Proceedings

NWCC Wildlife Workgroup Research Planning Meeting VI

San Antonio, Texas
November 14-15, 2006

Organized by
The National Wind Coordinating Collaborative
Wildlife Workgroup

Meeting Facilitated by
RESOLVE, Inc.
Washington, DC

March 2007

Suggested Citation Format

This volume:

PNWWRPM VI. 2007. Proceedings of the **NWCC Wildlife Workgroup Research Planning Meeting VI**. San Antonio, TX November 14-15, 2006. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 138 pp.

Preceding volumes:

POWIWD-V. 2005. Proceedings of the **Onshore Wildlife Interactions with Wind Developments: Research Meeting V**. Lansdowne, VA November 3-4, 2004. Prepared for the Wildlife Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 120 pp.

PNAWPPM-IV. 2001. Proceedings of the National Avian-Wind Power Planning Meeting IV, Carmel, CA, May 16-17, 2000. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed., 179 pp.

PNAWPPM-III. 2000. Proceedings of the National Avian-Wind Power Planning Meeting III, San Diego, CA, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by LGL, Ltd., King City, Ont., 202 pp.

PNAWPPM-II. 1996. Proceedings of the National Avian-Wind Power Planning Meeting II, Palm Springs, CA, September 1995. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by RESOLVE, Inc., Washington, DC, and LGL, Ltd., King City, Ont., 152 pp.

PNAWPPM. 1995. Proceedings of the National Avian-Wind Power Planning Meeting IV, Denver, CO, July 1994. Repot DE95-004090. RESOLVE, Inc., Washington, DC, and LGL, Ltd., King City, Ont., 145 pp.

Ordering Information

These Proceedings are available in PDF format with accompanying powerpoint presentations available as separate files. Proceedings may be ordered on CD from the NWCC c/o RESOLVE, Inc., Washington, DC: nwcc@resolv.org or by calling: (888) 764-WIND. They may also be downloaded from the NWCC website: www.nationalwind.org

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INTRODUCTION

This is the sixth in a series of meetings organized by the National Wind Coordinating Collaborative (NWCC)'s Wildlife Workgroup (formerly the NWCC Avian Subcommittee). Bringing together representatives from government and non-government organizations, from private business, and from academia, these meetings are convened to examine current research on the impacts of wind energy development on wildlife and to discuss the most effective ways to mitigate such impacts. While earlier meetings focused on birds; the scope has been expanded to examine study methods and metrics, impacts and mitigation strategies related to bats and other wildlife.

Wind energy is able to generate electricity without many of the environmental impacts (conventional and toxic air pollution and greenhouse gases, water use and pollution, and habitat destruction) associated with other energy sources. This can significantly benefit birds, bats, and many other plant and animal species. However, the direct and indirect local impacts of wind plants on birds and bats continue to be an issue. The populations of many bird and bat species are experiencing long-term declines, due to the effects of a wide range of human activities, including energy production and consumption.

Objectives of the Meeting

The objectives of the Wildlife Research Meeting are: to bring the interested stakeholders up-to-date on research being conducted to understand the interaction of birds, bats, and other wildlife with wind energy facilities; to examine what we've learned about ways to minimize or mitigate wind energy's adverse/undesirable impacts on wildlife; and to identify gaps in knowledge and research needs.

Process Guidelines

The Facilitator reviewed the draft agenda circulated before the workshop (Appendix A). There were no suggestions for changes. The format was a series of plenary sessions, each devoted to a specific topic. Panel moderators coordinated the presentations, and questions were fielded by panel participants after all presenters for a particular session had completed their formal presentations. These Proceedings present summaries of each presentation (presentation slides may be downloaded from www.nationalwind.org as a series of separate Powerpoint files), with question and answer sessions summarized at the end of each section.

The following ground rules for the workshop were proposed by the Facilitator and accepted by the group:

- All parties participate and will be acknowledged by the facilitator.
- Comments may not take the form of a personal attack.
- Participants should feel free to express their own opinions while respecting other points of view.
- No party will report or characterize any comment made in the meeting by any other

party in public statements, in discussions with the press, or in other venues outside of this meeting

- A meeting summary and proceedings will be prepared by the Facilitator. The meeting summary will document each presentation and will summarize discussions. Panel presentation and discussion summaries will be reviewed by panel moderators and participants, and a review draft of the complete Proceedings will be circulated to all meeting attendees prior to being finalized and made available to the public.

Research Meeting Organizers and Presenters

Members of the NWCC Wildlife Research Meeting VI Planning Group are listed below, along with their affiliations. A list of the panel moderators and presenters, their affiliation and their topic, follows. Appendix A provides a full list of speakers and participants and their contact information.

NWCC Wildlife Research Meeting VI Planning Group

Rene	Braud	BP Alternative Energy
John	Bruck	BHE Environmental, Inc.
Brian	Connor	U.S. Department of Energy
Edgar	DeMeo	Renewable Energy Consulting Services, Inc.
Jeff	Deyette	Union of Concerned Scientist
Michael	Fry	American Bird Conservancy
Brianna	Gary	NYS Department of Environmental Conservation
Alex	Hoar	U.S. Fish and Wildlife Service
Laurie	Jodziewicz	American Wind Energy Association
David	Klute	Colorado Division of Wildlife
Pete	Konesky	Nevada State Office of Energy
Karen	Kronner	Northwest Wildlife Consultants, Inc.
Jim	Lindsay	FPL Group
Al	Manville	U.S. Fish and Wildlife Service
Alejandro	Moreno	U.S. Department of Energy
Michael	Morrison	Texas A&M University
Dave	Plumpton	ecology and environment, Inc.
Mark	Sinclair	Clean Energy States Alliance
Karin	Sinclair	National Renewable Energy Laboratory
Linda	Spiegel	California Energy Commission
Dale	Strickland	Western EcoSystems Technology
Steve	Ugoretz	Wisconsin Department of Natural Resources Integrated Science Services
Mark	Woythal	New York State Department of Environmental Conservation

Panel Moderators and Presenters

	Session I: Interaction of Wind Power Facilities & Birds
Dale Strickland	Overview of What We Know Up To November 2004
Michael Green	*Moderator: New Studies Completed on Birds – Pre-construction & Post-construction*
Ommo Hueppop	Remote Techniques for Study of Offshore Bird Migration
Todd Mabee	Designing Nocturnal Bird Migration Studies for Proposed Wind Energy Developments
Sidney Gauthreaux	Thermal Imaging and Vertically Pointing Fixed-Beam Radar Technique for Quantifying Bird Movements
Robert McFarlane	Toward Prediction of Bird-Rotor Collision Mortality
Andrew Gregory	Genetic Consequences of Wind Power Development on Greater Prairie Chicken Leks of Eastern Kansas
Kathy Boydston	*Moderator: Questions to Address Based on Research Results*
Michael Schroeder	Effects of Wind Power Development on Sage-grouse
David Young	Impacts of Wind Power Development on Mountain Plovers at Foote Creek Rim
	What Have Marine Radar Surveys Taught Us about Wildlife Risk Assessment
David Mizrahi	Assessing Bird Movement Patterns on Cape May Peninsula Using Marine Radar
Karen Krijgsveld	Effects of Modern Wind Turbines on Birds: Results of Field Studies on Collision Victims & Nocturnal Flight Patterns in the Netherlands
Respondent Panel	*Andy Linehan, Rob Manes, Al Manville, Linda Spiegel, Dale Strickland*

	Session II: Interaction of Wind Power Facilities & Bats
Paul Cryan	Overview of Study Results up to November 2004
Al Hicks	*Moderator: New Studies Completed on Bats – Pre-construction & Post-construction*
Ed Arnett	Patterns of Pre-Construction Bat Activity at Proposed Wind Energy Facilities
Keith Lott	Daily & Seasonal Patterns of Bat Activity along Central Appalachian Ridges
Erin Baerwald	Bat Fatalities in Southern Alberta
Ed Arnett	*Moderator: Questions to Address Based on Research Results*
John Sherwell	Developing a Mitigation Strategy for Bat Impacts from Wind Power Development in Maryland
Al Hicks	Migratory Behavior of Female Indiana Bats in New York and Implications for Wind Development
Greg Turner	Bat Migratory Behaviors and Routes in Pennsylvania and Maryland
Joseph Szewczak	Evaluation of Acoustic Deterrents to Reduce Bat Fatality at Wind Facilities
Cissy Sutter	Bat Likelihood Assessment Protocol for Collision Mortality at Potential Wind Farms
Respondent Panel	*Paul Cryan, Bronwyn Hogan, Jim Lindsay*

	Session III: Applicable Methods and Study Design Specialized for Birds, Bats & Common to Both
Jon Belak	Development of a Cost-Effective System to Monitor Wind Turbines for Bird & Bat Collisions
Wallace Erickson	Objectives, Uncertainties & Biases in Mortality Studies at Wind Facilities
Manuela Huso	Pre-Construction Acoustic Surveys for Predicting Bat Fatality at Wind Farms: An Evaluation of Survey Protocols
Ron Larkin	Migration at Low Height over the Mountainous Areas of Vermont

	Session IV: Mitigation of Wind Energy Impacts
Lynn Sharp	Presentation of NWCC Mitigation Toolbox

Respondent Panel	*Michael Fry, Alex Hoar, Greg Hueckel, Stu Webster, Lynn Sharp*

Nancy Simmons	Lunch Address: Documenting Effects of Wind Turbines on Bat Populations Using Genetic Data

	Session V: Risk Assessment, Management & Wind Power in the U.S.
Rebecca Efroymnson	Ecological Risk Assessment for Wind Energy Facilities (NWCC White Paper)
Terry Root	Possible Ecological Consequences for Not Kicking our Fossil Fuel Addiction

Jan Beyea	Session VI: Adaptive Resource Management (telecast)

SESSION I:
INTERACTION OF WIND POWER FACILITIES AND BIRDS

This session consisted of a series of presentations on what we have learned from studies of avian/wind interactions, the questions those study results can help us address, and a panel response to the presentations. Dale Strickland (*Western EcoSystems Technology, Inc.*) and Doug Johnson (*US Geological Survey*) introduced the session with an **Overview of What We Know,** a summary of study results up to November 2004.

There followed a series of five presentations, moderated by Michael Green (*US Fish & Wildlife Service*), on pre- and post-construction studies conducted since November 2004. A second series of five presentations, moderated by Kathy Boydston (*Texas Parks and Wildlife Department*), focused on questions to address based on the results of this research. The session concluded with a respondent panel, moderated by facilitator Abby Arnold, addressing the question, **What New Insights Have We Learned About Avian/Wind Interaction?**

OVERVIEW OF WHAT WE KNOW

Dale Strickland, *Western EcoSystems Technology, Inc.*
Doug Johnson, *US Geological Survey*

Types of studies

Studies of avian-wind interaction fall into two main categories: pre-project studies of potential impact, and post-construction studies of actual impact.

Pre-construction studies of potential impact
The most common pre-project study is a ***site assessment***. This is a preliminary evaluation, typically consisting of a review of existing information, discussions with agencies and local experts, and an on-site evaluation of habitat and indications of important use areas (e.g., raptor nests, bat caves). This type of study typically involves a single site visit and cannot be considered a comprehensive study. It is primarily directed at looking for environmental red flags (i.e., a qualitative assessment of potential risk) and identifying where further study is needed.

A more systematic study which may be conducted pre-construction is a ***baseline study***. This produces a more rigorous characterization of the site which may be used to: quantitatively estimate risk and predict impacts; and to assist with wind plant design to reduce risk. When properly designed, data gathered in a baseline study also allows us to evaluate impacts and risk through comparison with data gathered in post construction surveys. (Ideally, when impact assessment is a goal both baseline and post-construction data would be gathered for the wind site and for one or more control or reference areas.)

Post-construction studies of project impact
Studies of project impact include both direct and indirect impact studies.
Direct impact studies typically focus on fatalities, usually collision fatalities, and direct habitat loss.
Indirect impact studies may look at short- and long-term displacement of species from suitable habitat, or they may look at how habitat impacts affect reproduction, and the extent to which this may have longer-term impacts on the population.

This presentation provides our view of what has been learned about the direct collision fatality and direct and indirect (habitat/reproduction-related) impacts of wind projects on avian species.

Fatality Impacts

Quite a few avian fatality studies were conducted prior to 2004, however, there are no records of such studies in Texas or much of the Southwest. (See map of study locations, slide #4.) Only 14 of those studies conducted at 11 sites in Washington, Oregon, Wyoming, Minnesota, Iowa, Tennessee and West Virginia (see slide #5) included fatality monitoring through all seasons of occupancy during a one-year period and with carcass removal bias and carcass detection biases calculated.

Habitat at these 11 sites included agricultural/grassland/Conservation Reserve Program (CRP), short-grass steppe, CRP only, agriculture only and eastern upland forest. Fatality search intervals ranged from as little as two days to as long as 28-day intervals, with 14-day intervals being the most common. Wind facilities ranged in size from three to 454 turbines and study sample size ranged from three at the three-turbine site to approximately 150 turbines at the 454-turbine site. At smaller sites, all turbines were searched; at larger sites, a sample of turbines was searched. All of these studies generally followed the NWCC Guidance Document for Studying Wind-Bird Interactions.

