind development.

Recognizing the need to strengthen the scientific foundation of the Guidelines, the California Wind Energy Association (CalWEA) commissioned this scientific review to evaluate and document the major bases for the recommended studies in the Guidelines. The major review objectives follow:

> (1) To provide CalWEA with an understanding of the scientific bases of the Guidelines.
>
> (2) To assist PIER in developing its research road map for bird and bat interactions with wind energy facilities as related to the Guidelines.

In addition to identifying the scientific underpinnings of the Guidelines' recommendations (or lack thereof), this review considers the importance of these issues for implementing the Guidelines, examines what the recent literature says on the subject, and proposes research that would provide insight into the issues.

This review of the Guidelines is focused on the methods recommended in the Guidelines and does not attempt to provide an exhaustive review of the literature. To support this scientific review of the Guidelines, two major literature reviews published just after the Guidelines were published were searched: the National Research Council (NRC) 2007 Report on Environmental Impacts of Wind Projects and the 2007 Review for the Canadian Wildlife Service by Kingsley and Whittam. Citations provided in the Guidelines were also reviewed.

Summary of Findings

The Guidelines' recommendations promoting the use of particular survey methods and the ability to use the results of those surveys to predict impacts are based on several assumptions. An examination of the current literature reveals that many of these assumptions are not scientifically supported for consistent application across all wind project sites.

This review identifies three major categories where the Guidelines require more documentation and research to support the recommended methods and metrics or modification of the recommendations. The major foundational areas are in methodology, ecology, and mitigation. Within these areas, a number of sub-categories were identified, reviewed, and evaluated. The following is a brief summary of the issues in these categories and recommendations for addressing them with further research.

Methodological Foundations

- Decision Framework for Assessing Wind Turbine Risk – This issue has implications for a number of Guideline topics, in particular the Guidelines' categorization of projects into four groups for the purposes of determining intensity of study required. Evaluations of other types of decision frameworks that may be more effective in decision-making are recommended.
- Statistical Aspect of Pre-permitting Survey Design – This issue has particular implications for the Guidelines' recommended approach to data collection and interpretation. Research should focus on compilation of data associated with various survey designs from existing projects and statistical evaluation of the data.
- Statistical Aspects of Operations Monitoring – This issue also has implications for data collection and interpretation. Research should focus on compilation of data associated with various survey designs from existing projects and statistical evaluation of the data.
- Statistical Methods and Models – The Guidelines' recommended formulas for adjusting predicted fatality rates are flawed, with broad implications for interpreting the results of observed and predicted mortality rates. Formula corrections are required. Research should focus on field studies to test the relationship between scavenger bias and observer bias.
- Analysis of Data – The Guidelines provide no guidance on appropriate statistical methods for evaluating pre-permitting data or monitoring data (other than the mortality adjustment guidance). A case study evaluation of existing data is recommended.

Ecological Foundations

- Abundance/Collision Mortality Relationship – The Guidelines imply that there is a simple positive relationship between abundance and collision mortality. They do not explicitly define the term abundance as it relates to collision mortality, which can lead to confusion in discussing its relationship to collision mortality, the most appropriate survey methods to choose, and how to use abundance information once it is collected. The Guidelines do not provide further differentiation of non-raptor taxonomic groups, such as songbirds, waterfowl, and shore birds, which have different behavior characteristics (e.g., flight behavior, breeding behaviors, and feeding) and thus different risks. A more detailed evaluation of the abundance/collision mortality relationship and the different avian and bat population survey designs and metrics is recommended. This analysis will better define the relationships between specific measures of abundance and mortality. It will also characterize the wind-related ecological factors in California that affect the relationship and make recommendations on what types of abundance data need to be collected and what survey methods should be used to collect this information in California.

- Individual Effect in Relation to Population-Level Effects – The Guidelines focus on individual effects and imply that mortality to individuals equates to population-level effects. The wind literature does show that effects to individuals occur, but population-level effects do not necessarily occur. This is especially true for threatened and endangered species and other species of special concern. From a wildlife policy point of view, mortality to individuals of these species may be in violation of the policy, but may not result in population-level effects. An analysis of the relationship of the magnitude of predicted versus actual collisions of individuals as well as population-level effects to species susceptible to collisions in California is recommended. Recommendations on the criteria for assuming and characterizing population effects should be developed. As a part of this analysis, models of population viability (i.e., Population Viability Analysis) should be reviewed and recommendations on their use should be included.
- Behavioral Avoidance of Wind Turbines – A high percentage of birds actively avoid wind turbines by purposely flying over, around, or between individual turbines and thus pass unharmed. Behavioral avoidance is the key parameter in adjusting predictions of risk based on abundance in the rotor swept zone. Research to monitor behavioral avoidance is recommended. This research should focus on representative species groups known to be frequently killed by wind turbines as well as threatened and endangered species and other species of special concern also known to be susceptible to collisions.

Mitigation Foundations

- Ability of Buffer Zones to Protect Wildlife – Buffer zones are assumed to protect wildlife, but no guidance is given on how much protection buffer zones might afford to wildlife and how they should be designed to achieve the intended level of protection. Research is recommended on what is known about buffers and what species are likely to benefit from buffer zones.
- Appropriate Turbine Design and Layout to Protect Wildlife – This is a subject where there is little and often conflicting information. Evaluation of existing wind projects to investigate the risks of turbine design and placement is recommended.

2. Methodological Foundations

2.1 Decision Framework for Assessing Wind Turbine Risk

2.1.1 Issue and Its Importance for Implementing the Guidelines

Some management actions, survey design approaches, and data collection activities described in the Guidelines are linked to the three site categories described on p. 8 of the Guidelines: (1) project sites with available wind-wildlife data, (2) project sites with little existing information and no indicators of high wildlife impacts, and (3) project sites with high or uncertain potential for wildlife impacts. (In addition, a fourth category is deemed off-limits to wind development due to government restrictions.) The characteristics used to define a site are not consistent among the categories. For example, Category (1) sites are generally defined based on the existence of data; however, the level of potential risk is not included in the definition. Category (2) sites are described as possessing little data and having no obvious “red flags” that emerge from a preliminary site assessment, and Category (3) sites are not linked to the amount of available data, but are principally defined based on “high levels of bird/bat use” or “considerable uncertainty regarding bird or bat risk.”

The categorization levels and the site characteristics/data availability/risk determinations required to categorize a site specifically are generally difficult to understand. In any case, no guidance is provided on the definition of “little data” or “high levels of bird use,” leaving the investigators confused during the initial project stages. Also, the Guidelines provide no information or decision pathways for re-categorization of a specific site. For example, initially a site could fall into Category 1 (little data), but after initial data collection investigators could determine that the site should have a designation of Category 3 (high use).

Furthermore, the concepts of data availability and risk are intertwined in the categories, leading to more confusion. Little data availability, for example, is not necessarily associated with high risk. Conversely, high use patterns are not necessarily determined from large amounts of data. Category 1 projects, for example, have the advantage of existing data from nearby similar projects, therefore a reduced study effort may be appropriate. However, explicit guidance on how to determine whether or not data from other sites is representative of the site of interest is not provided. In addition, the Guidelines state that Category 1 sites should have little uncertainty as to the level of impact, yet the Guidelines provide no information on the concept of uncertainty or the definition of an impact. Category 1 sites require less monitoring than other sites, but the vagueness of the definitions leave both regulators and wind turbine developers with no specific methods for judging whether or not additional data are required.

The Guidelines suggest that screening of the site for purposes of categorization should address whether the proposed site is “near a known or potential bat roost.” As stated in the Guidelines, implementation of this recommendation is not fully realistic, as a number of bat species in California either roost in crevices of trees or in the foliage of woody vegetation, and these species switch roosts frequently, often in the course of one or a few days. Recommendations concerning identification of bat roosts in pre-siting assessments in the Guidelines would be more useful if written to emphasize identification of important maternity roosts or hibernacula, rather than all potential roosts.

The Guidelines specify that if site-specific information indicate that risk to bats is low, pre-permit monitoring of bats is not necessary. Given the paucity of information about migratory patterns of bats, it is difficult to imagine what type of prior site-specific information could be used to conclude that the risk to bats is going to be low in the absence of data collected to determine this. That being said, given that it appears that bats may respond to changes in the environment resulting from construction of wind turbines by changing use of areas, the most appropriate pre-siting information to use for assessing risk to migratory bats remains unclear. Better understanding of the relationship between pre-siting activity data collected through echolocation monitoring and risk to bats is a key information need.

The initial categorization of a site is an important step in the Guidelines. For example, the study duration depends upon site classification (e.g., p. 16). In addition, the number of samples and types of data-collection methods are linked with site classification (e.g., p. 16 of the Guidelines links the amount of time associated with bird-use counts to the site category).

2.1.2 What the Recent Literature Says on the Subject

The References beginning on p. 83 of the Guidelines do not provide insights into alternative methods for categorizing a site nor do they provide insights into the development of the categorization scheme proposed on p. 8 of the Guidelines.

The Guidelines do not provide decision-oriented guidance for the classification of sites, nor do the Guidelines explicitly link the amount and types of data required to identify the magnitude of impact to birds or bats within a specific site category.

Decision-oriented frameworks leading to site classifications have been used by agencies around the globe. Some of these frameworks may be appropriate for assessing the effects of wind projects on wildlife. The National Wind Coordinating Committee (NWCC) Wildlife Workgroup, subgroup on Risk Assessment, produced *Ecological Risk Assessment: A Framework for Wildlife Assessments at Wind Energy Facilities (2007).* The NWCC document suggests that a decision-oriented tiered paradigm may be useful for determining impacts to birds and bats at wind turbine facilities. Some of the following information is taken from the NWCC document; the complete document is on the NWCC web site.