Overview of Fatality Study Results
Over the four regions (East, Midwest, Rocky Mountain and Pacific Northwest) encompassed by all of the studies reporting species composition of fatalities, passerines represented by far the largest percentage of fatalities (74%). Gamebirds represent 11% of fatalities overall, and raptors represent 6% of overall fatalities. Passerines accounted for 81% of fatalities at eastern sites, 78% at Midwestern sites, and 86% at Rocky mountain site. Other regional differences include:

- Raptors, game birds and water birds are more abundant among fatalities in the Midwest.
- Upland game birds are more prevalent at sites in the Pacific NW than elsewhere (18%), though passerines are still the most common fatality (69%).

These data are missing information about relative exposure of different species, which is based on abundance. Passerines are the most abundant species at all the sites, and thus more exposed to collision impacts, although appear less than would be expected based on the likely abundance relative to other groups, such as raptors.

Slides #11-12 show the relative number of fatalities per MW by site, with sites grouped by region for all birds and raptors, respectively. The horizontal line represents the mean number of avian fatalities per MW for each region. The fatality rates for all birds and raptors are reported on slides #34-35. At the five Pacific NW sites, the average fatality per MW for all birds was approximately 2.7.and at the two Rocky Mountain sites the average was 2.3 birds/MW. The average is higher in the East (3 birds/MW), and highest in the Upper Midwest (3.5 birds/MW). Calculating the average number of fatalities per MW allows for comparison among larger and smaller wind energy sites and among different sized turbines.

Slide #13 includes fatality data for raptors only for four studies of older generation smaller turbines at three sites in California (Altamont Pass, Montezuma Hills, Tehachapi Pass, and San Gorgonio) and from 14 studies of modern larger turbines at 11 sites in scattered throughout the country. While fatality rates illustrated for the 14 studies of modern turbines include carcass removal and searcher detection bias-adjusted estimates, only unadjusted fatality estimates are available from four projects in California (Altamont Pass, Montezuma Hills, Tehachapi Pass, and San Gorgonio). Of the newer sites, the Stateline Project (OR/WA) had the highest number of raptor fatalities, but far fewer raptor fatalities per MW than those measured at three of the four California sites. Because the California data are not adjusted for scavenging, the actual number of fatalities at those sites would be higher.

Even without correcting for carcass removal bias, it is clear that raptor fatality estimates per MW are generally higher at the California sites, with the exception of San Gorgonio, which is nevertheless higher than the adjusted estimates at all but five of the other 14 sites. Interestingly, with the exception of the San Gorgonio site the California sites have an abundance of raptors relative to the sites studied outside of California. It has generally been assumed that the older technology at many of the California sites resulted in greater risk for raptors, and the California sites represent older turbine technology. Nevertheless, the fact that there is a relatively high variance in raptor fatality estimates among the California sites with older generation turbines suggest that fatality risk may be influenced by both site characteristics, such as topography and avian abundance, and differences in technology.

Slide #14 shows the relationship between raptor use (as measured in observed numbers of raptors during 20-minute point-count surveys) and raptor fatality (using adjusted fatality rates) at nine sites (Wally Erickson, personal communication). The regression analysis further supports the possibility that at least raptor abundance is correlated with raptor fatalities.

Habitat Impacts

Habitat impacts include both ***direct loss*** of habitat associated with the footprint of the wind energy facility and ancillary features such as access roads and substations, and ***indirect loss*** of habitat via behavioral avoidance (displacement) of animals. Displacement may be a short-term phenomenon associated with construction of the facility with the behavioral response modifying over time (i.e., habituation), or it may be longer-term, with animals avoiding an area for the life of the project.

Predicted habitat disturbance impacts
While direct impacts have never been reported to our knowledge, direct disturbance has been predicted for a number of areas (Slide #17). Temporary direct impacts from construction of roads, turbine pads, substation, etc have been estimated at 0.4 to 2.6 acres per turbine. Long-term impacts during facility operation are estimated at 0.7 to 1 acre per turbine. The Bureau of Land Management (BLM) adopted a permanent footprint of 5-10% of the site in the Programmatic Environmental Impact Statement on wind energy development on public lands. Impacts likely vary by turbine type, site characteristics (climate, precipitation), and reclamation plan.

Displacement studies
There are no field study results available on the displacement impacts of wind energy facilities for most species. A 1999 study looked at the effects of wind turbines on grassland songbirds on CRP land at the Buffalo Ridge wind energy site in Minnesota (Leddy et al., 1999). Bird density increased as distance from the turbine string increased. Bird density was about 20% higher in a control area than at a distance of 180 m from the turbine string (slide #23). Another study at the Buffalo Ridge site (Johnson et al, 2000) also showed a small-scale displacement on the order of less than 100 m from turbines. On a large-scale basis (i.e., within the entire WRA), reduced use by birds was minor. At both small and large-scales the effect of turbines on use varied with species. Ongoing studies of bird displacement are being conducted at the Stateline facility and at sites in North and South Dakota.

In the absence of studies measuring the displacement impact of wind energy facilities, surrogate data from displacement impacts of other types of facilities may be useful. A 2005 study looked at the distance at which various anthropogenic features appeared to influence nesting of Lesser Prairie-Chickens (Pitman et al., 2005). The presence of a various man-made features within their study area were found to have effectively eliminated 53% of the bird's nesting habitat within the study areas, with nesting sites not found within approximately half a kilometer of features such as transmission lines, houses, or within more than 1 km from a large coal-fired power plant.

A U.S. Geologic Survey-sponsored study in South Dakota is looking at the compatibility of wind energy development and grassland breeding birds. Preliminary results are variable among replicates and are too preliminary to confirm effects (Slides #25-27).

Prairie habitat is being impacted by all types of development, with the resulting fragmentation affecting prairie species.

Summary

Based on studies to date, with the possible exception of Altamont, avian risk from individual wind projects appears to be a risk to individual birds and not to populations. Preliminary information suggests that wind facility siting practices may reduce risk for some bird groups and species.

Preliminary information suggests that new technology may reduce risk for some species, but may increase risk to others. The effect of turbine design (e.g., tower type, tower height, rotor swept area, revolutions per minute) on fatalities and the effectiveness of mitigation measures are poorly understood. Wind turbine lighting, for example, is not currently documented as a significant attractant for birds. There is limited data, and some confounding data on tower height v. lighting, but no evidence that fatalities increase around turbines outfitted with FAA lighting.

Estimated direct habitat impacts are relatively small. Displacement is likely, but the magnitude is uncertain and may range from near zero to several hundred meters. Siting – both on the macro level (wind projects) and on the micro level (turbine and turbine string location within the site) is believed to be the best way to minimize impacts.

Further Monitoring and Research Needs

As limited as these data are, there are better data about the impact of wind energy facilities on birds than for other sources of impact. That said, more monitoring and research are needed to:

- estimate impacts in unstudied and newly developed regions (e.g., SW, Coastal, offshore);
- determine effectiveness of mitigation measures
- consider the relationship of small- v. large-scale development impact;
- quantify/predict indirect (e.g., displacement) impacts; and to
- consider linkage of fatality and non-fatality impacts to population dynamics and biological significance.

Through 2000 we had data on a large percentage of the existing wind power projects, although the data were of varying quality. However, over the last five years a large number of projects have been built in different regions of the country with the potential of impacting new species and their habitats and studies have not kept up with this development.

WHAT WE HAVE LEARNED SINCE NOVEMBER 2004

moderated by
Michael Green, *US Fish & Wildlife Service*

Pre-Construction Studies

How to See the Invisible: Remote Techniques for Study of Offshore Bird Migration

Dr. Ommo Hüeppop[1]
Institute of Avian Research "Vogelwarte Helgoland"

This presentation focused on offshore studies of bird migration conducted primarily in the German part of the North Sea where a large number of wind farms are planned. Because many European migrating bird species are predominantly night migrants, and because of the nature of the offshore locations, methods of detecting night migrants that could be carried out on an unmanned platform located about 45 km north of the German coastline are presented. The main data collection method utilizes modified ship radars, but thermal imaging, video and acoustic observations also are used. These are the first studies to cover migration continuously year-round, and this presentation elucidates the different methods applied, including an evaluation of their advantages and disadvantages.

Background: Why offshore, why study nocturnal migration?

Given that terrestrial sites for the construction of wind turbines are increasingly limited, and the fact that winds are stronger and more constant at sea, many European countries have developed ambitious plans for large offshore wind facilities. Denmark and Sweden already have some offshore facilities. Germany is the world's leading country in the use of wind energy, and although it has not yet constructed offshore wind facilities, several are projected for the German part of the North Sea.

The governmental licensing process for the construction of technical buildings offshore addresses bird conservation (along with issues such as mining rights, shipping routes and safety). The Offshore Installations Ordinance explicitly mentions 'jeopardizing of bird migration' as a basis for rejecting a permit. Approval may not, however, be withheld in the absence of rejection reasons.

Research project objectives

Several research projects have been initiated by the German environmental authorities. Their primary objectives were to collect data on bird migration over the North Sea and the Baltic Sea with a variety of remote techniques. We know that hundreds of millions of birds cross the German marine areas (North Sea and Baltic Sea) at least twice every year, mainly

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birds that migrate from Scandanavia to central and southern Europe – and some even further to southern Africa. Most of these are nocturnal migrants. To judge potential risks to birds (and bats) by offshore wind facilities, most of the questions we need to answer are the same as need to be answered for land-based facilities:

- Spatial and temporal occurrence of various species of birds throughout the year
- Details of their behavior in general (e.g., migration intensity, altitude, flight distances, and direction)
- How their behavior is influenced by weather;
- How their behavior (e.g., avoidance/attraction, evasive movements, influence of lighting) is influenced by the presence and type of wind facilities

However, because there is no way to collect carcasses at sea, we need other means of measuring collision fatalities.

Methods Used

We gathered continuous data using equipment mounted on an unmanned offshore platform (see slide), a 100 m tower positioned 45 km north of the coast of Germany at 30 m water depth. A lot of the techniques we used have been used in the US as well, and so may already be familiar. However, modification and automation of the techniques might be of general interest. Methods used were:

- Marine radar in horizontal and vertical orientation
- Thermal imaging camera
- Video camera
- Microphone and bat detector
- Multi-sensor platform (with additional onshore evaluation)

Horizontal marine radar. Our horizontal marine radar is operating c. 20 m above sea level. This was designed to give us information about the flight directions of birds, however problems with sea clutter allow measurements only under calm conditions. Methods applied to avoid ground clutter on land, such as earth walls, are not applicable at sea. Hence we aim to modify the radar antenna.

Vertical marine radar. We turned the radar vertically to measure flight altitudes. Marine radars have an odd beam form (large vertical opening, narrow horizontal opening) making measurements of bird traffic rates difficult. We tried to overcome this by calculating an empirical curve that gives us the possibility for range and beam shape correction. However, birds flying more or less parallel to the beam are easier to detect (since they produce a trail) than birds flying perpendicular to it (which produce only single dots).

Migration intensity was calculated by the number of radar echoes per hour. (Slide shows radar echoes in units of 1000, 500, and 100 echoes per hour for each Julian day.) We found that although a lot of migration takes part in the night, there is an enormous day to day variation throughout the year as well as over each 24-hour period.

A rotating beam radar cannot tell us what are the species involved, or whether they are single birds or flocks. However, marine radar can be operated in a fixed position of the original antenna or a parabolic dish antenna to identify wing beat frequencies. (This has been done with military equipment before, but marine radars can easily be modified to do the same and are much cheaper.) Wing-beat frequencies (e.g. measured by FFT) and patterns (intermittent wing-beats mean songbirds) can be used to identify species groups. There is some correlation between bird size and wing beat frequency. (See slides for examples.) Insects also produce radar echoes. Often they cannot be separated from bird by conventional radar. Since we found a lot of insect migration, even under offshore conditions, measuring wing-beat patterns often seems to be the only solution to distinguishing birds from insects.

Thermal imaging camera. Thermal imaging cameras can be used to identify species, as well as to answer other questions (such as whether birds are attracted by the platform or by lighting); however, they have a much lower detection range than radar. The camera can be used with an automatic object detection system, or you can use peak storage images. This entails keeping the lighter pixels from a series of video images and putting them together to create a single image (as opposed to throughout a video). The slide images give some impression of flight activity at the research platform and of flight paths of nocturnal migrants around the Helgoland light-house and communication tower under bad visibility conditions.

Multi-sensor platform. This platform includes video, thermal imaging, and a laser distance meter (used in cooperation with the German Air Force). The combination of high resolution cameras with angle meters and a laser distance meter enables us to continuously follow individual birds or flocks to register their flight tracks up to several kilometers (depending on size of species). This is a good but expensive alternative to tracking radar. If you are lucky, you can get wing beat information as well. However, it cannot be operated in automatic mode yet

High resolution video camera with infrared spotlight. High-resolution cameras can provide similar information and are affordable, but require active illumination; we use an infrared spotlight. Precipitation presents a problem, but we are trying to work around that.

Microphone and bat detector. Bird and bat calls can tell you about bird species involved in migration. We can use the fact that bird calls have pronounced peaks in certain frequencies to reduce the amount of data collected, avoiding “rubbish” produced by wind or rain (this is large problem under offshore conditions). However, some birds do not call during migration, and others tend to call less when migration conditions are good. Nevertheless, continuous recording of calls provides year-round information on species spectrum, migration intensity and presumably on the proportion of birds being disoriented.