There are numerous examples where decision-oriented frameworks have been applied to wildlife assessments, including at wind energy facilities (Leddy et al. 1999). These decision-oriented approaches include ecological risk assessment (ERA) methods and practice.

As practiced worldwide, ERA is a tool that could be used to support regulatory decision making related to the Endangered Species Act, Migratory Bird Treaty Act, and other laws enacted to protect wildlife. ERA frameworks and underlying approaches are both broad in scope and adaptable for specific issues; see Urban and Cook (1986) and USEPA (2004). The actual practice of ERA depends on the issues under review; the regulatory agencies involved; and the depth, breadth, and scope of the biological and environmental implications of the resulting decisions.

By assessing the likelihood of an environmental impact to individual birds or bats (or in some cases populations of birds and bats) resulting from the decision to build a wind energy facility, a risk assessment can provide all parties with enough information to allow them to make an informed decision (USEPA 1992). For wind facilities in California, a concept of interest under the California Environmental Quality Act (CEQA) is "significant" impact. The definition of impact under State and Federal wildlife protection laws is more difficult because, for many species, the threshold of tolerable impact is legally zero.

Data supporting the decision analysis can come from historical or current studies of the site or similar sites, and the risk assessment results can be used for a variety of purposes, including environmental management decisions. For example, an assessment of current risk to bird populations from existing wind energy facilities can be used to focus the development of new approaches to reduce adverse impacts such as site-specific control measures. In a risk assessment, the potential for environmental impact and the uncertainty associated with that potential are examined in a structured context where the amount and types of information selected are tailored to the decisions or issues of interest.

Unlike the Guidelines' site characterization scheme, most risk frameworks focus on the methods and decisions inherent in an environmental assessment. As practiced, decision frameworks have some common characteristics: (1) a common vocabulary to enhance communication, (2) the use of a tiered framework for decisions, and (3) an emphasis on stakeholder involvement in the regulatory decision process. The tiered framework typically found in decision-oriented assessment guidelines is expected to provide a superior decision-making process over that presented in the Guidelines because (1) methods and metrics appropriate for each tier of the assessment are clearly defined, (2) an emphasis on the question or problem of interest must be clearly communicated, (3) methods for assessing the degree of impact are agreed upon and consistent among studies, and (4) the minimum amount of data required at each tier can be used in the decision-analysis, and additional information need not be collected unless required to achieve more accurate determinations of impact.

Many regulatory agencies have endorsed decision frameworks that apply a tiered assessment strategy. In practice, analyses conducted at a lower tier require less information to reach decisions than those conducted at a higher tier. Tiers are generally associated with the amount of uncertainty that is acceptable for supporting the decision(s) under review. For example, suppose that several sites are available for construction of a wind energy facility and the investigators are interested in comparing the relative magnitude of raptor mortality at each site. A lower tiered assessment, which can be accomplished in a short time on a limited budget, may include a literature study and a short-term field investigation. The relative uncertainty of this approach is high, but the cost is low. If the uncertainty in the magnitude of raptor mortality is high, or if the chance of raptor mortality is found to be unacceptable, then the investigators are required to proceed to the next tier in the assessment. However, if the chance of raptor mortality is low (with little uncertainty), the assessment Tier I assessment is considered final. The methods for assessing mortality, the minimum amount of data required, methods for the selection of biological metrics used in the assessment, and the definition of uncertainty are very clearly identified in the Tier I assessment.

Higher-tiered assessments generally require more extensive analysis of site-specific data, and may include the use of models. The need for any specific tier is established by the feedback loop built into most decision frameworks. As the information for each tier is processed, the need for additional studies to support the impact decisions can be addressed. In most decision frameworks, specific guidance is provided on the biological measurements and site-characteristics that should be collected within each tier of the assessment. In some cases, specific methods for analyzing the data are presented. In some cases, distinguishing between monitoring and research may become an important issue. The objective of monitoring is to track environmental changes over long time periods. Typically, a set of correlated variables that are indicative of environmental impact are measured and trends in the variables of interest are examined. Monitoring is less intensive, typically lacks a control structure in the survey design, and is less expensive than research. Research is generally considered a short-term activity, is usually expensive, and employs a structured study design. In a risk assessment framework for a specific site, short-term research may be of interest.

A review of the National Research Council's (NRC) *Environmental Impacts of Wind-Energy Projects* (2007) indicates that this document also does not provide guidance on the categorization of sites. However, the document discusses and encourages many of the standard characteristics of a formal decision framework. For example, in Chapter 4, Planning for and Regulating Wind-Energy Development, the document discusses policy implications of the assessment of wind turbine effects (p. 204), public participation in the review process (p. 200), and proactive planning and evaluation of cumulative effects (p. 209). A guide for evaluating wind energy projects appears in Box 5-4, p. 214 of the document. The guide is not generated in a risk context or a tier-decision context, but many of the issues addressed in Box 5-4 are elements of a basic decision-based approach for assessing wind turbine wildlife effects.

2.1.3 Proposed Research to Validate the Issue

The following activities are recommended prior to establishing a decision framework for wind power sites:

Comprehensive Literature Review

The NRC (2007) report attempted to review existing frameworks, but did not propose a formal decision framework in use for wind energy development. A comprehensive literature review of successful decision frameworks and strategies for use at wind turbine sites was not identified after extensive searching by the authors of this report. In some cases, individual site managers may be employing the characteristics of a decision framework, but the description of the decision-making activities may not be consistent with the typical language of a decision-oriented tiered assessment. The objective is to review and document successful decision frameworks in the U.S., Europe, Australia, Canada, and other parts of the world (Step A). The literature review would include resource development activities in the wind power literature, and other areas. There may be decision frameworks that are not risk-oriented, or risk-based, that could be useful in wind permitting issues. The literature review is intended to address decision-making frameworks generally. However, emphasis is placed on risk-based frameworks like those proposed by EPA.

Evaluation of Existing Decision Frameworks for Wind-Turbine Facility Assessments
Each of the successful decision frameworks in Step A should be evaluated (Step B). Information collected should include such topics as the following: (1) methods for establishing a tiered framework for decision-making, (2) types of pre- and post-construction data collected, (3) tier-specific and general methods for data analysis, (4) biological and site characteristics that were of most use in risk-based decisions, (5) interaction of the decision framework with local and national regulations, and (6) methods for incorporating stakeholder review and interaction in the decision process.

Selection of the Most Workable Frameworks
Based on the information evaluated in Step B, the "best" approaches for developing a risk-based decision framework for wind turbine development will be selected (Step C). Alternative "straw" frameworks will be constructed that include elements of the decision frameworks identified in Step B, above.

Onsite Evaluation and Testing of the Decision Framework
A proposed wind-turbine site will be selected for testing the proposed decision frameworks constructed (Step D). Agreements among the project team -- a wind turbine developer and regulatory personnel – will be required for successful implementation and testing of the frameworks as part of the site-selection process. Participating regulatory agencies will be full participants in the planning and implementation of the risk-assessment methods and procedures, including selection of biological endpoints, evaluation of tier characteristics, analysis of data, and determination of risk. Decisions generated from the alternative frameworks will be generated and contrasted.

Proposed Final Framework
The results of the assessment conducted under the proposed frameworks will be evaluated (Step E). Those aspects of the program that were successful or unsuccessful will be closely examined. Changes in the decision framework and risk-assessment implementation procedures will be proposed based on the information gained during the field trial. A final risk framework will be published in the peer-reviewed literature.

2.2 Statistical Aspects of Pre-Permitting Survey Design

2.2.1 Issue and Its Importance for Implementation of the Guidelines

Chapter 3: Pre-Permitting Assessment contains information for conducting a pre-construction assessment of a wind-turbine facility. The Guidelines states (p. 40) that "a pre-permitting study begins with a clear identification of the impact questions that must be addressed and then establishing a study design appropriate for answering those questions, including sampling units, parameters, metrics (measurements), and specific methods to employ." Specific statements concerning statistical design issues that are found in Chapter 3 of the Guidelines follow:

Bird Use Counts (BUCs)

- Conduct BUCs for 30 minutes once every week during the season of interest; sequence observation times to cover most daylight hours (p. 44).

- For raptor behavior studies, the surveyor should record locations and behavior at short intervals (30 seconds, for example) (p. 44).
- Report the results of bird use surveys as number of birds for a specified time period and area (p. 44).
- Select BUC sample sites at vantage points that offer unobstructed views; the sample sites should be approximately 5,200 ft (1,600 meters) apart for large wind resource areas with good viewsheds (p. 45).
- The spacing of sample sites can vary, as needed, depending on topography (p. 45).
- The BUC locations should coincide with proposed turbine or turbine string locations. If the turbine sites are unknown, the researcher can superimpose a grid over the portion of the site that will support turbines and select sample points either randomly or systematically from the grid (p. 45).
- The number of selected sample points depends on the number and spacing of turbines, the ability to observe several potential turbine locations from a single point, whether large or small birds are the study focus, and the heterogeneity of terrain and habitats (p. 45).
- Establish sufficient sample points to achieve an average minimum density of 1 to 15 sample points every 1 square mile. The number of points can be reduced in overlapping viewsheds (p. 45).
- On large projects, a systematic sample with a random start can reduce bias (p. 45).
- If the project consists of nine or fewer turbines, sample each site (p. 45).
- If greater than 50 turbines, a systematic sample selecting every third turbine may be used. The goal is to achieve analytical and statistical variance objectives (p. 45).
- On sites that support multiple habitat types, systematically stratify sampling among the habitats to ensure sufficient analysis of habitat variability (p. 45).

Raptor Nest Searches

- Conduct raptor nest searches within a radius of a least one mile of proposed turbine locations (p. 46.).
- Nest surveys can be conducted from the ground or air (p. 46).

Song bird counts (SBC)

- SBC sampling sites can be the same as BUC sites, but with a smaller radius ranging from 160 to 330 feet depending on habitat type (p. 47).
- SBC sampling points should be 820 ft (250 meters) apart to reduce the probability of double-counting birds (p. 47).
- The exact number of SBC sample sites is difficult to determine without knowing the size and extent of the project site, but sample the site sufficiently to obtain data for answering the research question within acceptable confidence limits (p. 47).
- To determine which birds are breeding on the project site, conduct SBCs three times at approximately two-week intervals during the appropriate time of year. Conduct surveys no earlier than a half-hour before and no later than four hours after sunrise. Time spent at each count station should be 10 minutes (p. 47).

- If precise estimate of density is required for a particular species, the researcher should establish enough sample points to have about 100 independent observations of the species (p. 48).

Study Design

- Use before-after/control-impact (BACI) and impact gradient designs for projects that need to address displacement effects (p. 48).
- BACI designs with replicated reference sites provide a rigorous basis for statistical analysis and supportable scientific conclusions (p. 48).
- Multiple references improve discrimination between project impacts and impacts resulting from natural temporal changes or other factors (p. 48).
- A BACI design with a single site, the site that will be developed, but no reference site, only provides a comparison of data from before and after construction of the project (p. 48).
- For small and homogeneous sites, an impact gradient design may be a more appropriate means to assess impacts on resident populations (p. 49).
- Area searches are used infrequently, but can augment BUC data on species presence if the avifauna of the project site needs more thorough documentation (p. 49).
- Standardized area searches are also useful for providing species richness data that can be compared between different project areas or for sites within a single area wind resource area (p. 49).

Migration Counts

- Station surveyors throughout the wind resource area approximately every two miles along an east-west axis (p. 50).
- Start observations around 0900 hours. Migration counts are typically conducted for an eight-hour period, four days per week for 10 to 13 weeks to assess large bird migrations during the fall and 8 to 10 weeks during the spring (p. 50).

Mist-Netting for Birds

- Establish mist-net stations, with 10 nets per station, approximately every two miles in an east-west axis. (p. 50).

Bat Survey Methods - Acoustic Detection

- Conduct acoustic monitoring for bats at all proposed wind energy sites unless defensible site-specific data are available indicating there is no risk. Monitoring for a full year is recommended (p. 55).

2.2.2 What the Recent Literature Says on the Subject

After reviewing the references beginning on p. 83 of the Guidelines, no literature (in either the References section or the additional literature reviewed) supporting the following statements was found:

- “Select BUC sample sites at vantage points that offer unobstructed views; the sample sites should be approximately 5,200 ft (1,600 meters) apart for large wind resources areas with good viewsheds.” (p. 45)
- “Establish sufficient sample points to achieve an average minimum density of 1 to 15 sample points every 1 square mile. The number of points can be reduced in overlapping viewsheds.” (p. 45)
- “If the project consists of nine or fewer turbines, sample each site.” (p. 45)
- “If greater than 50 turbines, a systematic sample selecting every third turbine may be used. The goal is to achieve analytical and statistical variance objectives.” (p. 45)
- SBC sampling sites can be the same as BUC sites, but with a smaller radius ranging from 160 to 330 feet depending on habitat type (p. 47).
- SBC sampling points should be 820 ft (250 meters) apart to reduce the probability of double-counting birds (p. 47).
- To determine which birds are breeding on the project site, conduct SBCs three times at approximately two-week intervals during the appropriate time of year. Conduct surveys no earlier than a half-hour before and no later than four hours after sunrise. Time spent at each count station should be 10 minutes (p. 47).
- If precise estimate of density is required for a particular species, the researcher should establish enough sample points to have about 100 independent observations of the species (p. 48).
- “Establish mist-net stations, with 10 nets per station, approximately every two miles in an east-west axis.” (p. 50)
- “Station surveyors throughout the wind resource area approximately every two miles along an east-west axis.” (p. 50)

A review of the literature indicates that there is little consistency among approaches for monitoring at wind turbine facilities in the pre-permitting phase. Recommendations provided in the Guidelines are of a general nature (e.g., “sample the site sufficiently to obtain data for answering the research question within acceptable confidence limits”), do not provide data quality objectives, and do not provide guidance on how much data is required for permitting decisions. For example, no studies were found in the literature that rigorously evaluated the amount of data required to establish estimates of time and space variability.

Particularly insightful references for a general understanding of the issues in survey design include Anderson et al. (1999) and Morrison et al. (2001) [note: the Guidelines reference this book as Strickland et al. 2002]. A review of the wildlife survey design literature finds that most references agree with the following Guidelines statement: “a pre-permitting study begins with a clear identification of the impact questions that must be addressed, and then establishing a study design appropriate for answering those questions.”

In general, a large range of approaches and methods associated with implementing site-specific survey designs at wind energy sites is available in the literature. There seems to be little consistency among such issues as selecting survey design specifications, methods for selecting the amount of information collected during the survey, placing stations, and determining the duration of sampling. This lack of consistency in the literature may have lead to the greater use of general statements in the Guidelines.

Anderson et al. (1999) and Morrison et al. (2002) provide clear descriptions of the types of survey designs available to wildlife biologists. However, neither document provides guidance on the selection of specific survey designs within the context of a specific biological or regulatory context. The Guidelines statements, such as the one on p.48, "A BACI design with a single site, the site that will be developed, but no reference site, only provides a comparison of data from before and after construction of the project" are well referenced in the literature, but in context these type of general statements may leave project-level investigators with little understanding of how to evaluate, select, and implement a specific design.

Morrison et al. (p. 144) provides general guidance on the difference between a survey resulting in an inventory and a survey associated with monitoring. In the context of the Guidelines, an inventory sample may be part of a pre-permitting assessment, while a monitoring study is associated with post-construction. From a survey design perspective, the implementation of the data-collection process and the amount of data required during these periods may be different. When designing a study related to wind energy, the guiding principles described in references such as Anderson et al. (1999) and Morrison et al. (2002) should be followed.

In addition, linking the survey design, including the amounts and types of data required for various decisions, may be even more important within a tiered-decision framework (see above). For example, the relative degree of impact at sites with "high" risk may require information leading to greater accuracy and precision in bird/bat mortality estimates than those sites with less measureable risk. The statement found on p. 49 of the Guidelines, "for small and homogeneous sites, an impact gradient design may be a more appropriate means to assess impacts on resident populations" is relatively useful. However, without a definition of a "small and homogeneous site" this statement leaves investigators with only their subjective judgment on whether or not to employ a gradient design. Latitude of this type within a guidance document can, in some situations, be useful because individual site investigators are free to conduct research on survey design selection issues and make site-specific determinations leading to design selection. On the other hand, without explicit guidance on the issues that should be considered in selecting a specific design alternative, the array of approaches used across wind projects in California may lead to inconsistency in risk determinations during the data analysis phase of a site assessment.

For BUCs and SBCs, explicit guidance on the number of samples and placement of sampling locations is provided in the Guidelines. However, no supporting evidence is given for the stated specifications which would support their accuracy over other approaches. In particular, the expected accuracy and precision of the estimates that result from the Guidelines' stipulations are not stated.

A key issue in survey design is the determination of the number of samples required for the question of interest. For example, Morrison et al. (2002) states: "Wildlife populations and ecologies typically vary in time and space. A study design should account for these variations to ensure accurate and precise estimates of the parameters under study" (p. 115). The Guidelines provide the reader with no understanding of how the BUC and SBC survey specifications were determined, how the Guidelines provide the required accuracy and precision needed for the questions under review, or why these approaches are superior to alternatives.

Anderson et al. (1999, pp. 20 - 36) presents an excellent review of various statistical designs, the use of pilot studies, and the differences between survey-based and model-based inferences. Although this information is presented in a general form, the information and concepts in these sections are important considerations in the generation of a pre-construction survey design. However, the Guidelines provide little or no information on these key issues; or information allowing the reader to choose among the various designs that may be site-appropriate.

References and discussion that may be useful for establishing the placement and spacing of samples (p. 113), methods for sampling small areas (p. 114), the difference between sampling and complete enumeration (p. 114), and sampling for rare species (p. 114) are provided in Morrison et al. (2002). Although these issues are addressed in practice during the survey selection phase, they are not directly addressed in the Guidelines. The Guidelines should provide clear guidance on these issues.

Another key issue that could be addressed by the Guidelines is the use of observational studies that are sometimes used in Tier I (initial-stage) assessments (Kerlinger 2005). For example, guidance could be provided on the characteristics of observational studies and the degree to which comprehensive literature reviews are required to ensure the site-specific impact potential.