Conclusions

The final slide indicates the instruments used to generate the desired measures of bird activity and migration:

Intensity: vertical radar (rotating and fixed beam)
thermal imaging (flight call recording)

Altitude: vertical radar (rotating and fixed beam)
multi-sensor platform

Direction: horizontal and vertical radar
Multi-sensor platform (

Species: vertical radar (fixed beam)
Multi-sensor platform (thermal imaging, flight call recording, video camera with infrared spo

Avoidance/attraction/collisions:
Thermal imaging
Video camera with infrared spotlight (?)
Modified marine radar (?)

Questions following Presentation

***Question*:** Does the technique described detect birds just above water level?

Response: Radar detection is influenced by sea-clutter. But, depending on weather conditions and altitude of the radar, birds can be detected at least down to 20 m. Under very calm conditions even bird swimming on the water are detected. With thermal imaging it depends in part on the temperature of the water; it seems to easier to pick out the warm birds during the winter, when the water and air are cold. Again, waves influence what can be detected.

Question: How much did this study cost, and who paid for it?

Response: The studies were financed by the German Ministry for Environmental Affairs and Nuclear Safety, and by the German Air Force (evaluation of the multi-sensor-platform). To give some examples of the equipment costs:

- The multi-sensor platform certainly cost more than a million dollars.
- A high resolution video camera is available for little more than $1,000.
- Marine radar systems cost $15-20,000 not including a computer and hard- and software needed to digitize the radar output (another $5,000).
- A modified parabolic dish antenna can be manufactured by an additional $5,000.

Designing Nocturnal Bird Migration Studies for Proposed Wind Energy Developments

Todd Mabee[2]
ABR Inc. Environmental Research and Services

The construction of wind energy developments throughout North America has increased markedly over the last decade and has raised concern over the potential impacts to birds, particularly for those species vulnerable to collisions. In the U.S., half of the bird fatalities that occur at wind energy facilities are of nocturnal passerine migrants. Marine radar has been used extensively over the past five years to assess nocturnal migration at wind projects. Designing robust studies of nocturnal migration can be challenging – not only because observations need to be made at night, but because patterns of migration tend to vary both spatially and temporally.

This variability has implications for study design in general, and sampling intensity in particular. Studies vary with respect to both the length of intervals between observation nights and the sampling intensity (both number of nights sampled per migratory season and number of hours sampled per night). Inadequate sampling produces estimates that may be biased and have a large amount of uncertainty, confounding site comparisons. However, excessive sampling constitutes an inefficient use of time and resources.

Objectives

How long do we have to be out there to have confidence in our sampling methods? To date, no published studies exist that evaluate the influence of study design and sampling intensity on the passage rate and altitude metrics used to assess avian use of prospective or actual wind energy facility sites. This information is needed to make recommendations for pre- and post-construction assessment guidelines.

Our objective was to see how different combinations of study design (consecutive sampling nights) and sampling intensity (seasonal, nightly, and hourly sampling) influenced the accuracy of nocturnal migration metrics (i.e., passage rates and flight altitudes). Results are presented so that researchers can select a combination of study design and sampling intensity to achieve desired levels of precision for migration metrics.

Nocturnal Migration Studies

We looked at data from six nocturnal migration studies conducted during spring or fall migration in New York, Pennsylvania and West Virginia. These studies used marine radar (in both vertical and horizontal modes) to estimate seasonal mean passage rates (targets/km/hour) and seasonal mean flight altitudes (meters above ground level), of

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[2] Co-authors: J. H. Plissner, B. A. Cooper, R. H. Day, and A. Prichard. ABR Inc. Environmental Research and Services, Forest Grove, Oregon, USA and ABR Inc. Environmental Research and Services, Fairbanks, Alaska, USA.

nocturnal migrants. These are common metrics relevant for use in pre-construction risk assessment.

Data analysis

We picked the "best" studies for this, looking only at data for nights that had an intensive sampling effort (7-9 hours per night). Metrics were selected for their potential use as building blocks for risk analysis. All possible combinations of consecutive nights per season and consecutive hours per night were examined. We used untransformed data, because our goal was not to test hypotheses, but rather to evaluate the effect of sampling intensity, using the coefficient of variation (CV).

Number of nights/season sampled

Slides (11-14) show the CV analyses evaluating the effect of sampling intensity (number of consecutive nights observed per season) on estimates of passage rates. In slides 11-13, the passage rate data (targets/km/h for each night observations were made for the season) is shown on the left, with the mean passage rate on the y axis and the date observations were made on the x axis. Data were taken from fall and spring migration observations at Clinton County, NY, and Prattsburgh-Italy, NY, and from fall migration observations at Swallow Farm, PA and Mt. Storm, WV. Fall passage rates were more variable than spring passage rates.

The CV analyses appear to the right of the passage rate data. In the CV analyses, the CV is measured on the y axis, and all possible combinations of consecutive night observations are shown on the x axis. As the number of consecutive nights sampled increases, the coefficient of variation decreases, resulting in a more accurate estimate of the mean passage rates. From an observation of a single night to observations of ten consecutive nights, the CV decreases dramatically. However, as the number of consecutive nights sampled approaches the maximum, the line flattens out. Evidence of excessive sampling would be a CV that has flattened out for a number of days before the end of the study.

Slide 14 summarizes the CV analysis for the two spring migration studies and the four fall migration studies. These figures give good evidence of excessive sampling, particularly for the fall studies when data were available for as many as 45 consecutive nights. Beyond the 30th night, variation flattened out, indicating that there was no benefit of additional sampling.

Slides 15-18 show the same type of CV analyses for the flight altitude metric. Variation was much lower from night to night for flight altitude than it was for passage rates. In the fall, after about 10 nights the variation flattens out. Slide 18 summarizes the CV analysis for flight altitude. It shows some convergence, with the decrease in variation reaching a plateau after between 5-15 nights.

Slide 19 summarizes information needed to determine the number of nights needed to estimate passage rates and flight altitudes with approximately 90 percent certainty.

Number of hours/night
Slides 20-24 show the results of the CV analyses for different levels of hour-per-night sampling intensity.) Slides 20-21 show what percentage of the total nightly passage rate occurred during each hour after sunset. As shown in the CV analysis on the right-hand side of these two slides, while passage rates do follow a pattern over the course of the night, the overall variation is not dramatic. The results for flight altitudes (slides 22-23) show even less variation.

Slide #24 summarizes the information needed to determine the number of hours per night needed to estimate passage rates and flight altitudes with approximately 90 percent certainty.

Conclusion

It cannot be overstated that a good study design requires adequate sampling intensity that produces accurate metrics, comparability among studies, and efficient use of time and resources. Although these results are preliminary, this analysis suggests that a study design that calls for a census of all migration nights or all migration hours may be excessive, at least for inland locations during fall migration. Additional data is needed before making formal recommendations as to the number of nights/season or number of hours/night.

Design considerations should take into account that passage rates exhibit greater variability (especially from night to night) than flight altitudes. Migratory start dates and periods depend on the taxa of interest, and the variability of migration metrics depends on whether the pattern of migration is even or pulsed.

These results are preliminary. Future analyses will include additional studies and designs (e.g., alternate and split-night sampling). Other metrics, such as passage rate within turbine height, and other methods of observation (e.g., acoustic and visual) could also be evaluated.

Response to Presentation

Question: How do we identify the migration period of interest?

Response: This is driven by the study location and taxa of interest.

Comment: The coefficient of variation for these metrics varies from one locality to another and from year to year. The conclusions of this analysis shouldn't be made the basis of fixed guidelines.

Response: Yes, these are good words of caution, although if additional studies show similar patterns of CV then there may be a stronger basis for recommendations.

Question: Is radar study always called for?

Response: If you have a radar study that's been done next to your area and there is no topographical difference, the existing study could be applicable. This is really a question for the regulatory agency. My message is that if you need to do a radar study, have us out there only for the number of nights and hours/night that you need us.

Question: Is there a variation between times of day?

Response: My data focus on the period from dusk-dawn, and the variation between crepuscular and nocturnal periods will depend on the site location (e.g., near or far from wetlands or stopover habitat), and on what types of birds are using or passing through the area.

A Thermal Imaging and Vertically Pointing Fixed-Beam Radar Technique for Quantifying Bird Movements

Sidney A. Gauthreaux[3]
Clemson University

Because the greatest amount of passerine bird migration occurs at night, special remote sensing techniques must be used to monitor the quantity of bird migration at different altitudes passing over a proposed wind development site. Two techniques have proven to be very useful for this task: high resolution fixed vertical-beam radar (VERTRAD) and thermal imaging (TI).

Vertical-beam Radar (VERTRAD) Equipment

Off-the-shelf marine radar (25kW or more powerful) can be used in a horizontal surveillance mode to determine the flight directions of migrating birds, and the radar can be operated in a vertical scan mode to determine the altitudinal distribution of the migrants. Marine radars with parabolic dish antennas instead of the open array (t-bar) antenna can measure both the flight direction and the altitudinal distribution of individual migrants passing over a project site.

We used a ***Pathfinder Model 3400 marine radar*** (Raytheon, Inc., Manchester, NH) with a 61-cm diameter parabolic antenna that produced a beam width of 4°. The vertically-pointing antenna sat on top of a transmitter-receiver (TR) unit connected by cables to a display unit (178 mm CRT) and rectifier. The transmitter frequency was 9410 $\pm$ 30 MHz (3-cm wavelength) with a peak power output of 5 kW and a minimum range of detection of 25 m. (We are now exploring 50 km radar to make sure we are not missing higher altitude targets.) the system has a protective collar to protect against scatter.

Raw radar data are first digitized and then processed with sophisticated algorithms to

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produce information on target reflectivity, size, track, etc. The data are output to databases for additional analysis.

Thermal Imaging (TI) Equipment

Thermal imaging can be used to identify the sources of the radar targets. It can detect individual birds and bats 2-3 km out, depending on weather conditions. Using TI technology developed in the mid-1990s, we can measure altitude, direction of movement, and flock size.

We used a ***Radiance 1*** (Raytheon Amber, CA) with a 256 x 256 detector array, and a 3 µm to 5 µm spectral bandpass. Display resolution is 640 X 482 full screen, 60 frames per second. With a 100-mm lens, the field of view is 5.57° (horizontal screen dimension) and 4.82° (vertical screen dimension).

Thermal imaging cameras can be used in several different surveillance modes, but when used with a vertically-pointing, fixed-beam radar, accurate computations of migration traffic rate (the number of birds crossing a mile of front per hour) for altitudes above 30 m are possible. With the latter approach one can determine the relative amount of bird migration in different altitudinal bands (e.g., within rotor swept area (RSA), above RSA) and discriminate the types of targets (migrating bird/bat, foraging bat, insect).

TI-VERTRAD Target Detection

At night the video range is a quarter-mile. When a target goes through you can see a characteristic echo in the vertical beam. We used a video peak store (VPS) to make time exposures of target tracks in the video record of the TI and developed criteria to distinguish birds, foraging bats, and insects based on characteristics of the tracks in the VPS images and the altitude of the targets. Video frames were enhanced to maximize detection of weak radiance signals from high flying birds.

When targets go through, we see an echo in the vertical pointing radar beam. We use VPS to make time exposures of the target tracks and develop criteria to distinguish birds

Discrimination of Targets

The enhanced thermal image shows patterns much more, including wing beat patterns. Speeding the tape up or slowing it down can provide better information on the targets. At altitudes of turbine height or below, we can see wing beat signatures. Targets produce a more intense radial signature when wings are open. A thermal imaging time exposure generates more specific information about bird species.

- Insects produce relatively weak thermal signatures that do not show modulation. There are many more insect targets at lower altitudes.
- Birds produce relatively strong thermal signatures that show distinct modulation that is in keeping with their wing beat pattern.
- Foraging bats show strong thermal signatures with sharp turns and non-linear flight. Fast flying bats show distinct modulation patterns, but these patterns are obscured

when bats are flying more slowly.
- It is nearly impossible to distinguish bats and birds in linear migratory flight, unless they are flying at very low altitudes (< 25 m).

Slide #16 summarizes some of the altitude information gathered on birds and bats during one evening in September 2000 and nine nights between mid-October and early November 2003, and for birds from one day in spring 2003. In the daytime, birds flying north off the Gulf of Mexico are flying at all altitudes, with the highest coming in much higher. The data indicate a lot of bat activity at very low altitudes, where thermal imaging and radar give us good information.

Advantages and Disadvantages

Principal disadvantages of the TI/VERTRAD system include:
- Thermal Imaging cameras are very expensive ($50-75,000).
- TI cannot be used to see small targets through heavy cloud and precipitation.
- The TI/VERTRAD system samples a narrow cone directed vertically when configured to detect higher altitude targets.
- Analysis of the data is time consuming; however, algorithms are being developed to automate this analysis.

The principal advantage of TI is that it provides the most accurate migration traffic rates (number of birds or bats crossing 1609 m [1 statute mile] of front per hour) for birds or bats flying below 25 m agl. (With vertical radar alone, you cannot see any targets below 25 m, although you know that they are there.) This is important for estimating potential risk of migrating birds colliding with man-made obstacles. Other advantages include:
- TI cameras can be used to identify sources of radar echoes at a greater distance than image intensifiers, and can be used to quantify the displays.
- The same methodology can be used day and night without requiring any target illumination as is the case for image intensifiers.
- TI/VERTRAD systems are portable and can be deployed in many different topographies.

Application of TI/VERTRAD Technique using Weather Radar

We used the TI/VERTRAD system to quantify weather surveillance radar (WSR-88D, or NEXRAD) displays of arriving trans-Gulf spring migration. Data were extracted on the number of birds passing through the sample volume of the thermal imager above 250 m when clouds were not present. We recorded the altitude of each individual target or flock. Birds detected below 250 m were excluded – both because the radar beam did not sample below 250 m and because we did not want local foraging birds to be included in the samples.

Note that the diameter of the sample volume increases with altitude, so that higher flocks show up as thicker lines in the images (slides 22-23). We converted the number of birds per sample time to the number of birds crossing a mile of front (1.609 km) per hour, the migration traffic rate (MTR). To convert MTR to a density, we divided MTR by the radial velocity (km/h) of the migrants measured in the base velocity product of the WSR-88D.

There are about 50 WSR-88D (NEXRAD) Doppler weather radar stationed throughout the Continental United States, Alaska, Hawaii, and Puerto Rico. WSR-88D provides information on movements within 230 km or 124 nautical miles for a single radar station as well as regional and national scale for multiple radar sites. We used the Lake Charles, LA (KLCH) radar when it was available and the Houston, TX (KHGX) radar when KLCH was not operational. From KLCH we collected radar reflectivity data (dBZ values from a total of 25 pulse volumes between 90-94 km along five radials centered on the radial at 240°. From KHGX we collected radar reflectivity data (dBZ values from a total of 25 pulse volumes between 99-103 km along five radials centered on the radial at 73°.

Slide #26 shows relative reflectivity (dBZ) data transformed into mean reflectivity (Z). Mean Z values were computed for the 25 pulse volumes. The mean Z values froom this data were then fit linearly to the bird density values from the TI/VERTRAD data using JMP software (release 5.0).

Discussion and Conclusions

Only half the variance in radar reflectivity accounted for by variation in bird density. Several factors may contribute to this.

- Flock sizes varied greatly (in dense flocks, some birds may be blocked by other birds).
- Not all individuals are accounted for, because not every individual in a flock passes through the sample volume.
- The exact altitude of the radar sample changed depending on atmospheric conditions
- Not all of the reflectors aloft are birds (there may be insect contamination).

The TI and VERTRAD system provides quantitative Migration Traffic Rates. However:

- In this study, low-flying birds (below 500 m) were probably missed by the WSR-88D samples taken at ranges of 90-94 km from KLCH and 99-103 km from KHGX
- Very high-flying birds above 3 km detected by the WSR-88D likely were missed by the thermal imager.

Future studies will be made at a site that permits better overlap of the VERTRAD/TI and WSR-88D data.

Response to Presentation

Question: Can NEXRAD pick up birds flying at turbine rotor height?

Response: WSR-88D or NEXRAD is used only for the determination of large scale migration patterns. WSR-88D can tell when and where migration is occurring within a range of 124 nautical miles. It does not pick up low flying birds as the altitude of the base of the radar beam in creases with increasing range from the radar. At 30 nautical miles, birds flying below 250 m are likely not detected. However it is important to know when birds are coming over a project area, because there are times when weather conditions (e.g., low ceiling and mist) will force migrating birds down to the rotor level. The array of weather radar sensors in the US is a very important source of information on bird migration patterns.

Question: How is one-mile front calculated?

Response: Migration traffic rate is the number of birds crossing a mile of front per hour, and it is a standard metric for comparing the amount of bird migration from areea to area. Sample spaces can be corrected to equal a mile of front e.g., correction factors). The cone of observation (thermal imaging, moon-watching) increases with distance (and altitude), and if one knows the distance of a bird, then the width of the sampling cone can be computed and this can be corrected to equal a mile of front. Correction factors decrease in magnitude and distance increases.

Toward Prediction of Bird-Rotor Collision Mortality

Robert McFarlane[4]
McFarlane & Associates

How can we predict collision mortality before construction? The prediction of avian mortality due to birds colliding with wind turbine rotors has remained elusive.

Existing Methods for Estimating Avian Use

Pre-construction estimates of avian use of an area or potential exposure to rotors typically come from point counts and line or point transects. The NWCC Guidelines do not recommend a specific method but offer the Buffalo Ridge installation as a case study. This study calculated an exposure index that permitted a comparison of relative risk among avian species but did not provide an estimate of mortality. There have been few comparisons of pre-construction predictions and actual post-construction mortalities.

Point counts of birds provide numbers, but not much information. In the first place, they do not detect all birds; if a bird doesn't fly or vocalize, it is likely to be missed. Secondly, point counts do not provide an estimate of bird density (the number of birds per unit area). They do not measure avian use of an area or exposure to rotors.

Line transects use a laser range finder to calculate perpendicular distance from the line transect to the bird. The method is very accurate, but cumbersome because you have to know where the line transect is. Line transect data can be entered into the computer program DISTANCE to calculate density ± 95% Confidence Level.

[4] McFarlane & Associates, Houston TX

Point transects use a laser range finder or radar to measure only distance from observer to bird. The data consist of 5-minute count snapshots covering 360 degrees. Point transects do not differentiate between birds flying within the rotor swept zone altitude and birds flying above or below (90-92% of birds I have counted pass below the zone).

Proposed Dual Sampling Method

I propose a dual sampling method, incorporating both a *point transect* to estimate density, and a ***plane transect*** to estimate transit, to improve estimation of avian mortality. The concept is that of a virtual vertical plane defined by the rotor swept area of a string of turbines. The metric of interest is a count of birds that penetrate the plane within a defined time period.

A standard 360° *point transect* count is conducted for 5-minutes (to limit entry and departure of birds from the count circle). Distances from the observer to the birds are determined by laser rangefinder or marine radar. These data are used with the computer program DISTANCE to estimate bird densities. The DISTANCE program calculates a probability of detection curve, with probability decreasing as distance from bird increases. DISTANCE calculates bird density w/ 95% confidence level, providing a way to measure the “birds you didn’t see.”

Immediately following the point transect count, a unidirectional plane transect is established from the same point perpendicular to the prevailing wind. The transect length is measured by laser rangefinder or radar. All bird penetrations of the imaginary plane during a 30-minute (or other) time period are tallied. The compass direction of the plane mimics a string of proposed turbines at the site. Dual samples are obtained from multiple points and/or dates for the study area. Absent an accurate method to determine the height of a bird flying above the ground, bird passage is categorized as above, within or below the rotor-swept height zone.

The dual sampling method yields:

1) an estimate of bird density (number/ha)
2) an estimate of bird passage through a string of turbines (birds/km/hr), and
3) crude estimates of bird exposure to the rotors.

Probability of Bird-Rotor Collision

To refine the estimate of bird exposure within the plane transect, we use site-specific turbine height, spacing, rotor length and frontal-section width information to calculate the total collision surface, and divide that by the total area of the vertical plane of the turbine string’s rotor swept zone. The formula assumes that the probability of collision is the same whether the rotor is moving or not, because the surface area is the same in either case. However, if we know that birds are able to avoid the tower itself as well as the slow-moving larger part of the blade, we can exclude those surfaces from the calculation. In general, however, avoidance is calculated separately.

Estimates of bird exposure to the rotors provide a worst-case assessment of collisions.

Predicted collisions based on this calculation, MINUS bird avoidance of the turbine rotors, equals actual collisions. Bird avoidance of the turbines remains to be measured, however. Accurate determination of the height above ground of a flying bird also remains technically challenging.

Are bird density and passage rates related?

Slides #18-20 show rates of passage plotted against bird density for both coastal seabirds and upland birds. Overall, there does not appear to be a strong relation between density and rate of passage of coastal seabirds. Over coastal waters, bird densities ranged from 5.7 to 17.4 birds/km^2 and bird passage ranged from 85 to 388 birds/km/hr (n=10). There was no correlation between the two measurements (r^2=0.027).

Over coastal upland areas bird densities ranged from 2.9 to 12.2 birds/ha and bird passage ranged from 71.3 to 1930 birds/km/hr (n=12). The correlation between bird density and bird passage was greater somewhat stronger for upland birds than for coastal birds, but still not significant (r^2=0.206). (Notice the outlier point on slide #19 – this is attributed to a flock of redwing blackbirds. If this outlier is removed from the analysis, a moderate relationship can be shown (r^2=0.48). However, these pulses created by large flocks of birds are not anomalies and should be retained in the analysis.

We used the dual sampling method at four sites in Texas to come up with estimated collisions/turbine/year. Slide #17 summarizes the data and the predictions made for these four sites. Sites 1 & 2 show high risk (46.0 and 44.3 collisions per turbine per year, respectively); sites 3 & 4 show much lower risk (7.7 and 9.7 collisions per turbine per year). All are worst-case estimates as the actual number of birds flying within the rotor-swept zone is over-estimated because one cannot accurately measure the height of a flying bird above ground.

Next Steps

The next step is to compare predicted collision rates with actual collision rates at sites with known bird-rotor collisions. We must then address two questions:

1) Does the difference (between predicted and actual collisions) equal bird avoidance?
2) Is there a relationship between bird density and the bird collision rate?

Post-Construction Studies

The Genetic Consequences of Wind Power Development on Greater Prairie Chicken Leks of Eastern Kansas

Andrew Gregory[5]
Kansas State University

Earlier presentations have addressed the visible consequences of wind power development; this presentation focuses on not-so-visible consequences: genetic consequences on Greater Prairie Chickens of eastern Kansas.

Why do we want to address population effects?

Understanding the population genetic characteristics of a species are important to our understanding and mitigation of extinction processes. Population genetics can tell us about:

- population structure;
- recent and historical expansions or declines in population size;
- population reproductive strategy, success, and history; and,
- historical movements of a population on the landscape

This presentation introduces several key terms:

- F_{st} is a fixation index, the degree of genetic differentiation among a number of populations. The smaller (closer to 0), the larger and less fragmented a population; the larger (closer to 1) the F_{st} value, the greater the degree of differentiation into genetically distinct sub-populations.
- N_e is the effective population size, usually between one and ten percent of the overall population census size.
- *Allele* is the same as a gene. Micro-satellites yield neutral alleles or neutral genes- that is an allele or gene which is not actually coding for a specific structure, chemical, or behavior under selective pressure. An individual's genotype for a specific locus will be the set of alleles possessed.
- H_z (heterozygocity) is a measure of the average number of individuals in a population that are heterozygous at a locus.
- *Population* A series of connected groups of individuals that regularly interbreed with each other to produce viable offspring capable of interbreeding with each other.

From a genetic perspective, the effective size of a population is determined by its allelic diversity or richness – that is, how many different alleles exist within the population for a given trait. For example if a populations census size (N) is 200 individuals, with an even sex ratio, and all individuals mate randomly and have equal reproductive success, then the effective population size should also be 200 individuals. Discrepancy between effective population size and census population size arises because, while all individuals in a

[5] Co-authored by Lance McNew, Brett Sandercock, Samantha Wisely.

population are assumed to have an equal probability of mating, reproductive success exhibits a Poisson distribution. Consequently the genetic material of non reproductive animals is lost to the population, and the genetic material of highly successful animals is magnified in the population. As a result of this genetic inheritance in the population behaves as if it were a smaller population than the actual census size population, we call this new genetic population the effective population. Officially the effective population is an ideal population (one with random mating and equal reproductive success) that looses genetic diversity at the same rate as the focal or census population.

The greater the allelic diversity, the more likely a population will be able to persist on a landscape. When a population starts to lose genetic diversity, potentially harmful recessive traits are unmasked and the population's ability to adapt to change is reduced, making it more vulnerable. The formula $1/[2 \times (N_e)]$ gives us the rate at which a population loses genetic diversity; the smaller the effective population size, the faster diversity is lost.

A population with a small F_{st} value (close to zero) is large and unfragmented, with different alleles equally likely to be found in any part of the territory inhabited by the species in question as in another. Large F_{st} values (close to one) indicate that the population is differentiated into genetically distinct sub-populations. If you have a large, contiguous population, allelic diversity is lost at a slow trickle. However, if you have a small population, or one that is fragmented into small isolated pockets of sub-populations, population bottlenecks are more likely, and as a result rare alleles will be lost rapidly. Because small and genetically fragmented populations lose low-frequency alleles quickly, they are at greater risk of extinction.

Studying the impact of wind power development on Kansas Prairie Chicken populations

The Kansas Flint Hills are a top choice for wind turbines, but they also are important habitat for the Greater Prairie Chicken (GPC), representing the last core of remaining intact tall-grass prairie for this tall-grass prairie obligate species. Wind energy facilities have relatively small footprints, but turbines and access roads fragment the landscape, and fragmentation is thought to be a key factor contributing to the loss of genetic diversity. It is known that as prairie chickens lose their allelic (heterozygotic) diversity, their hatch rates decline. Population decline leads to loss of allelic diversity, which leads to increased inbreeding, reduced fecundity, decreased population and reduced N_e and N to decreased population and reduced N_e and N, etc. This is what is called an "extinction vortex."

The Kansas GPC Population Genetics study focused on sites throughout the Flint Hills, a stronghold for the GPC. Using a Before-After Control-Impact (BACI) design, the study integrates molecular DNA analysis and demographic parameter methods to achieve four objectives.

1) Perform a baseline genetic assessment of Kansas GPC populations
2) Assess the influence of landscape patterns on the genetics of Kansas GPCs
3) Assess the influence of wind power development on the genetics of Kansas GPCs

4) Assess the combined influence of landscape and wind power development on the genetics of Kansas GPC populations.