Finally, lack of firm recommendations on use of pre-permitting assessment data in the Guidelines creates a high likelihood that considerable time, effort, and resources will be devoted to collecting data that will not be used in a meaningful way in macro- or micro-siting decisions. In addition, a lack of *a priori* understanding of the use of the data impedes development of appropriate survey design; without a clear linkage between survey data and their practical application it is not possible to determine critical elements necessary for survey design, such as the precision needed from data collected in surveys, and thus the most appropriate sampling intensity. Moreover, without a clear linkage between survey data and their eventual use, sampling is likely to be inefficient, resulting in excess information on species or factors unimportant in the decision process and inadequate information on others, resulting in inefficient use of human and financial resources. The lack of *a priori* linkages between data collected and their eventual use could create an uncertain management context for the wind industry; this uncertainty could impede the use of these voluntary guidelines. In sum, the Guidelines' lack of well articulated linkages between survey data collected and use of those data, could seriously undermine the efficacy and meaningfulness of the survey efforts.

2.2.3 Proposed Research to Validate the Issue

Specific guidance for determining pre-permitting survey designs, including the selection of specific statistical designs to answer specific scientific and regulatory questions, would be a useful contribution to the wildlife literature. The steps in the development of this research follow.

Review of Available Literature
After extensive searching, a literature review summarizing successful approaches to, and applications of, study designs associated with pre-permitting assessments was not found. This

review could focus on the following issues: (1) precision and accuracy of specific metrics (like mortality or abundance) associated with various survey designs, data-collection protocols, sample sizes, sample placement strategies, and monitoring durations; (2) successful strategies for linking specific designs with regulatory and scientific issues of interest to the investigators; (3) proper interpretation of the resulting information; (4) methods for generating risk-based decisions associated with various monitoring strategies, and (5) successful approaches for communicating the results of the survey to both regulatory staff and the public.

Compilation of Data Associated with Various Survey Designs

The results of the above literature review may indicate that information on key issues may not be readily available in the open literature (e.g., estimates of precision and accuracy for specific metrics collected under specific survey design strategies). A compilation of available data from wind turbine sites may allow statistical issues of key importance to design selection to be evaluated. Hopefully, such information can be obtained confidentially and compiled into a readily available data base, such as Microsoft Excel or Access.

Statistical Evaluation of Data

Using the data compiled in the above step, simulations could be conducted to evaluate survey design issues such as the amount of data required to meet pre-defined requirements for accuracy and confidence, and the impact of pre- and post-construction sampling duration on environmental decisions. Of course, the data base will not be completely representative of the large variation in environmental conditions found in California, but many of the insights gained from the analysis of these data may be applicable on a wide geographical scale. In any case, the resulting information could provide insights leading to more precise guidance on these design issues than is currently readily available in the literature or in the Guidelines. In addition, the resulting information should provide insights into (1) the relative precision for specific metrics that can be achieved under various design strategies, (2) insights into the selection of design strategies based on confidence and accuracy requirements, and (3) insights into successful approaches for answering specific questions or issues.

Association of Pre-Permitting Data and Survey Requirements with Impact Quantification

The Guidelines link data requirements with the categorization scheme described on p. 8 of the document. A protocol for linking design requirements to specific tiers within a structured decision framework may prove a useful approach to establishing the data requirements that are consistent with site conditions. Guidance on the placement of samples, the amount of data required, and methods for interpreting the resulting information could be useful. For example, if Tier I pre-permitting survey approaches indicate little possibility for significant impact, the amount of additional data could be minimized. However, if the potential for significant impact is high or uncertain, additional pre-permitting data collected under rigorous survey design protocols may be required.

2.3 Statistical Aspects of Operations Monitoring

2.3.1 Issue and Its Importance for Implementing the Guidelines

Chapter 5, Operations Monitoring and Reporting, describes techniques for collecting, interpreting, and reporting post-construction operations monitoring data for comparison to impact estimates generated from pre-permitting studies. Specific statements concerning statistical design issues found in Chapter 5 follow:

- "The number of carcasses counted during operations monitoring is likely to be an underestimate of the birds and bats actually killed by wind turbines." (p. 71)

Duration of Operations Monitoring

- "Category 2 and 3 projects will need two years of carcass count data to assess whether pre-permitting impact estimates were accurate, evaluate the effectiveness of mitigation measures, and capture variability between years." (p. 72)
- "Category 2 projects may be able to reduce the level of study effort for Year 2 if the results of Year 1 monitoring indicate fatality rates equal to or lower than those estimated during pre-permitting studies …" (p. 72)
- "Category 3 projects may need additional study effort in Year 2 and possibly beyond if the first year of data shows fatalities higher than expected and/or to different species than anticipated." (p. 72)
- "Category 1 projects may need only one year of operations monitoring. Reduced monitoring during the second year might be appropriate for Category 1 projects if the first year provides scientifically defensible data documenting that fatality rates were as expected and similar to those from nearby projects." (p. 72)
- "The two years of operations monitoring need not necessarily be consecutive. After monitoring the turbines during the first year after operation, one option is to wait a few years to complete the second year of monitoring." (p. 72)
- "Operations monitoring beyond two years will rarely be needed if impacts to birds and bats estimated during the pre-permitting studies have been adequately avoided…" (p. 72)
- "Operations monitoring on a periodic basis (for example, every 5 years) for the life of the project should occur if operations monitoring data or other new information suggest that project operation is likely to result in fatalities to birds or bats that were unanticipated and unmitigated during permitting of the project." (p. 73)

Determining Bird and Bat Abundance and Behavior During Operations

- "For Categories 2 and 3 projects, conduct one year of bird use counts during project operation to characterize bird species composition and abundance, behavior, and season presence." (p. 73)
- "Bird use count methods should be consistent with those used during the pre-permitting studies, but can be tailored to specifically address issues that may have arisen during those studies." (p. 73)
- "Acoustic monitoring for bats during operations is not recommended unless data from pre-permitting studies indicate information about the ambient level of bat activity is necessary to adjust the bat fatality data." (p. 74)

Carcass Searches

- "Establish search plots at approximately 30 percent of the turbines." (p. 74)
- "The search area should have a width equal to the maximum rotor tip height." (p. 74)

- "Surveyors can select a search area that does not encompass 100 percent of the carcasses, as indicated by pilot searches or incidental observations of carcasses outside the search area. However, surveyors must quantify that source of error, make corrections in the final calculation of fatalities, and disclose that information in the monitoring report." (p. 74)

Conducting Searches

- "This document recommends a standard transect 20 feet wide, 10 feet on either side of the centerline, but adjusted to the transect width for vegetation and topographic conditions on the site." (p. 17)

Frequency of Carcass Searches

- "Carcass searches for birds and bats should occur approximately every two weeks, with searches more or less frequent if pilot scavenging trials indicate high or low levels of carcass removal." (p. 76)
- "Establish the frequency of carcass searches at wind energy project site after analyzing the results of pilot scavenging trials…" (p. 76)
- "Most researchers conduct carcass searches on a regular schedule of days with the assumption that fatalities occur at uniformly distributed, independent random times between search days." (p. 76) Researchers should be aware that if the fatalities are highly clustered, estimates of fatalities could be biased, especially if carcass removal rates are high.

2.3.2 What the Recent Literature Says on the Subject

The literature does not contain any guidance that is consistent with the specification of site Category. Statements (like the following) that require specific actions that are a function of a category designation are not in the literature:

The following guidance statements are supported in the literature generally, however, a rigorous statistical evaluation of the following was not found:

- "Category 2 and 3 projects will need two years of carcass count data to assess whether pre-permitting impact estimates were accurate, evaluate the effectiveness of mitigation measures, and capture variability between years." (p. 72)
- "For Categories 2 and 3 projects, conduct one year of bird use counts during project operation to characterize bird species composition and abundance, behavior, and season presence." (p. 73)
- "Category 1 projects may need only one year of operations monitoring. Reduced monitoring during the second year might be appropriate for Category 1 projects if the first year provides scientifically defensible data documenting that fatality rates were as expected and similar to those from nearby projects." (p. 72)

In addition, literature supporting the following was not found:

- "Establish search plots at approximately 30 percent of the turbines." (p. 74)
- "The two years of operations monitoring need not necessarily be consecutive. After monitoring the turbines during the first year after operation, one option is to wait a few years to complete the second year of monitoring." (p. 72)

- This document recommends a standard transect 20 feet wide, 10 feet on either side of the centerline, but adjusted to the transect width for vegetation and topographic conditions on the site.

A review of the literature indicates that there is no consistent approach for monitoring at wind turbine facilities during the operations phase. Therefore, the recommendations in the Guidelines that are of a general nature (e.g., using one or two years of monitoring data) can be found in various literature sources. However, the survey designs proposed in those sources appear to be opinion- or experienced-based, rather than based on rigorous statistical goals (e.g., collecting enough data and data of a certain quality to be accurate within a pre-specified percentage). A rigorous approach for establishing the amount and types of data required for operations monitoring was not found in the literature.

Overall, the amount of monitoring data and the survey strategies used to generate the data vary greatly among studies. For example, Erickson et al. (2007) states: “We recommend a minimum of two years of pre-construction study to estimate densities of bird species. However, the typical schedule of permitting and development for projects and the uncertainty in the specific project layouts often limit pre-project sampling to a single year. A bare minimum of two years is definitely recommended for post-construction study, so that longer-term effects can be distinguished from transient ones.” However, even Erickson’s document does not provide statistical arguments for these recommendations, but rather bases the recommendations on practical experience and knowledge of the biological system and dynamics of the avian population.

A review of issues for establishing survey designs during the post-construction period is found in Morrison et al. (2002, Section 6.3, pp. 144 – 155). Morrison et al. provides insights into such issues as selecting proper monitoring designs, selecting monitoring designs for specific goals, timing sampling to meet population cycles, and providing alternatives to long-term studies. However, the Morrison et al. text and other documents providing general guidance (e.g., Anderson et al. 1999) do not provide detailed guidance for specific site conditions or site-specific regulatory and scientific questions of interest (although Morrison et al. and Anderson et al. do present case studies as an aid to the reader). While the Guidelines do provide general recommendations such as the following, “Establish the frequency of carcass searches at wind energy project site after analyzing the results of pilot scavenging trials …. (p. 76),” details on the methods and procedures for establishing the statistical survey details are not provided and are not explicitly linked to the potential effects on wildlife.

The Guidelines do not explicitly link the duration of monitoring required, the types of data collected, and the amount of data collected to the level of risk attributed to a specific site. In most risk-based paradigms, an assessment of potential risk is required before establishing post-construction monitoring requirements and the methods for assessing the risk potential are explained in sufficient detail to foster consistency among the regulated community.

2.3.3 Proposed Research to Validate the Issue

Research on the statistical aspects of operations monitoring should contain the same steps and components as those presented for statistical issues associated with pre-permitting studies: (1)

review available literature, (2) compile data associated with various monitoring designs, (3) conduct a statistical evaluation of the compiled information, and (4) generate a guidance document linking monitoring requirements with measured risk metrics. Again, the approach would be to generate specific decision-based approaches for selecting specific designs and their associated characteristics (e.g., duration, sample placement, methods of statistical inference, etc.).

2.4 Statistical Methods and Models: Recommended Formulas for Adjusting Fatality Rates

2.4.1 Issue and Its Importance for Implementing the Guidelines

Appendix F (p. 79) presents a conceptual equation for adjusting the unadjusted fatality rate to the true mortality rate based on (1) the probability that the carcass has not been removed in an interval ($S_{nr)}$, and (2) the probability that a carcass present at the time of a count period is detected (p_d). The Guidelines provide the reader with references for formulating, and methods for calculating, adjustment factors and fatality rate (p. 79): Gauthreaux (1995), Orloff and Flannery (1992), Kerns and Kerlinger (2004), Erickson et al. (2004), Shoenfeld (2004), and Smallwood (2006).

2.4.2 What the Recent Literature Says on the Subject

A review of the references beginning on p. 83 of the Guidelines indicates a great deal of discrepancy in the approaches used to adjust the found mortality rate to the true mortality rate. However, none of the references provides experimental evidence that the Appendix F equations result in accurate mortality rates. In fact, the references do not contain the equation presented in Appendix F.

A number of equations are found in the peer-reviewed literature for adjusting the measured mortality for the true number. Shoenfeld (2004, and as cited in Erickson et al. 2004) provide an interesting mathematical basis for the derivation of an adjusting constant that reflects both observer bias and scavenger bias. The equation, which is dependent upon several distributional assumptions, is tested using mathematical simulation techniques. Other available methods calculate the potential incremental increase due to various sources of bias (e.g., search, removal, habitat, and crippling bias), and use a linear additive model (e.g., Gauthreaux 1995) to estimate true mortality. Smallwood (2006) uses the Appendix F equation (along with a non-linear model for scavenger efficiency) to adjust measured mortality. However, the Smallwood (2006) paper provides no empirical support that the resulting adjusted mortality results in the true mortality rate. In addition, except for the Schoenfeld model, methods for estimating the uncertainty in the adjusted mortality rate are not provided in the literature.

Environment Canada’s 2006 guidelines document (Environment Canada 2006) also notes that various methods for experimentally deriving searcher bias and scavenging rates are not consistent in the wildlife literature. For example, carcass removal experiments to estimate scavenging rates must be conducted (1) at least twice during each season when searches are being undertaken, as the suite of scavengers is likely to change through the year, and (2) with carcasses that resemble native birds and are freshly dead or were frozen when freshly dead. The Canadian guidelines state that searcher efficiency must be tested for every individual or team involved in searching for carcasses (including teams using dogs). Searcher efficiency values are not transferable to a different individual or team or to a different substrate. The Canadian guidelines also note that a variety of statistical approaches have been used to estimate total mortality, incorporating all necessary correction factors. Because these are likely to improve over time as further data are accumulated, all proponents are asked to retain all raw data to allow for flexible reanalysis in future.

2.4.3 Proposed Research to Validate the Issue

Calculating adjusted mortality is an extremely important step in permitting and operating a wind turbine facility. Estimating equations should be experimentally vetted for accuracy, ensuring that the resulting mortality estimates do not, on average, either over- or underestimate the true mortality (or rate). The following example is presented to show the conundrum associated with the Appendix F equation.

Assume the following scenario: observer bias and scavenger bias studies were conducted independently at the site of interest. The result of these studies is considered truth (no uncertainty). The result of these studies is $p=0.2$ (observer bias) and $S=0.2$ (scavenger bias). To test the validity of the observer and scavenging studies, a third blind study was conducted at the site and 50 birds were put into the field. The investigators have no idea if observer bias is operating or scavengers are scavenging, and if both issues occur during the survey, the investigators do not know the proportional number of birds missed due to each cause (i.e., the blind study replicates the conditions most often encountered in wildlife studies). During this third study, the observers follow a pre-defined standard operating procedure for transect-line searchers with a search area consistent with the studies generating the bias constants. The equation used to calculate the “true” mortality is $M/ (S * p)$, as shown in Appendix F of the Guidelines.

The observers were able to find 10 birds. This is not unexpected or considered unusual since the true site-specific observer bias is 0.2. Perhaps there were no scavengers. Also, if the scavenging bias term in the equation is ignored, the truth is indeed found by calculating: $10/0.2 = 50$. Thus, by ignoring scavengers the equation works perfectly. However, the same result is found if observers are perfect and only scavenging occurs. Again, if the observer bias term is ignored in the equation, the equation works perfectly: $10/.2 =50$. Given the results of the independent scavenging study, the field results cannot be considered unusual.

The question thus remains: Which process is operating in the field, observer bias or scavenging bias? Is the combination of scavenging bias and observer bias equal to 0.2? The answer is unknown because the observer and scavenger bias study designs were conducted independently, and the interaction of these competing processes in the field was not tested under experimental conditions.

In most field searches the observer walks down a transect looking for a bird within a pre-defined area. If the bird is truly within eyesight and the observer misses the bird, then the “true” number of birds is miscounted and this finding could correctly be attributed to observer bias. However, if a scavenger obtains the bird before the observer has an opportunity to view the bird, observer bias has not occurred. In this case only scavenging bias has occurred. Notice that once the scavenger obtains a single bird, the number of birds that could be “found” by the observer during the observer bias study is reduced by one, thus changing the denominator of the observer bias "rate." The probabilities of observer bias and scavenging bias are therefore not independent. The interaction of observer and scavenging impacts on the ability to find the "true" number of birds is generally not evaluated during the independent studies used to generate observer and scavenging bias constants.

The Appendix F equation results in a high chance of overestimation for small birds and bats and a smaller chance of overestimation for larger birds. For example, in the above scenario the adjusted mortality accounting for both observer and scavenger bias is $10/ (.2 * .2) = 250$, which is very different from the true number of birds (50).

From a probability perspective, the observer bias is "conditional" on the chance of scavenging. Conditional probabilities are not calculated from standard field tests of observer and scavenger bias.

Resolving these issues will require two distinct areas of research. Initially, standard operating procedures for implementing field trials in which the interaction of observer bias and scavenging bias over the long term can be measured should be developed and tested. Field experiments should be designed to generate mathematical distributions representing the probability of observer bias conditional on the occurrence of scavenging. In addition, the probability of scavenging over time (similar to the data-based model generated by Smallwood 2006) should be generated under a variety of field conditions.

Given an understanding of the interaction of observer bias and scavenging generated in the initial experiments, various mathematical approaches and search protocols for estimating the true mortality (or mortality rate) should be tested under conditions in which the true mortality is known. Mathematical and statistical methods for estimating the error in the resulting estimates should also be tested under experimental conditions.

2.5 Analysis of Data

2.5.1 Issue and Its Importance for Implementing the Guidelines

The Guidelines provide little or no guidance on the appropriate statistical methods for evaluating the pre-permitting data or the monitoring data (other than the mortality adjustment in Appendix F). However, the Guidelines do imply that the proper analysis of data is a critical aspect of risk-based decision making in both the pre- and post-construction phases. Examples taken from the Guidelines follow:

- "Statistical methods for calculating bird and bat abundance and the associated variance within a year." (p. 41)
- "Estimation of seasonal variation associated with the time birds and bats spend in a risk zone." (p. 41)
- "Evaluation of existing data for the purpose of refining collection protocols." (p. 41)
- "Methods appropriate for estimating the uncertainty in mortality and other metrics." (pp. 9, 37, and others)

- "Approaches for estimating enough sample points to meet analytical and statistical variance objectives and to completely cover the area occupied by the proposed turbine locations." (p. 46)
- "The next level of a risk analysis is to make the assessment more quantitative by collecting data on the abundance and spatial and temporal distribution of birds and bats using the site, as well as data on their behavior and on the time birds and bats spend in areas where they might be at risk of collision and then comparing this information to existing data on fatalities at wind resource areas." (p. 62)
- "Before-after/control-impact: A study design that involves comparisons of observational data, such as bird counts, before and after an environmental disturbance and 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)." (p. 48 and in the definitions on p. 103)

2.5.2 What the Recent Literature Says on the Subject

As previously noted, Anderson et al. (1999) and Morrison et al. (2002) provide excellent general discussions of the statistical methods and decision-making approaches for addressing the above issues. However, detailed methods for addressing site-specific questions associated with these issues, such as time-series methods for estimating seasonal variation in bird and bat populations, are not explicitly addressed in these documents. A review of statistical methods associated with variance estimation on both temporal and spatial scales is probably beyond the scope of the Guidelines. However, the Guidelines could provide suggested methods for (1) site-to-site comparisons, (2) comparison of site-specific data to national averages, (3) comparison of site-specific data to comparable data collected at reference sites, and (4) general methods for communicating the statistical characteristics of the collected data to regulators and the public.