This presentation focuses on the first of these objectives: to assess whether, prior to wind development, there is evidence of a genetic bottleneck or genetic isolation in Greater Prairie Chicken populations in Kansas.

The two sites, with data ready in 2006, are about 186 km apart, one in Geary County near Manhattan, KS, and the other 186 km away in Elk County near Wichita, KS. We looked at about 30 birds per site, at only five molecular markers, so our estimates at this time have fairly low confidence levels. Slide #15 summarizes the findings of the DNA analysis. We expected to see a low F_{st} value (.01) between sites in Elk County and Geary County, because the Flint Hills area is still relatively unaltered tall grass prairie with few anthropogenic structures. Consequently prairie chickens should be able to move across the entire region easily. This unhindered movement is what has allowed for the flint hills prairie chicken population to function as a single large population and consequently there is a large effective population size.

Comparisons with populations that are known to be isolated or fragmented in Illinois and Wisconsin (see slide #16) show that the Kansas GPC is doing well in terms of fragmentation and effective population size. However, analysis of allele distribution using program bottleneck indicates that the allele frequency in Kansas show a marginally significant excess of heterozygotes and some bimodality in allele frequency. This suggests that while Kansas prairie chickens may not currently be bottlenecked they may be in the process of bottlenecking. Alternatively, the observed bimodality could be a signal from a past bottleneck from which the population is in the process of recovering. Observations overt the next few years should elucidate which is the case. Finally, we observed greater genetic structuring at a finer spatial scale Within Elk county than we did across the entire study area ($F_{st} = 0.038$, across a 7 Km distance). This could also be related to the decline of tall-grass prairie, and greater prairie chicken territory compression, throughout the Midwest since human settlement.

Implications of Preliminary Findings

Our first finding, then, is that currently there is a large, stable population of Greater Prairie Chickens in the Flint Hills. If wind development fragments the landscape, we would expect to see:

- F_{st} is likely to increase as the population is subdivided.
- Heterozygocity may remain the same, but more likely will decrease.
- Effective population size is likely to decrease.

Slides 20-22 show how planned wind energy development may fragment GPC populations. From a prairie chicken’s perspective, if wind turbines fragment a landscape, but are built parallel to historical dispersal movements, then wind-power construction would be relatively benign. Evidence for this would be maintained low F_{st} values and low relatedness between all greater prairie chicken groups both pre- and post-construction.

However, if the planned development is built orthogonally to historical dispersal routes it would effectively fragment the landscape (slide #21). Under this scenario we would expect to see F_{st} and relatedness values increase between formerly connected sites (slide #22). This would result in a once-contiguous population being subdivided into a series of smaller sub-populations.

Please note that physical distance between populations is less important than connectedness of the populations. If, for whatever reason, the animals' historical dispersal patterns do not link two adjacent groups, then those two populations are isolated from each other in space. Conversely, if two groups are located at a great distance from each other, but historically dispersal was regular between the two then those groups are connected and is essentially one population. The take home message is that, while Euclidean distance is an important factor in determining whether two groups are in fact one population or not, an even more important factor is landscape connectivity and gene flow.

Response to Presentation

***Question*:** If you know that fragmentation causes population decline, why not just divert wind development to agricultural land, away from tall grass prairie?

***Response*:** This is a good thought, but these flat prairie table areas are very attractive to both GPCs and wind developers, so it's not quite that simple. Additionally, there is very little agriculture throughout the Flint Hills region as the underlying bedrock makes growing crops very difficult. Western Kansas has far more agriculture than Eastern Kansas, but the western side of the state lacks the needed infrastructure to get power produced onto the grid.

***Facilitator*:** In a couple years, we should hear more on this research from the Grassland and Shrub-Steppe Species Collaborative (GS3C), which is a subgroup of the NWCC Wildlife Workgroup.

***Question*:** What difference in pre- and post-construction F_{st} values is significant for the population?

***Response*:** There is not really an absolute value. In general, once you get an F_{st} value above 0.15, you would consider the population to be existing as a series of meta-populations as opposed to one contiguous population. However, a more refined method is to make comparisons of F_{st} values observed between several populations at increasingly greater spatial scales, and increasing likelihood of being isolated from each other.

For example, if you compared a population of some terrestrial mammal from Russia to one in the United States and obtained $F_{st} = 0.18$, we would know these two populations are likely completely isolated from each other and have been for several generations – so $F_{st} = 0.18$ is the greatest observed F_{st} value you are likely to find for this animal. If then you compare your two local populations, living at a distance from each other of 120 Km and find $F_{st} = 0.11$, you would still consider this evidence for population fragmentation even though this value is less than the 0.15 guideline.

Based on Research Results: Questions to Address

moderated by
Kathy Boydston, *Texas Parks and Wildlife Department*

Effects of Wind Power Development on Sage-grouse

Michael A, Schroeder[6]
Washington Department of Fish and Wildlife

There is a lack of published data on wind power development within the occupied range of both species of sage-grouse (*Centrocercus* spp.). Presently, most wind power developments within the range of either species are in marginal habitat for sage-grouse or their impacts are not easily identified because of other confounding factors including major highway systems. We expect this to change, however, as the number of wind power developments increases.

Potential Effects

The greater sage-grouse (*C. urophasianus*) is a wide-ranging species while Gunnison sage-grouse is more restricted, but both species are large-bodied, long-lived animals exhibiting low productivity and low density. This creates a challenge when looking for possible effects from development. Unlike other bird species, direct collision mortality with scattered obstacles (such as turbines) is likely not as much of an issue for sage-grouse as fences, guy-lines, and power lines. There is only one known example of a grouse that was most likely killed by a turbine. The primary concerns with development are direct loss and degradation of habitats, and indirect impacts due to habitat fragmentation, increases in predation risk, and increases in visual and auditory disturbance.

Impacts on other species of prairie grouse and from other types of development

Data on wind power effects on sage-grouse are lacking, but there are data on other types of development and with other similar species of grouse. Kansas State University Professor R. J. Robel recently argued that a proposed 8,000-acre wind development in the Flint Hills of Kansas, with about 80 turbines, would adversely impact the suitability of "15,000 to 18,000 acres [~6,100-7,300 ha] of very good to excellent greater prairie-chicken [*Tympanuchus cupido*] nesting and brood-rearing habitat" (Robel 2002). Although the direct footprint of a wind development may be as little as 2% of the overall area, there is potential for much more extensive impacts on grouse. Robel argued that greater prairie-chickens have "a low tolerance for human disturbance" and would likely avoid areas within 1 mile [1.6 km] of turbines. This effect is exacerbated by the large home ranges of

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[6] Co-authors: Clait E. Braun, *Grouse Inc.*; John W. Connelly, *Idaho Department of Fish and Game*

prairie grouse, including sage-grouse.

Research on lesser prairie-chickens (*Tympanuchus pallidicintus*) illustrates some of the potential affects suggested by Robel (2002). Robel and his graduate students observed avoidance by lesser prairie-chickens of houses, well-traveled roads, and compressor stations in southwestern Kansas. These observations were consistent with those of Hunt (2004) in New Mexico. Hunt found that development (gas wells, roads, power lines) had an adverse affect on occupancy by lesser prairie-chickens.

Similar adverse affects of development have been documented for greater sage-grouse in the sagebrush (*Artemisia* spp.) steppe (Lyon 2000; Braun et al. 2002; Lyon and Anderson 2003; Connelly et al. 2004; Holloran 2005; Naugle et al. 2006*a, b*). For example, Holloran (2005) documented decreased sage-grouse activity close to drilling rigs, gas wells, and haul roads; overall, energy development had a negative affect on sage-grouse. Connelly et al. (2004) documented a negative affect on Interstate 80 (I-80) in southern Wyoming. Of 802 leks identified within 100 km of I-80, there were no leks within 2 km of the highway, and very few within 4 km of the interstate; leks outside the I-80 corridor tended to be somewhat evenly distributed. Leks relatively close to I-80 were also more likely to be inactive; 44% of the 34 leks found within 7.5 km of I-80 were active, compared with 67% of the 84 leks found between 7.5 and 15 km of I-80. Similar observations were noted for leks in relation to power lines in Washington State; the likelihood of lek extirpation appears to be negatively correlated with distance to the nearest power line.

Despite these documented relationships between development and prairie grouse in general, and sage-grouse in particular, there is a great deal that is not known. For example, little is known about the specific relationships between grouse and environmental disturbances. Are grouse responding to habitat loss, auditory disturbance, visual distance, increased risk of predation, an unidentified factor, or a combination of factors? Identification of the specific relationships between sage-grouse and disturbance will be important so that suitable minimization and mitigation measures can be considered, where appropriate.

Case studies

It is difficult to document current impacts of wind development on sage-grouse for 2 basic reasons: (1) sage-grouse typically inhabit sagebrush habitats at relatively low densities; and (2) few wind developments are in prime sage-grouse habitat. For example, Foote Creek Rim in Wyoming is the only development with a documented sage-grouse mortality, and yet it can be argued that it is not in the best sage-grouse habitat. Other current or potential developments (Pleasant Valley, Medicine Bow, Elkhorn, Stateline, Nine Canyon, Cotterel) are either in marginal sage-grouse habitat or they are in areas where sage-grouse populations have been inadequately monitored.

Some of the best pre-treatment data for sage-grouse in a wind development site exists for the Wild Horse development near Ellensburg, Washington (numerous observations of unmarked and radio-marked sage-grouse). Ironically, even with the grouse observations, the Wild Horse development is not considered to be part of the current breeding distribution of sage-grouse in Washington (Schroeder et al. 2000, 2004). The rapid expansion of wind power in the west is likely to result in marked increases in potential conflicts with sage-grouse. This is the primary reason why the Washington Department of Fish and Wildlife's Wind Power Guidelines (2003) recommend that "Wind project developers should be discouraged from using or degrading high value habitat areas, especially shrub-steppe habitat in 'excellent' condition."

Response to Presentation

Question: The wind developer in Douglas County went ahead with development; was there some other mitigation that was used?

Response: The local public utility is the developer and, at this point, the development is only proposed. The utility has been very forthright; there is an existing power line with capacity to handle 10 turbines in a pilot project, with a maximum buildout to 47 turbines. Douglas County PUD has all the energy it needs to serve a relatively small population in a huge county, so the issue is whether to develop wind energy as an export, helping other communities to meet the state's requirement that 15% of energy production be non-hydro renewable. In other words, there are other issues to consider besides sage-grouse habitat.

Question: In Idaho, the Fish & Game Department is funded by the sales of hunting licenses; yet the same agency is charged with sage grouse study and protection. How do we resolve this conflict?

Response: In Washington State the population of sage-grouse is under Federal scrutiny, so no hunt tags for sage-grouse are being sold. The question is valid, but it doesn't apply in the case of Douglas County or elsewhere in Washington State. It should also be noted the issue is not necessarily the loss of a few individuals due to mortality, but rather the permanent loss of the habitat needed to support populations.

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Impacts of Wind Power Development on Mountain Plovers at Foote Creek Rim

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The breeding population of mountain plovers (*Charadrius montanus*) in the Foote Creek Rim wind project located in Carbon County, Wyoming has been studied annually since 1994. Mountain plovers occupy short-grass prairie or shrub steppe habitat with a prevalence of bare ground and very low relief. The Foote Creek Rim (FCR) wind plant is located in sparsely vegetated short-grass prairie along approximately five miles of flat top mesa that features steep, sloping sides.

Plovers are a migratory shorebird species, arriving in breeding grounds late March to late April. Nesting occurs in May-July, and the young fledge in July and August. The presence of mountain plovers was identified during scoping for Phase I (133 turbines), and surveys targeting the plover were included in the protocol for Foote Creek Rim. In 1999, the US Fish & Wildlife Service had proposed listing this species, but now it is merely a "species of concern."

Survey Methods and Data Analysis

Field survey methods included transect surveys to census mountain plovers twice a month during the breeding season (May through July). Nest searches were conducted most years primarily in June, and mortality studies were conducted from 1998-2001 after turbines had become operational. Based on first and last observation dates, it is believed that mountain plovers occupy FCR from late April to early August.

Transect surveys. Transect surveys were conducted six times during breeding season, twice a month during May, June, and July. Surveys were conducted along 29 east-west transects 300 m apart to provide full coverage of the wind project. Numbers, age, and estimated distance to each plover observation were recorded. Analysis of the transect data included correcting observed numbers for visibility bias using the program DISTANCE. Population estimates varied over the study from approximately 60 to 18 but showed a decline through the construction period followed by a slow increase post-construction.

Nest searches. Restrictions on off-road travel limited the effort to search for plover nests. An on-foot observer would prompt plovers to leave their nests; the observer would then return to the vehicle to watch for plovers returning to their nests. While the level of search effort varied from one year to another, some nests were found every year, and each nest found was monitored for outcome.

Nest success was determined based on eggshell fragments (small fragments buried in the nesting material indicate success of hatching) or direct observation of chicks. Infertile eggs are left behind, so can determine rate of hatching success. Nest success varied from 0 to 100%. Over all years and all nests monitored, (n = 41 nests), the success rate was 63%.

Nest success was lowest during the construction years, although the sample size is small. Average number of young hatched per nest varied over the years from 0 to 2.5. Over all nests (n = 41) and all years, the number of young hatched per nest was approximately 1.76.

Fatality monitoring. Carcass searches were conducted during plover occupation (April-August) for three consecutive years (1999-2001), as part of a larger bird and bat mortality study. Rectangular plots, 126 m per side and centered on each turbine, were searched once every 28 days by walking parallel transects. Searcher efficiency and carcass removal trials also were conducted, to correct observed fatalities. No mountain plover fatalities were found during the mortality studies in the wind project. Given searcher efficiency (for medium-sized birds) of 79% for spring and 82% for summer, and that the mean length-of-stay for medium-sized bird carcasses of 47 days for spring and 50 days for summer, it is likely that nearly all medium-sized bird fatalities due to the wind project were found.

Results

Population dropped during the construction period, from a mean of 50 plovers during the three pre-construction years to a mean of about 26 birds during construction (1998-2001), but has gone back up to a mean of about 34 plovers during the six years post-construction. Nest success similarly dropped (from 90% to 44%) during construction, with 75% of nests successfully hatched (1.9 chicks per nest) during the six years post-construction. Nest success was lowest during construction and in 1999 (during construction), all four nests were predated. In general, however, it does not appear that nesting plovers are shying away from turbines. Plover density is highest at the northern end of the wind development, where a prairie dog colony is located.

Conclusions

The initial impression is that the low population on FCR from 1998-2000 followed by a steady recovery was related to displacement during construction of the wind plant and subsequent habituation to the facility by plovers. However, it is hard to separate potential disturbance or displacement type effects from a broader decline in the mountain plover population. Nest numbers and nest success declined during construction, but we also found population declines in reference areas, and in the Pawnee National Grasslands in Colorado, during the same period (1995-2000). It also appeared that the FCR population was declining in the years prior to construction.

Our overall conclusion is that wind development and mountain plovers are compatible. Breeding ground behavior puts them at low risk (mostly moving about on ground or at very low altitudes). Habitat disturbance doesn't appear to be a big issue, provided historical land use practices are maintained.

Response to Presentation

Question: Do you have numbers for fledging success?

Response: No. It's tough to give fledging numbers, because plover young leave the nest within hours of hatching, and it's very hard to monitor them over the 60 days from the time they leave the nest to fledging.

What Have Marine Radar Surveys Taught Us About Avian Risk Assessment?

David Young[7]
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Pre-project studies of potentially affected wildlife for impact assessment has been a challenge for wind project development in most of the US. Agency recommendations and requirements vary across the country, but many studies of wind resource areas in the northeast US have included mobile marine radar surveys for nocturnally migrating wildlife. This presentation:

- Reviews and summarizes a suite of radar studies from US wind projects that provide consistent values for metrics that are believed to be related to risk, such as bird flight altitudes, passage rates and flight directions
- Demonstrates how results can be used in a predictive fashion to help meet permitting or regulatory objectives of impact assessment for avian resources
- Provides information supporting an alternative approach to studies of nocturnal migration at wind projects.

Nocturnal Avian Migration

Many species of birds migrate at night. Evidence supports the "broad-front" theory of migration: ubiquitous nocturnal migration occurring in variable pulses over time and space. Nocturnal migrants appear to take advantage of favorable weather events that produce prevailing winds in the appropriate direction. The altitude of nocturnal migrants varies, apparently influenced by species, weather patterns, time-of-night, season, and topography. We know that some migrants – especially neo-tropical songbirds – are at risk of collision with tall structures.

Review of Radar Study Literature

We began by collecting radar study literature published since 2000. Our survey included 25 radar studies of avian migration conducted at 21 sites in the eastern United States and at four sites in the western US. Studies used X-band radar transmitting at small wavelengths (to detect small targets), utilizing both horizontal and vertical sampling methods, surveying areas of 1.4-1.5 km (~ 0.75 nautical miles). Data collection was primarily observer-based (either real-time or post-processing from video). There was no automation of target decision or detection, and no modeling of flight characteristics or altitudes.

We summarized results to look for trends, using standard risk assessment metrics:
- ***Passage rate***, expressed as number of targets/km of migratory front/hour
- ***Target flight direction***, expressed as mean direction (compass bearing) of travel
- ***Target altitude,*** or flight height, expressed as meters above ground level (agl) or above radar level

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- ***Percent of targets below 125 m altitude.***

Several assumptions are important to the analysis, the most important of which is that a target is assumed to be one or more migrating bird or bat. Insects and other non-avian/bat targets can be removed from the data set, screened with either radar data or observer criteria. It was assumed that radar viewsheds from each study are similar, both horizontally and vertically, and that equipment and settings produce similar returns from one study to another.

Similar results across studies have helped to validate this study approach. Direction of travel results are what we would expect for both spring and fall. This gives us confidence that we are detecting migrant birds or bats with the radars. The mean altitude of targets is well over the height of turbine rotors, and in most cases targets were flying higher in the spring than in the fall. On average, the study results indicate that fewer birds are at risk on any given night during the fall, both because fall migration is more spread out over a longer period, and because fall migrants appear to be flying at higher altitudes overall.

Interpreting the Data for Risk Assessment

In interpreting radar data to develop a risk assessment, several assumptions are made.

- The east-west transect of the project area is the width of the migratory front
- That mean passage rate is representative of migration over the site and for the whole season.
- Fall migration extends from August 1 to November 1; spring migration from April 1 to June 1.
- There is an average of ten hours of migration per night.

Given these assumptions, for a site 10 km wide (east to west) with a mean passage rate of 247 targets/km/hour in fall and 258 targets/km/hour in spring (the overall seasonal means for the 21 eastern studies), approximately 3,738,700 targets would migrate over the site each year. Given a mean 6.5% of targets flying below 125 m in fall and 14% flying below 125 m in spring (again the overall seasonal means for the 21 eastern studies), these data suggest that approximately 356,625 targets would migrate over the site each year within the risk zone defined as the rotor swept area.

An alternative qualitative approach to risk assessment is to graphically plot the distribution of targets flying over the site with a modified box-plot (Slide 23). The horizontal line is the median flight height, which is typically lower than the mean. The boxes represent the middle 50% of the flight heights recorded for any given night and the vertical lines represent roughly 90% of the data. This plot illustrates that, on any given night, about 90% of nocturnal migrants fly higher than risk zone represented by the shaded area along the bottom of the chart.

Estimating impacts based on these data requires a further set of assumptions about mortality rates. Using assumptions based on the existing fatality study literature, if mortality is about 5 birds per MW per year (the mean for eastern projects is 4.8 bird fatalities per MW per year), and roughly two-thirds of the fatalities are migrants (the mean estimate for eastern studies is 63.5% migrants), then for a 100 MW wind farm we would predict 500 bird fatalities per year, with 335 of those being migrants. Based on the radar data summarized above, this represents ~0.09 percent of the migrants passing over the site below 125 m, or less than 0.009 percent of all migrants passing over the site.

Studies at three western wind projects (Nine Canyon, WA, Buffalo Ridge, MN, and Stateline, WA/OR) have included both radar studies to calculate passage rates and fatality monitoring post-construction. In all three cases, fatality estimates of migrants based on the studies were as the pre-construction radar studies would have predicted. In all three cases, mortality of migrants was below 0.01% of the number of targets passing over the sites.

What are next steps?

The comparison of pre-construction sampling with post-construction fatality monitoring at western sites is promising. However, migration is lower in the west than in the east, and more post-construction monitoring studies are needed. In particular, there is a need for post-construction monitoring in the east that covers both spring and fall.

There are inherent difficulties in comparing studies because of differences in effort, methods, and equipment (e.g., x-band v. s-band radar). Yet the weight of evidence would suggest that in most cases extensive multi-year radar surveys are not warranted as a pre-construction risk assessment tool. One option would be to compare pre-project radar studies with post-construction fatality surveys. Another, preferred alternative that would focus resources available for wildlife surveys would be a comprehensive post-construction monitoring study using concurrent radar and fatality searches. A designed study to look at risk as the number of targets in the zone of influence and impacts as the number of dead birds could provide more conclusive data directed at quantifying risk to nocturnal migrants. Such a study would have benefits for all concerned. The wind industry would benefit from streamlined wildlife study requirements, maximized gain from resources available for wildlife study, and reducing pre-project effort and costs. Regulatory agencies would be able to operate with better, science-based evidence and decision-making data, including concurrent risk and impact data. And birds and bats would benefit from focused, evidence-based mitigation.

Response to Presentation

Question: What accounts for the big difference between spring and fall percentage of passage under 125 m?

Response [D. Young]: A couple of different things are going on. Birds tend to fly higher in the fall. The characteristics of spring migration may be different, perhaps because birds are not flying as great a distance during any given night.

Response [Sid Gauthreaux]: If birds are forced to fly against the wind, they are going to fly lower. An Illinois study found birds flying at lower altitudes in the fall than in the spring. Look at cold fronts; birds sometimes fly above the cold front.

Question: Is there a correlation with stopover behavior?

Response: Migrant behavior may differ depending on locations; for example, flight characteristics are likely different near stopover habitats. Radar studies typically don't address stopover behavior but are characterizing movement over a site that likely doesn't have stopover habitat.

Question: What about weather conditions?

Response: The studies typically try to sample every night, but for any given study, a portion of the nights or of a given night may be missed because of rain which compromises the radar's ability to record small targets.

Question: Knowing what we do about broad-front migrations, altitude of migration, % of targets <125 m, and fatality rates, why do pre-construction radar studies at all? Would the efforts be better spent doing post-construction daily fatality searches and linking results to weather events to develop mitigation measures?

Response: The short answer is that we do pre-construction radar studies because agencies require pre-construction studies. But it's a good question to ask; the weight of evidence suggests it might make sense to focus more on post-construction monitoring.

Comment [Abby Arnold]: Is there anything we can agree on from what is being presented here about what agencies should require and why? It is good that people here are looking across the studies being done with the idea in mind of what have we learned and what should we be focusing on next. What should be in the guidelines that are now being developed by Federal and state agencies?

Assessing Bird Movement Patterns on Cape May Peninsula Using Marine Radar

David Mizrahi[8]
New Jersey Audubon Society

The proposed Cape May Cable-Stayed Bridge project offers some parallels to wind energy development. The structure would span Middle Thoroughfare to connect Seven-Mile (Wildwood) Island with Cape May Peninsula at the southern end of New Jersey. Wildwood Barrier Island is open marsh and maritime forest. Cape May is a renowned nexus for migrating birds of many kinds, including water birds and fowl, raptors, shorebirds, and passerines.

The road bed of the proposed bridge is 35 m above sea level, supported by a network of steel cables 0.3 m in diameter. Stanchions would extend 100 m above sea level.

Our goal is to understand spatial and temporal dynamics of nocturnal bird and bat movements during migration periods, using marine radar. We have outlined four objectives, of which we are mainly concerned with the first two.

- Estimate target densities and passage rates
- Estimate the altitudinal distribution of targets
- Estimate target velocities and direction of movement through the study area
- Investigate relationships between movement patterns and weather conditions.

Methodology

Marine radar data were collected at Cape May over a total of 42 nights during spring migration (15 April – 31 May, 2005) and over a total of 107 nights during fall migration (1 August – 30 November, 2005).

We used two 25 kW x-band marine radar units operating simultaneously to collect data in the vertical and horizontal planes. Both units had two 6.5 foot open array antennas rotating at 24 rpm with a frequency of 9410 MHz (3 cm) and a pulse length of 0.07 μ sec. In vertical scanning mode, the antenna rotates perpendicular to the ground, giving us a 180° horizon-to-horizon scan over a 0.75 nautical mile (1.4 km) range, sampling about 1 cubic km of space to estimate target altitude and target density/passage rate. In the horizontal scanning mode, the antenna rotates a full 360° parallel to the ground, detecting small passerines within a range of 1-1.5 nautical miles (1.85-2.75 km). At 1 nm, the radar samples of to 483 m above radar level for a total of about 4 cubic km of air space. The horizontal mode was also used to estimate target density/passage rate, as well as target direction and velocity.

We made five successive radar sweeps every 2.5 sec, from two hours before sunset to two

[8] Co-author: Robert Fogg

hours after sunrise. The data from these sweeps were captured as bitmap images every ten minutes.

Given the sheer quantity of the data (675 hours' worth from the spring observation period and 1,700 hours from the fall period), it was necessary to automate the data processing. Black box radar processing allows us to automate the data collection and process/analyze it later. Processing included getting rid of the "ground clutter" and identifying and enumerating targets. Using images taken when targets were absent, we were able to identify persistent stationary reflectors and create a mask to remove those reflectors from data images. We identified and enumerated targets using two-dimensional Gaussian transforms to mark and locate targets in the two-dimensional image plane. We then used GPS data to locate each target's altitude

Data Analysis

All data images were reviewed to identify incidents of precipitation, fog, and insect contamination. (Data with meteorological or insect contamination were excluded from these analyses.) Various methods, including manual removal, were used to identify and exclude non-target data. Text file outputs of image data processing were used to summarize flight pattern metrics, including:

- Target count
- Mean flight altitude
- Percent of targets at or below designated altitude
- Temporal patterns of flight altitude.

Metrics were summarized on a ten minute, hourly, and nightly basis.

Slides #11-18 are typical data slides from spring and fall migration. Slides #11-12 summarize data from two nights in Spring 2005. The upper left-hand graph shows change in mean targets as a function of time, with data points representing mean targets per 10-minute sample (red arrows point to sunset and sunrise). The numbers peak just before midnight, but there is also a peak between about 8:00 am and 10:00 am. The latter represents coastal water birds (such as herons). The upper right-hand graph shows the percent of targets flying at various altitudes. The graph on the lower left shows the percent of targets detected at <100 m (the height of the bridge) at different times relative to midnight. The graph on the lower right shows the percent of targets detected at < 200 m. There is nothing surprising in these data, which show bi-modal patterns with peaks around sunrise and sunset.