There are many advanced statistical text books on these issues, any one of which will provide details of the theoretical and practical considerations of wildlife data analysis.

2.5.3 Proposed Research to Validate the Issue

A reasonable approach to addressing wildlife data analysis issues is through the use of case study data. A data set containing monitoring information from wind turbine sites representing diverse biological systems in California or across the country would provide opportunities to address specific statistical issues. Once compiled, a variety of statistical approaches to the following issues could be evaluated: (1) time-series approaches for detecting trends and patterns, (2) statistical methods for comparing site-specific data to reference data, (3) methods for estimating variance components associated with biological metrics, (4) methods for estimating uncertainty, (5) model-based approaches versus survey approaches for estimating mortality, (6) the statistical advantages and disadvantages of estimating mortality under various survey design strategies, etc.

3. Ecological Foundations

This review identified several ecological assumptions upon which the Guidelines are based, including several survey approaches and data interpretations. Many of these assumptions are not supported by peer-reviewed publications. Some assumptions are supported by literature published after the Guidelines, such as NRC 2007.

3.1 Relationship of Abundance to Collision Mortality

3.1.1 Issue and Its Importance for Implementation of the Guidelines

The Guidelines assume that higher abundance of birds and bats will result in higher collision mortality at a wind farm. For example, the Guidelines assume that a high concentration of wintering raptors or breeding raptors is an indication of high risk (p. 9). The Guidelines do not clarify what abundance metrics are most appropriate and how they are associated with collision mortality.

The Guidelines do not explicitly define the term abundance as it relates to collision mortality. This can lead to confusion in discussing the relationship between abundance and collision mortality and the most appropriate survey methods to choose. Abundance is a general term that means quantity (e.g., number of birds) without necessarily specifying spatial and/or temporal dimensions. Two other forms of abundance are mentioned in the Guidelines: relative abundance and density. Relative abundance is the only term defined: “a percent measure or index of abundances of individuals of all species in a community” (p. 108). Density, although not defined in the guidelines, is the number of individuals per unit area.

The Guidelines recommend different survey techniques to collect information on species abundance (see Table 1. Comparison of Diurnal Bird Survey Techniques for Pre-Permitting Studies), but do not provide guidance on what to do with the information once it is collected. A raptor-use-versus-turbine-mortality regression from Strickland et al. (2006) is presented on page 163, although a note on page 123 cautions against using this simple assessment approach and extrapolating to fatality rates.

Another assumption in the Guidelines is that all non-raptor species respond the same way and have the same risks. The Guidelines differentiate between collision mortality risks to raptors and those to non-raptors and do not provide further differentiation of non-raptor taxonomic groups, such as songbirds, waterfowl, and shore birds, which have different behavior and thus different risks. This assumption is also seen in the discussion of special status species (Step 1, p. 6) and Category 3 projects (pp. 38-39). No references are provided. The implicit generalization is that special status species are more threatened by wind turbines or that any additional mortality may jeopardize them. This generalization is not supported by the literature.

3.1.2 What the Recent Literature Says on the Subject

According to recent literature, the assumption that high abundance of birds or bats indicates high collision mortality has not been consistently or commonly observed at operational wind farms (NRC 2007). Kingsley and Whittam 2007 (citing Everaert 2003) discuss the relationship of abundance in the form of density (i.e., number of birds per unit area) and mortality, stating that it theoretically makes sense, but has only been documented for gulls in one published study.

Examples where the assumption of a positive abundance-mortality correlation is not supported by the literature:

- Some species of passerines with relatively low abundance (e.g., horned lark, vesper sparrow, and bobolink) have behaviors that expose them to the rotor swept area, while other species are common (e.g., the western meadowlark), but are not commonly seen flying in the rotor swept area, although they are frequently reported killed (Kerlinger and Dowdell 2003, cited in NRC 2007).
- Crows, ravens, and vultures are some of the most common species seen flying within the rotor swept area (Orloff and Flannery 1996; Anderson et al. 1995; Erickson et al. 2004; Smallwood and Thealander 2004 and 2005, cited in NRC 2007), but are seldom found killed.
- Golden Eagles at Altamont have a mortality rate that is disproportionately high compared to their relative abundance (NRC 2007).
- High abundance of waterfowl and their frequent passage through the wind project area has not resulted in a proportionately high mortality rate for them as a taxonomic group (Koford et al. 2004).

For nocturnal migrations of birds and bats, the literature does provide examples of a positive correlation between abundance and mortality (e.g., Anderson et al. 2004):

- Higher mortality rates (e.g., birds/MW) have been reported for nocturnal passerine species as a species group during seasons of high abundance. Passerines as a group are the most common birds found in terrestrial ecosystems. Nocturnal passerine mortality can account for 69% to 86% of the mortality at wind farms nationally and regionally (Erickson et al. 2000, 2003b, 2004; Howe et al. 2002; Johnson et al. 2002, 2003b; Kern and Kerlinger 2004; Koford et al. 2004; and Young et al. 2001, 2003b, 2005, cited in NRC 2007).
- High mortality for bats occurs during peak migration periods (i.e., periods of high abundance) (Arnett et al. 2007). Arnett et al. (2007) and Cryan (2008) point out that bats may actually be attracted to wind turbines, thereby increasing their risk. However, this hypothesis needs to be tested to determine its validity and to identify the attractions.

The number of individuals per rotor swept area or rotor swept zone is an important abundance metric for assessing the impacts of wind turbines. The literature describes different kinds of abundances, including crude density (number per unit total space), ecological density (number per unit of habitat space), and population density (mean number per unit area). Although the number of individuals breeding in a WRA may not be an indicator of collision risk, the passage rate through the rotor swept area or rotor swept zone (e.g., number of birds per hour) is a temporal abundance index that has been used to characterize risk.

NRC (2007) points out that a number of factors -- spatial, temporal and locational occurrences, season, weather, ecosystem type, and the species themselves affect abundance and ultimately risks. Behavior and several other species-specific biological variables can affect avian mortality, as indicated by NRC 2007 and Kingsley and Whittam 2007. Migrant vs. resident birds, flight height, behavioral avoidance, and habitats can contribute to exposure and ultimately to mortality. NRC (2007) concludes that species differences affect their vulnerability and that abundance and behavior interact to influence the exposure of birds to wind turbines.

Based on estimates of relative abundance, resident birds have a lower collision rate than migrants. While there is a great deal of uncertainty regarding the actual percentage, the relative abundance of residents (hundreds) versus migrants during the migration season (tens to hundreds of thousands) suggests that the collision rate (# of collisions vs. # available to collide) would be much greater for migrants than for residents (Strickland 2008, personal communication). This difference in susceptibility may be due to the residents' familiarity with the area and their greater experience with turbines. Migrants may not have that familiarity and may encounter turbines more frequently under conditions of poor visibility (e.g., darkness or poor weather) that limit early detection and avoidance (NRC 2007). Periods of peak migration in most regions occur over several weeks each spring and fall. Collision mortality, particularly for passerines, at wind projects correlates to these migratory seasons, with most fatalities reported in the spring and fall. The pattern and timing are highly unpredictable at the fine scale of a particular project site and bird species.

Several environmental conditions (visibility, wind direction, speed, and duration) influence the likelihood of collision. Visibility is affected by ambient light levels, atmospheric conditions, and physical site conditions. Although these issues are important factors in bird mortality with communication towers, they do not seem to be as important with wind turbines. However, they are discussed here since they may act in association with other conditions to increase exposure (NRC 2007).

The literature suggests that differential mortality exists between different species and species groups. Monitoring methods need to be tailored to different species groups or different species to account for their characteristics (e.g., flight behavior, breeding behaviors, and feeding). Table 1 provides examples that illustrate differences observed in the abundance/collision mortality relationship for different species and taxonomic groups.

For bats, the abundance/collision mortality relationship is less well known than with birds. NRC 2007 (p. 135) lists 11 hypotheses to explain mortality in bats. A number of these hypotheses are behavioral, in which bats are attracted in larger numbers to wind turbines.

Table 1. List of Species Groups with Comments on Reported Mortality at Wind Farms (Sources: NRC 2007 and Kingsley and Whittam 2007).

Species Groups	Comments on Observed Mortality at Operational Wind Farms
Waterbirds (Duck, Goose, Pelican, Tern, and Skimmer)	• Mallards most commonly reported species of ducks killed. • Several species of gulls including the Herring Gull and several species of terns (Europe) commonly reported killed. • In U.S. no mortality of terns was observed for a single turbine coastal site, behavior avoidance was observed • Brown Pelican reported killed at the Altamont WRA.
Wading Birds (Heron, Egret, Ibis, and Spoonbill)	• A few species of herons and egrets infrequently reported including Black-crowned Night-heron (Altamont).
Shorebirds (Gulls, Terns)	• Small number of birds killed compared to abundance.
Raptors (Hawk and Eagle), Vulture, and Owl	• Various species of hawks, eagles, vultures, and owls reported, but higher raptor mortality in the U.S. is associated with certain wind farms (e.g., Altamont) where situational conditions and higher abundance result in atypical mortality rates. • Raptor fatalities at the modern High Winds and Diablo Winds facilities in California and Cotterel Mtn Idaho are much higher than areas outside of California, but raptor abundance is relatively high. The literature suggests that raptor fatalities are not infrequent where species prone to collision are abundant (e.g., Golden Eagle, Red-tailed Hawk, Kestrel).
Passerines	• Passerines (nocturnal migrants) account for majority of avian mortality reported at wind farms. The literature suggests that they are exposed in much higher numbers, but a quantitative estimate of exposure is lacking for nocturnal migrating passerines.