Patterns change in the fall. The September graph (slides #13-14) shows a peak after sunset, and then again between 2:00 and 4:00 am, and again right after dawn. More targets were found at higher altitudes during the fall. This corresponds with what others have found.

Seasonal comparisons for the various metrics were made using Kruskal-Wallis one-way ANOVA tests.

Metric	Spring	Fall	*P*
Mean targets per night	2,515	5,246	< 0.0001
Proportion targets/night (asin transformed) ≤ 100 m	0.19	0.05	< 0.0001
Proportion targets/night (asin transformed) ≤ 200 m	0.39	0.18	< 0.0001
Mean targets/night ≤ 100 m	411	184	< 0.0001
Mean targets/night ≤ 200 m	916	843	*NS*

Conclusions

This data gives us a different risk profile during spring v. fall for targets: 1) < 100 m and 2) < 200 m. Below 100 m, there is a lower risk for spring as compared with fall. The same is true for targets flying below 200 m, but there is less of a seasonal difference.

We need to pay attention to biases in target density/altitudinal distribution estimates.

- Target detection decreases both with distance from the radar and with distance from the radar beam's center.
- Sample volume increases with distance from radar, resulting in a bias in volume sampled at high v. low altitudes and far v. near locations.
- Target aspect affects detection probability and target size estimates.

Calibration is another important consideration. We need to assess the relationships between target cross-sectional area, reflectance, and target size estimates.

Response to Presentation

Question: Did you experience any interference from both X-band radars running simultaneously? Some literature suggests that you can't run two x-bands together because of interference caused from both radars rotating at the same time (at the same oscillation rate). Did you have to change the oscillation rate of one radar?

Response: We did experience some interference from operating two X-band radars simultaneously. However, this is caused by the two radars transmitting electromagnetic energy of the same frequency and wavelength, not by the antennas rotating at the same rate at the same time. The interference we experienced manifests itself as radial lines emanating from the center of the scan area shown on the monitor. However, the Furuno units we use provide an interference suppression function that dramatically reduces this problem without losing sensitivity. We remove any remaining interference lines not removed by the suppression function during post collection data processing.

Effects of Modern Wind Turbines on Birds: Results of Field Studies on Collision Victims & Nocturnal Flight Patterns in the Netherlands

Karen Krijgsveld
Bureau Waardenburg, Netherlands

We have been studying impacts of wind turbines on birds since the early 1990s. Turbines are now much bigger and much higher above the ground. Effects are often calculated based on studies that were done on the older turbines. Newer turbines have a greater rotor surface area, and species-specific flight altitudes mean different species may be affected differently by the newer turbines. The higher clearance and larger distance between turbines may result in birds flying below or between turbines. . Also, the newer, larger turbine rotors have a lower rpm, changing the risk of collision. How do these changes affect collision risks, barrier effects and disturbance effects of birds?

Collision Rate and Risk

In the first field study, we studied collision risk of nocturnally migrating birds and of local birds such as waders, ducks and gulls at three modern wind farm sites on agricultural fields in the Netherlands during autumn and winter. Two of these sites have a linear arrangement of turbines, the third is a cluster. The turbines are 1.7 MW, with a hub height of 75 m and rotor diameter of 66 m. The rotational speed of the rotors is 21 rpm.

Fatality studies consisted of ground searches conducted every 2-3 days along 4-6 m search bands within a 100 m radius of the turbines. Disappearance rates (20-60% within five days) and recovery rate (searcher efficiency = 75%) were measured to adjust fatality numbers. To calculate collision risk, nocturnal flight activity was measured by means of marine surveillance radar.

With the first generation of smaller turbines, collision rates are estimated at 0-125 victims per turbine per year. At the three wind farms in this study, the collision rate was found to be similar for newer turbines as was found in old turbines: on average, 28 bird victims/turbine/year (min 19 – max 68) for the three sites. Extrapolation of collision rate from old turbines would predict 94 victims/turbine/year; thus the actual rate is three times lower than the predicted rate. Collision victims were diurnal birds as well as nocturnal migrants, local foraging birds as well as migratory birds. Over the three sites, approximately 25% of collision victims were migratory birds, and 45% were nocturnal.

Collision risk was 0.14% on average (min 0.01 – max 0.16), which is relatively low. The risk was markedly higher for local birds (0.16%) than for migratory birds (0.01%).

Disturbance and Barrier Effects

To study the disturbance and barrier effects of wind farms on waterbirds, we looked at a 5-km line of 19 turbines along the dike of Lake Eemmeer (Netherlands). The turbines have a hub height of 60 m, with rotors 55 m in diameter. Using a Before-After / Control-Impact

(BACI) study design,[9] we studied the number of birds in relation to distance from the dike, and flight paths in relation to the wind farm and weather conditions.

Disturbance effects. Looking within 500 m from the turbines, we found virtually no effect on the *number* of most species of local birds (geese, grebe, gulls, cormorant, most ducks). Only pochard (*Aythya ferina*) decreased when turbines were introduced. Looking at the *distribution* of birds as a function of distance from the turbine string, only Mergansers and Goldeneye were disturbed, other speciesof water birds did not appear to be affected.

Barrier effects. To determine whether the wind farm has a barrier effect, we looked at the flight paths and flux of water birds in and around the wind farm. Specifically, we measured the number of land-water passages of ducks, geese, and swans either crossing the wind farm or passing beside it. (Horizontal flight paths were measured using a marine surveillance radar.) We also recorded weather conditions and day/night to take those factors into account.

Water birds were found to avoid the wind farm on a large scale when the turbines were moving. During turbine operation, the number of flight movements *outside* the wind farm was much greater (85% during the day, 75% during the night) than flights *through* the wind farm. Waterbirds made long deflective flights to avoid the wind farm when the turbines were moving (wigeons and geese at night, swans during the day). When turbines were not moving, birds cut through the wind farm. Thus there tended to be a higher percentage of birds crossing through the wind farm during foggy conditions, because fog correlates with a lack of wind, hence the turbines were standing still.

Conclusions

Our findings of collision risk, disturbance effects and barrier effects are similar to results . The new, larger turbines present a collision risk similar to or smaller than that of the earlier generation of turbines. The collision rate was 28 birds/turbine/year, with a collision risk of 0.14% of birds flying through wind farm.

Other than mergansers and goldeneye, the number of water birds in the vicinity of the turbines was not affected. However, the wind energy facility did have a significant barrier effect, with ducks, geese and swans going to some length to avoid foraging flights through the wind farm when turbines were moving.

Implications for siting. These findings have important implications for where wind farms are sited and how they are laid out. To minimize collision and barrier effects, wind farms should be sited in areas with limited flight paths, and wind turbine strings should not be arrayed perpendicular to major flight paths.

Further research efforts. Current studies are looking at collision risk with turbines and effects on foraging behavior of geese and swans in agricultural areas. We are using remote

[9] The control area was an adjacent lake without turbines; the before and after periods were 1998 and 2003, respectively.

techniques to measure flight patterns and collision risks offshore.

Response to Presentation

Questions about offshore studies (e.g., effect on sea mammals, impact on soundscape of the night sky) were referred outside the plenary discussion. Facilitator noted that the NWCC website has some relevant presentations on offshore wildlife impacts, as well as links to other websites.

Question: Are US and European researchers using different methods for calculating the number of bird fatalities per turbine per year? At US sites, researchers are finding annual per turbine fatalities closer to 2, whereas in Europe, the number is closer to 28. Why the difference? Is the method (or are the metrics) different?

Response [K. Krijgsveld]: The main source of variation in collision rate was that no count was made of depredation rate and recovery rate. I don't think it is a biological difference. It is important to distinguish between collision *risk* and collision *rate*. Risk, which includes the flight intensity through the site, may be the same, but rate may be different because flight intensity is different. The crucial thing is that for collision *risk* you need to know the actual numbers of birds passing through, not just the numbers of victims found, and you need to be able to measure disappearance and recovery rates. As long as all these are accounted for, you should get a comparable measure of risk.

Response [D. Strickland]: I'm not sure why the difference. Winkelman's data are primarily coastal areas with a higher density of birds than in many areas in the US.

RESPONDENT PANEL:
WHAT NEW INSIGHTS HAVE WE LEARNED ABOUT AVIAN / WIND INTERACTION?

Facilitated by
Abby Arnold, RESOLVE

Panelists:
Al Manville, US Fish & Wildlife Service
Andy Linehan, PPM Energy
Rob Manes, The Nature Conservancy, Kansas
Linda Spiegel, California Energy Commission
Dale Strickland, Western EcoSystems Technology, Inc.

Facilitator Abby Arnold asked panelists to open the conversation by "reflecting on what we knew two years ago, what you think is coming out that is different or new, and what other observations do you have?" Panelists' observations were followed by responses and open discussion from the floor.

Al Manville, US Fish & Wildlife Service

We have, over the past two years, gained ground in our understanding of avian-wind interactions, and we continue to learn more. We had a radar workshop just last month and another a year ago; other meetings are taking place around the country. The NWCC Steering Committee was asked to identify research needs, issues and priorities. Some of the issues we've heard here this morning reflect what's in the research priorities draft white paper.

Duration of studies was touched on in Otto Hüppop's presentation. The issue of ***start dates*** also comes up. We should think about ***standardizing studies*** and start dates. As has been pointed out before, there is a need for ***consistent metrics***. Different kinds of data collection for different taxa and species. Tom Kunz and team are working on a nocturnal metrics and methods primer.

Both Todd Mabee and David Mizrahi's presentations touched on the question of ***sampling intensity***: how many nights and how many hours per night we need to be collecting data in order to get 90% certainty? What constitutes ***adequate sampling*** v. ***oversampling***? The issue of ***cost*** comes up repeatedly. A ***multi-platform tool*** such as Hüppop's study used is worth considering, but it is essentially a military tool and quite expensive. ***Variation in migration patterns*** needs to be considered

Radar use depends on what taxa, what species we are concerned with at a given site. We are not just talking about passerines. The use of ***wing-beat patterns*** to coarsely differentiate songbirds from other kinds of birds when looking at radar targets is of interest. The ***combination of thermal imagery and radar*** to discriminate birds and bats from insects is useful.

How do we ***integrate this with weather (NEXRAD) radar?*** This is a challenge we discussed in Albuquerque – it shows a lot of promise, and deserves more focused discussion. USFWS will be developing a team with USGS and others who were at the Albuquerque meeting discussing the ***use and calibration of radar***. It is important to note that most of what we are looking at is clear weather data—how do you deal with the effects of inclement weather? X-band radar cannot distinguish between targets and precipitation, and this raises some questions.

How to accurately ***predict traffic rates*** of species? We need to validate Robert McFarlane's model with ***mortality monitoring***, fine tune the collision prediction.

Automated data processing is a valuable tool

Increasing turbine heights raises concerns with USFWS. Flight heights, data skewing, percent of targets flying near the ground spring v. fall also are of concern.

We need to look more at ***impact of habitat fragmentation*** on grassland species, using BACI method recommended in the 1999 Methods and Metrics doc. The sage-grouse presentation we heard this morning illustrates the difficulty of looking at large-range, low-numbered species. Genetic studies are a good step

The issue of ***barrier effects*** and ***alteration of flight behavior*** as discussed in Karen Krijgsveld's presentation is important to look at.

Andy Linehan, PPM Energy

One difference from two years ago is that there have been a lot more radar studies in the Northeast. Yet these studies are not telling us much new about avian migration in the Northeast. The great percentage of birds are consistently shown flying above turbine heights. What this says to me is not that radar studies are useless, but that ***we need to use radar in a more focused way, correlated with intense mortality monitoring.*** That is expensive, however, and the best hope for doing it right would be with a combination of industry and government and NGO funding. Such correlated studies would be helpful.

Dale's summary about what we knew as of 2004 mentioned a ***comparison of pre-construction density and post-construction raptor mortality*** – we have found that the former is a good predictor of the latter, which is very useful.

Rob Manes, The Nature Conservancy, Kansas

There is a group of long-term questions that we are struggling to answer, as well as some short-term questions that we are able to advance on. In particular, there were questions raised early on about migration elevations that we're beginning to answer. We have identified ***multiple combined technologies*** that have us to the cusp of understanding those issues.

I'm hopeful that we're ***on the way to understanding some of the longer-term issues*** that are more difficult to grasp (e.g., indirect effects on habitat impacts). Over the long haul, these may be the issues we need to focus on; we still have a long way to go on this. We need to get better at interpreting surrogate data, but there really is nothing quite like a wind plant with regard to its impact on the landscape as well as the height of the structures.

Linda Spiegel, California Energy Commission

There have not been a lot of new studies coming out of California. Some monitoring work is being conducted in Altamont and Solano Counties. Mostly, however, we are seeing new research coming from the East.

There needs to be ***greater standardization***. Using different methodologies makes it difficult to do a credible meta-analysis. On the other hand, it may not be appropriate for us to do meta-analysis with data from outside California. Though I would like to see more studies in California like Sid Gauthreaux's and Todd Mabee's, all of our areas seem to have higher risk even when adjusted for new technology. It may be that the difference is not linked to technology. California's wind farms are much larger than those in other states, for example Altamont has about 5,000 turbines. The shear number of turbines in a given area increases collision risk.