3.1.3 Proposed Research to Validate the Issue

A more detailed evaluation of the abundance/collision mortality relationship and population survey designs and metrics for the different avian and bat species is recommended. This analysis will better define the relationships between specific measures of abundance and mortality. It will also characterize the wind-related ecological factors in California that affect the relationship and make recommendations on what types of abundance data need to be collected and what survey methods should be used to collect this information in California.

Data for the evaluation can be obtained from representative California wind projects that have both pre- and post-construction monitoring data. Evaluation of the abundance metrics collected should be compared to actual mortality observed. These studies should be examined to identify California species that are more prone to collisions and those that are less prone (focus will be on non-raptor species pending the results of the Altamont studies), what study methods used during pre-construction to provide abundance information, and what information is necessary to predict the collision risk found in the mortality monitoring studies.

The results of this evaluation should be used to answer the questions: “Are there more appropriate methods for abundance/collision risk analyses? If so, which methods and under what conditions should they be used?

3.2 Observed Individual Mortality and Population-Level Effects

3.2.1 Issue and Its Importance for Implementation of the Guidelines

The Guidelines seem to equate individual mortality with population-level effects. No references are provided to support inferences that wind turbine collision mortality leads to population-level effects; it is an implied conclusion that needs to be clarified or evaluated further. The Guidelines do not specifically address how to evaluate population-level effects, but instead focus importance on the effects to individuals. From a wildlife policy point view, mortality to individuals of listed species or other species of special concern may be in violation of the policy, but it may not result in population-level effects. It is important to accurately address population-level effects in the general impact analyses and especially in the cumulative impact analysis.

The CEQA Guidelines do address the issue of population-level effects. CEQA specifies that a project is considered to have a “significant” effect on the environment if, among other things, it has the potential to “substantially degrade the quality of the environment; substantially reduce the habitat of a fish or wildlife species; cause a fish or wildlife population to drop below self-sustaining levels; threaten to eliminate a plant or animal community; substantially reduce the number or restrict the range of an endangered, rare or threatened species…” (CEQA Guidelines §15065[a][1], p. 44).

3.2.2 What the Recent Literature Says on the Subject

Recent programmatic impact assessments of wind projects (e.g., BLM 2005) have indicated that no population-level effects are expected on federally listed endangered species in the Western U.S. (BLM 2005). Two Incidental Take Permits issued by the USFWS for wind farms in Hawaii and Puerto Rico have concluded that although mortality may occur to federally listed species, this morality does not jeopardize these species. NRC 2007 provides modeling approaches to demonstrate this for cumulative effects. NRC 2007 also suggests that the monitoring of productivity and survivorship can be used as an alternative to the direct estimation of fatalities and abundance when looking at cumulative effects (p. 284).

3.2.3 Proposed Research to Validate the Issue

An analysis of the relationship of the magnitude of predicted versus actual collisions of individuals as well as population-level effects to species susceptible to collisions in California is recommended. This analysis can be based on a thorough review of existing pre-construction and post-construction mortality predictions and mortality monitoring data from representative wind facilities to determine the individual vs. population-level relationships. The same data set described for the evaluation of the abundance/collision mortality relationship can be used. This analysis will also be dependent upon the results of the statistical methods and models analysis of mortality described in Section 2, Methodological Foundations. Implications for special-status species should be discussed. Recommendations on the criteria for assuming and characterizing population effects should be developed. As a part of this analysis, models of population viability (i.e., Population Viability Analysis) should be reviewed and recommendations on their use should be included.

3.3 Behavioral Avoidance and Displacement

3.3.1 Issue and Its Importance for Implementation of the Guidelines

Behavioral avoidance of wind turbines and avoidance of and displacement from within wind resource project areas occurs (NRC 2007 and Kingsley and Whittam 2007). The Guidelines address the second type of behavioral avoidance, i.e., habitat avoidance or displacement (e.g., Table 1 Small Bird Use Counts on page 42 and the use of BACI on page 48). The Guidelines (p. 59) state that “displacement and site avoidance impacts have not been evaluated as extensively in California as they have been in other areas.”

Behavioral avoidance of turbines and turbine blades is an essential factor in estimating collision rates. It is used to explain why lower-than-expected mortality to some species of birds and bats is observed. Behavioral avoidance of the rotor-swept zone, rotor-swept area, and the turbines themselves is not explained in the Guidelines although it is mentioned in the discussion of thermal animal detection systems (TADS) (pp. 53-54). Estimates of species-specific behavioral avoidance are needed to improve predictions of mortality.

3.3.2 What the Recent Literature Says on the Subject

The literature discusses two types of behavioral avoidance. Birds may avoid wind project areas or they may avoid turbines by actively reacting to the presence of a particular turbine or string of turbines. Such responses may include altering flight course or height to avoid the project area. Avoidance may also include changes in flight speed, direction, or other evasive maneuvers to avoid contact with a turbine.

Studies of birds approaching wind turbines indicate that birds can change their flight behavior to avoid wind turbines (BirdLife 2002 and 2003). Studies comparing flight behavior over operating wind farms to control areas without wind turbines have shown that migrating birds pass over wind farms at higher altitudes than over reference areas (BirdLife 2002). In Tarifa Spain, observations of 72,000 migrating raptors showed that birds flew at higher average altitudes (>100 m versus 60 m) over wind turbines than over two other reference areas without wind turbines (Janss 2000). BirdLife (2003) concludes that most birds tend to fly around turbines instead of flying among them. In Belgium, Everaert (2007) observed that the chance of a bird colliding with a turbine was 1 in 12,000 and 1 in 600, depending upon the species. Winkelman (1995) observed that, during more than 1,100 observations, 75% of the reactions occurred 100 m from the turbines. At closer distances birds showed specific avoidance behaviors, including accelerated wing beats, fluttering flights, and alteration of the angle of their bodies. Species-specific differences were noted.

Avoidance capabilities are influenced by species-specific differences in morphology and visual acuity (see discussion of hawks in Kerlinger 1989). Differences in body and wing morphology affect maneuverability. Species with reduced maneuverability may have a greater likelihood of collision when response time is limited (Winkelman 1995, Kingsley and Whittam 2007). For example, species that hunt in forests (e.g., Northern Goshawks) are more adapted to flying through complex environments (trees and limbs) than species that hunt in open country (Kerlinger 1995). Therefore, species adapted to flight in such environments can be expected to have a lower exposure value than open-country species because of their greater flight maneuverability when encountering stationary objects. However, this hypothesis needs to be tested.

Ambient light conditions and visibility are thought to affect behavioral avoidance. Differences in bird flight behavior during the day and night have been observed. Because of better visibility during the day, birds appear to be more aware of wind turbines and alter their behavior accordingly. In the Netherlands, fewer birds were observed within 20 m of rotors during the day than at night (Winkelman 1995). In addition, fewer closely approaching birds altered their flight to avoid crossing the rotor swept zone during the night than in day (15% versus 36%). Those birds that did cross the rotor swept zone during the day primarily made horizontal shifts in their flight behavior rather than panic reactions of accelerated wing beats, fluttering flights, and alteration of their bodies. Changes in flight behavior, including altitude changes, were observed to occur at greater distances from the turbines during the day than at night (100 m versus 20 m), and fewer birds were killed during the day than at night (Winkelman 1995). These observations suggest that birds are less likely to encounter turbines during the day versus under low light conditions.

Wind conditions have been demonstrated to affect behavioral avoidance at some wind facilities (e.g., Buffalo Ridge, Minnesota), but not at others (e.g., Vansycle, Oregon) (Strickland et al. 2001). Winkelman (1995), making nocturnal observations, showed that behavioral avoidance of wind turbines occurred most often with headwinds (87% of the time) and least with tailwinds (29% of the time). Although the rates of behavior avoidance are lower for tailwinds, the flight heights of migrating birds tend to be higher (BirdLife 2002), resulting in fewer birds being exposed to the turbines.

Another potential effect that has been studied is the displacement of species from their preferred or commonly used habitat by the presence of wind turbines and whether large wind turbine farms may block or change historical migratory routes of birds, causing a decrease in population size in certain localities (BirdLife 2002). Displacement has been observed (e.g., Buffalo Ridge and Stateline), but not on local and regional scales. In Tarifa, Spain, where thousands of birds, including raptors and passerines, annually migrate over hundreds of wind turbines, no measurable decrease or change in the use of this migratory route has been observed since the wind turbines were constructed (Janss 2000). Behavioral observations by Janss do show micro-displacement (e.g., behavioral avoidance) for birds flying over wind turbine facilities, but no significant spatial displacement of migratory routes has been observed. Shorebirds in the Netherlands have been observed to suffer habitat loss and disturbance effects from 250 m to 500 m from wind turbines, depending upon the species and other variables (Crockford 1992, cited in

Sterner 2002). BirdLife (2002) recommended continued observations to document and quantify whether this effect actually occurs.

It has also been hypothesized that wind turbine facilities could cause shifts of breeding or foraging of birds to less-optimal habitats. Studies of various species of shorebirds, waterfowl, and passerines in Europe (e.g., Netherlands and UK) and the U.S. (e.g., Minnesota) show no disturbance in the use of breeding habitat following operation of wind farms. Some temporary disturbance of birds has been observed during construction in some studies (BirdLife 2002). Variable amounts of avoidance of feeding and roosting areas has been observed from 100 m to 300 m, primarily for waterfowl, in the vicinity of wind turbine farms in Europe, but this habitat avoidance is not considered significant. In Altamont, California, Golden Eagles and other raptors have not shifted their foraging habitats due to the presence of wind turbines. Wind turbines located in grassland habitat do displace some grassland species (Leddy et al. 1999).

3.3.3 Proposed Research to Validate the Issue

Research to monitor behavioral avoidance is recommended. This research should focus on representative species groups known to be frequently killed by wind turbines as well as threatened and endangered species and other species of special concern also known to be susceptible to collisions. The objective of this research is to characterize behavioral avoidance of wind turbines by birds and bats known to occur in the rotor swept zone or rotor swept area. This research should involve a study design that will monitor flight behavior (avoidance and non-avoidance) of selected species of birds known to occur in the RSZ and RSA. Initially, the research should focus on selected diurnal species. For nocturnal species, different study designs should be investigated including the use of Thermal Animal Detection System. Species or taxonomic group behavioral avoidance factors should be developed.

4. Mitigation Underpinning

The Guidelines' third major underpinning is the assumption that there are viable mitigation strategies that will reduce mortality. Chapter 4, Assessing Impacts and Selection Measures for Mitigation (p. 59), presents a list of mitigation techniques and strategies that might be used for micrositing or mitigation (see the subheading "Impact Avoidance and Minimization"). There are several key mitigation topics that deserve further analysis; buffer zones and turbine design and layout are considered here.

4.1 Use of Buffer Zones to Protect Wildlife

4.1.1 Issue and Its Importance for Implementation of the Guidelines

The Guidelines promote the use of "buffer zones" to protect wildlife (pp. 25, 27, 39, 57, 60, 77. 117; also see Mitigation Topics below). "Risky" habitats are identified in the Guidelines, including wind projects near avian migratory stopovers which pose a risk (p. 43, use of mist netting).

Although the idea of protecting risky habitats makes sense, no references are provided to support the specific application and use of the concept. Because the idea is untested, mitigation could be recommended that will not achieve the desired outcome of reducing the mortality associated with a wind project. The Guidelines refer to two types of buffer zones:

1. Buffer zones to protect species that occur in "high-risk" habitats and will result in minimizing collision hazards (pp. 12. 24, 63 et al.).
2. Buffer zones to minimize effects to sensitive species from human activities associated with wind development.

Untested buffer zone mitigation requirements may result in expense and operational constraints that do not address the impact of concern. Species-specific buffer zones can lead to species protection.

4.1.2 What the Recent Literature Says on the Subject

In regards to habitat buffers, most of the literature has dealt with wetland buffers and their application (e.g., California Rapid Assessment Method for Wetlands, Estuarine Field Book (Collins et al. 2007)). Certain habitats critical to some species need to be buffered from human activity, presumably including wind turbines. In the Midwest, certain species of birds (e.g., Prairie Grouse) have specific habitat requirements for breeding. These habitats are considered high risk habitats since their use for breeding may be threatened by the presence of wind turbines. There is literature supporting the use of buffers around prairie grouse leks to reduce disturbance from some other forms of development, however, nothing is known about the effect of wind turbines on grouse behavior specifically.

Buffer zone literature has also dealt with visual and auditory disturbance of wildlife, including birds. Such disturbance can cause birds to avoid areas and interrupt activities such as feeding and nesting. Birds have limited hearing range and may not be disturbed by noises such as emanating for construction equipment. Visual disturbance might occur, but consequences to most species are not known. For prairie grouse this could be an important issue. Prairie grouse are thought to avoid overhead structures and wind turbines could create significant disturbance leading to habitat fragmentation and population declines. Buffer zones for Bald Eagles of ~ 660 ft have been recommended by USFWS. NRC 2007 calls for research to develop viable mitigation approaches.

4.1.3 Proposed Research to Validate the Issue

Buffer zones are assumed to protect wildlife, but no guidance is given on how buffer zones should be designed and how much protection they afford to wildlife. Untested buffer zone mitigation requirements may not be effective. Research is recommended on what is known about buffers and what species are likely to benefit from buffer zones. The following are suggested steps for this research.

1. Identify habitat-specific and species-specific buffer zone mitigation strategies that have been employed at operating wind energy projects. Describe the goals of these buffer mitigation strategies, e.g., to avoid high-risk areas or protect species from visual or auditory disturbance.
2. Review studies to see if post-mitigation monitoring was conducted and, if so, what the results were in regards to buffer zones.
3. For habitat-specific sensitivities, review literature for species in California that have been considered sensitive and recommended for buffering.
4. Look at the life histories of specific species for reported habitat disturbance and/or sensitivities and consequences.
5. For those species potentially sensitive, evaluate existing wind sites to determine the extent to which birds are displaced through post-construction monitoring.

4.2 Appropriate Turbine Designs and Layout to Reduce Impacts

4.2.1 Issue and Its Importance in Implementation of the Guidelines

The Guidelines (pp. 63-64) indicate that appropriate turbine layout will reduce impacts to birds and cite several references (e.g., Orloff and Flannery 1992 and 1996; Smallwood and Thelander 2004 and 2005, cited in NRC 2007). No specific details are provided. There are other statements unsupported by references:

- "As the number of turbines increases, the magnitude of the potential impacts to bird and bat populations increases." (p. 39)
- "Reduction of habitat for prey near turbines will reduce impacts." (p. 65)

4.2.2 What the Recent Literature says on the Subject

A number of engineering factors have been hypothesized as contributing, singly or together, to increase the likelihood of exposure or collisions, including type of turbine, the physical dimensions of the turbine and blade, the rotation speed of the blades, height, turbine position relative to other turbines, and the FAA required lighting regime.

Turbine Type

Studies to date indicate that there is no direct relationship showing that different types of turbines have different risks (NRC 2007 (p. 85)). Conclusions should not be drawn until additional studies are conducted (e.g., old vs. new turbines). NRC does comment, however, that in California mortality is expected to decline with newer turbines.

Size or Diameter of Rotor Blade

Injury or mortality can occur from direct collisions with the nacelle, tower, and/or rotor blades and by birds being swept downward to the ground by rotor wind draft (Winkelman 1995). The proportional contribution of each component is unknown, although modeling studies indicate that the central portion of the rotor may have higher collision probabilities than the distal portions (Tucker 1996). NRC (2007) and Sterner (2002) concluded that an increase in the size of the rotor diameter and RSA does not cause a proportional increase in mortality.

Speed of Rotor Blade

Faster rotor speed and tip speed might be assumed to result in higher mortality (Sterner 2002). However, no field studies have been conducted to test the importance of this factor relative to other engineering factors. Two studies suggest that operating turbines may be more readily detected than stationary turbines (Winkelman 1995 and DeLucas et al. 2004).

Visual Blur of Rotor Blade

Visual blurring of turning rotor blades, and the resultant inability of birds to detect the blades, has been suggested as a cause of collisions based on laboratory studies of kestrels (Hodos 2003).

Tower and Rotor Height

There is no strong evidence that tower height or rotor height are strongly correlated with avian mortality (NRC 2007). Based on observations of bird behavioral avoidances (see above discussions), birds will likely adjust their flight altitudes and fly over turbines of different heights. This was observed at a coastal site in Europe (Horn Rev’s Wind Farm in Denmark).

Turbine Position and Alignment

Bird behavior and mortality studies have been conducted regarding the effects that turbine positions (e.g., end-of-row versus mid-row in a string) and alignment of turbines have on the likelihood of collisions. However, variations in site characteristics, turbine configurations, and design make it difficult to draw specific conclusions regarding how turbine position or alignment may influence exposure of birds to turbines (Sterner 2002). In some studies, end row turbines have been shown to cause higher mortality (Orloff and Flannery 1992 and 1996, cited in Sterner 2002), while in other studies mid-row turbines were shown to cause the highest mortality (e.g., Winkelman 1992, cited in Sterner 2002). Howell and Noone (1992, cited in Sterner 2002), found mortality was random along a string. The differences in these study results are likely due to the variation in site conditions and the flight behavior of different species.

The NWCC Mitigation Subgroup prepared a Mitigation Tool Box that provides an annotated bibliography on the effects of turbine design and bird and bat mortality. This literature review suggests that different factors appear to be important under different environmental and engineering conditions. Different mitigations are recommended, but no synthesis was provided.

4.2.3 Proposed Research to Validate the Issue

This is a subject where there is little and often conflicting information. Evaluation of existing wind projects to investigate the risks of turbine design and placement is recommended. The objective of the research is to determine how turbine designs and layout affect the risk for collision. The following is a list of proposed research tasks.

1. Based on a literature review, summarize the evidence of the relationship of turbine design and layout affecting mortality.
2. Characterize the risks from turbine designs, including review of mortality data.
3. Based on the first two tasks, develop a monitoring protocol for one or more representative existing projects.
4. Conducting monitoring at representative turbine designs and layouts to validate the characterization.

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