We have to do post-construction mortality studies to better understand risk. Mortality estimates rely on scavenger adjustments but equations, surrogate species, and condition of species vary. This also casts doubt on the usefulness of comparing mortality estimates between sites. Scavenger adjustments may not be as much of an issue with large birds as with smaller species and bats.

The ***genetics work*** we are hearing about here is helpful for showing significance of impacts.

Dale Strickland, Western EcoSystems Technology, Inc.

Regarding the ***relationship between use and fatality rates***; we don't believe that it's just a question of measuring use; ***species-specific behavior*** also affects fatality rates.

Impact of management actions. At Altamont Pass WRA, industry is attempting to reduce avian mortality through management actions, and is carefully measuring the effectiveness of the actions being taken. The initial analysis for the first seasonal shut-down is underway; we should have some results in a few months.

Issue of ***displacement*** is still very much a "known unknown." The actual footprint of a wind energy development is relatively small, and there is no doubt that it has a larger impact – the question is, how much larger? Does an 8,000-acre wind plant impact a 13,000-acre habitat for prairie grouse as has been posited? At this point we don't know. Like some of the others here, I am interested in the use of a genetics approach to measure the impact of fragmentation on population diversity and viability.

Use of radar. We need to focus on methods to address outstanding questions. This is particularly true with regard to use of radar. I agree with those saying not to do single radar use at sites over and over again. I would rather we try ***relating radar data and fatalities to address risk***, and to look at the effect of topography on specific sites (e.g., Mount Storm).

As Al Manville has pointed out, we also need to address the ***weather*** issue. Radar doesn't help us with what happens in inclement weather, and we need to know what happens when the weather prevents the collection of useful radar data. While S-band radar appears to be less influenced by precipitation it doesn't do so well as X-band with passerines, so we can't just rely on s-band radar to overcome the weather-related limitation of X-band.

Other observations:

- David Young's presentation underscores the value of having reference data; you always learn a lot more when you have reference data, as in case of decline in population of plovers at other reference sites.

- We depend a lot on fatality information to learn about effects. It is a good idea to put fatalities in perspective by using them in combination with other data such as use.

- Karen Krijgsveld noted that resident birds were at higher risk of collision than migrants in her shoreline studies. This makes the point that, because populations of local birds are going to be smaller than the numbers of migrants moving through, lower numbers of local bird fatalities can still mean higher risk for the local population.

- NEXRAD is useful for evaluating migration data.

From the Floor

Question: If you have daily fatality searches, why do you need radar data for weather?

***Response [D. Strickland]*:** Using radar and other methods before a project is developed is a viable approach to estimating risk to birds, and when used in conjunction with existing fatality data can help developers and others decide whether a site is appropriate for development. One problem with fatality data in terms of risk prediction is that we typically do not know how many birds were exposed to the turbines. Post-construction, radar may help estimate exposure for nocturnally active species.

Note that 28-day interval searching protocol means there is a 28-day interval between searches at a given turbine, but people are typically out there on the ground on a daily basis somewhere on the site. If you can estimate carcass removal rate, you can adjust how often you need to be out there searching.

If you want to relate fatalities to real-time weather events, you need to make the temporal link, which will require much more frequent searches.

Question: We're looking at what we don't know. Why not assume that there is some impact from wind plants, and put our resources into proactive mitigation through partnerships to re-knit fragmented habitat, restore habitat, etc.?

Responses:

[R. Manes]: It is easier to do this in some areas than in others, and the price tag for mitigation is staggering.

[A. Hicks]: The Avian Power Line Interaction Committee (APLIC) is a good model of a joint venture program to focus resources on mitigation.

Comment: If you think about the wind industry's evolution over 20 years, it started out in desert and rangeland, and has moved in to agricultural lands and now into forested and marine environments. I'd like to forecast that we will be looking increasingly at forested v. non-forested sites, and ***there will be systematic differences in the kinds of tools and methods used to do predictive and post-monitoring studies in forested sites***. Half of Washington is forested. BLM has opened up lands, and I predict that USFS is going to be next. We need some meta-analysis of what we know already, as well as more guidance as to what we need to develop in the way of tools and approaches to deal with forested land.

Comment: If wind is going to reach 6% of electric generation in this country, we need to think more about ***cumulative impacts***.

Comment: We need to make a point of specifying ***count data v. density data***. All the data is count data!

Question: Dale spoke about raptors, what about passerines?

Response [D. Strickland]: We don't have sufficient data to relate fatalities and use for passerines. Given the number of nocturnal migrating passerines and because the fatality rate appears so low for passerines, at least in existing studies, even if there is a correlation we might not detect it.

SESSION II:
INTERACTION OF WIND POWER FACILITIES AND BATS

This session consisted of a series of presentations on what we have learned from studies of bat/wind interactions, the questions those study results can help us address, and a panel response to the presentations. Paul Cryan (*US Geological Survey*) introduced the session with an **Overview of What We Know,** a summary of study results up to November 2004.

There followed a series of three presentations, moderated by Al Hicks (*New York State Department of Environmental Conservation*), on pre- and post-construction studies conducted since November 2004. A second series of five presentations, moderated by Ed Arnett (*Bat Conservation International*), focused on questions to address based on the results of this research. The session concluded on Wednesday morning with a respondent panel, moderated by facilitator Abby Arnold, addressing the question, **What New Insights Have We Learned About Bat/Wind Interaction?**

OVERVIEW OF WHAT WE KNOW

Paul Cryan
US Geological Survey

The history of bats and wind turbines as we know it is very short. Most of the information we have has surfaced within the past eight years. In that short period, however, we've made quite a bit of progress. As recently as the turn of the millennium, none of us anticipated that bats would show up under wind turbines in large numbers. And yet, as someone who studies migratory tree bats, it's becoming very apparent that they particularly are susceptible to wind turbines.

History of Bats Running into Tall Structures

What we know about bats colliding with tall structures dates back to the nineteenth century.

Sailing and steam ships. There have been 11 reports of bats landing on, ships at sea, with most of these reports dating from before 1950 and occurring on sailing ships and steamers. All involved tree bats (red bats and silver-haired bats), and all occurred during autumn migration periods. Three of these incidents involved flocks of over 100 bats. This history has implications for off-shore turbine siting.

Large buildings. There are also reports of bats colliding with tall structures on land. In September 1929, there were two major fatality incidents at the Long Point Lighthouse on Lake Eerie. The first incident, which took place on September 9, resulted in 600 bird fatalities and three eastern red bat deaths. The second, which took place overnight from September 24-25, likewise involved hundreds of birds and a few bats (1 hoary, 1 silver-haired). Both incidents took place during conditions of rain and fog. In October of 1954 and again in October of 1955, there are reports of incidents in which birds of many species and small numbers of eastern red bats crashed into the Empire State Building. Maintenance workers reported that bats struck the building at 11 pm, while birds struck at 8 am, indicating that birds and bats collided under different circumstances.

The Chicago Convention Center, with its bank of windows facing Lake Michigan, was monitored for bats over a period of eight years (1979-87). Daily searches during the months of February to June and August to November indicated that 1,500-2,000 birds per year were colliding with the building's windows. During that same eight-year period, a total of 79 bat collision victims were found, almost all during the autumn. Eastern red bats predominated (50). Silver-haired bats made up almost a third of the bat victims (27); one hoary bat and one little brown bat were also found.

Communication towers. We also have data on bats colliding with communication towers. In Leon County, Florida, 54 bat fatalities were identified over 25 years of monitoring (1955-1980). Most of the fatalities (86%) occurred on autumn nights, and most were migratory tree bats, 87% of them were species *Lasiurus* (eastern red bats, hoary bats, Seminole bats, northern yellow bats). On most of the nights when bat collisions occurred, numerous birds were killed as well; however, on some nights only bats were killed. Other incidents reported in the literature support these findings, suggesting that, compared to birds, fewer individuals of fewer bat species collide with communication towers and buildings and that bat collisions are most likely to occur during autumn migration.

Early windmills. There is one record of 22 bats (a tree-roosting potential migrant *Nyctinomus australis*) colliding over a five-year period with a small scale wind farm in Australia. But despite the fact that there are thousands of small windmills near open water in North America, there are no reports in the literature of bat fatalities at early North American windmills. The collision of bats with large modern wind turbines appears to be an emerging, unprecedented, and unanticipated phenomenon.

Review of Bat-Turbine Collision Studies

Prior to 2004, there are about a dozen sites where data was collected on bat collisions with wind turbines, including: Altamont Pass, CA; Buffalo Ridge, MN; Kewaunee Co., WI; Top of Iowa; Ponnequin, CO, Foote Creek Rim, WY; and several sites in the Pacific Northwest (1999-2001). As with earlier reports at other types of tall structures, most bat fatalities are found in early autumn and involved mostly migratory tree bats.

Altamont Pass. Operational since the early 1980s, Altamont Pass Wind Resource Area (APWRA) has been developed with over 6,000 wind turbines covering some 70,000 acres of arid foothills. There has been no targeted bat research at APWRA. Avian collision studies estimate more than 1,000 birds (about half of which are raptors) are killed annually, while fewer than ten bat fatalities have been reported – all hoary bats killed during autumn.

Upper Midwest. Studies looking for bat fatalities at three wind energy sites located in croplands and grasslands in the Upper Midwest have found mostly tree bat fatalities. At Buffalo Ridge, MN, mortality does not reflect the relative abundance of local species sampled by other methods (e.g., mist netting and acoustic detectors). The first quantitative fatality estimates for bats were calculated at this site and were generally less than three bats per turbine per year. Searches conducted 1998-2001 among the 31 660-kW turbines at Kewaunee, WI resulted in estimates of about four bat fatalities per turbine per year. At the Top of Iowa wind farm, 26 of 89 (990 kW) turbines were searched, resulting in estimates of 6-9 bat fatalities per turbine per year – again, primarily migratory tree bats killed as a result of collision during late summer and early autumn.

Rocky Mountain sites. A total of 28 bat fatalities have been found at the 44-turbine Ponnequin, CO wind energy site, all hoary bats found in late summer and autumn. At Foote Creek Rim, WY, fatality searches were complemented by a targeted study of bat roosts and activity in the area of the wind development. Hoary bats (which represented 81% of the fatalities at Foote Creek Rim) are not residing long in the area, but were found to roost in the tallest trees when moving through the area.

Pacific Northwest sites. Four wind energy sites in the Pacific Northwest (Klondike, OR, Nine Canyon, WA, Vansycle, OR, and Stateline, OR/WA) are likewise characterized by crop and grasslands, with bat mortality affecting predominantly tree bats, mostly during the late summer and autumn. Annual per turbine bat fatalities are fairly low at these sites, ranging from less than one to less than three bats per turbine per year.

Appalachian Sites Set off Alarm. The first wind sites to cause concern among bat researchers and wind developers were located on the forested ridges of the Appalachians. At a three-turbine site at Buffalo Mountain., TN, 120 bats of six species – primarily tree bats (eastern red and hoary bats) and eastern pipistrelles – were found dead over a four-year period (2000-03). Again, mortality reflected autumn migrants rather than local species. More kills were observed during low and changing winds, and there was an observed correlation between acoustic activity and bat mortality. The fatality rate was estimated at 20 bats/turbine/year – much higher than at any of the crop and grassland sites west of the Mississippi.

Researchers were further alarmed by fatality rates observed at the Mountaineer, WV and Meyersdale, PA sites. Comprised of 64 turbines located at two sites about 90 km apart on a contiguous forested ridge, these sites became operational in 2002 and 2003, respectively. During a three-day period in August 2003, 132 bats of six species were found dead at these sites. The following autumn, the Bat Wind Energy Collaborative (BWEC) found 633 bats of seven species over six-week study period. Fatality rates were estimated at 25-38 bats per turbine during the period, with a total estimate of 1,764 to 2,900 bats killed.

BWEC's Mountaineer and Meyersdale bat fatality studies used infrared imaging to observe bat-turbine interactions. Turbine lighting was not observed to have an effect, but higher mortality was observed on low wind nights and before and after storm fronts. This study "set the bar" for estimation techniques, taking into account searcher efficiency (trained dogs proved better than humans at detecting carcasses), search intervals, and scavenger removal rates (much higher here than at western sites, with evidence of scavengers learning to look for carcasses).

General Patterns in Bat Mortality Data

In "A review of bat mortality at Wind-energy developments in the United States," Greg Johnson (2005) reported that about half the bats reported killed at wind sites during 2004 were hoary bats, while about 25% were eastern red bats. Looking at both incidents reported in the literature that involved migratory tree bats and turbine mortality studies, the timing of fatality incidents appears to peak in mid-September.

Why are they colliding? A number of published and upcoming papers (see slides #37-38) address this question. As of 2004, there were many hypotheses, but no definite answers. Researchers have hypothesized that bats are: following linear corridors; failing to detect turbines when echolocating; experiencing decompression near blades; being brought into blade range by thermal inversions; or, that they are attracted to turbines by:

- altered landscapes
- insects around the turbine rotors
- turbine sounds
- turbines as roosts
- magnetic fields

My hypothesis (crazy idea) is that tree bats are behaviorally programmed to gravitate toward and loiter around the tallest "trees" along their migration route as rendezvous points or places to mate.

Why do bat-wind turbine collisions matter and how to stop them?

Wind is an important source of energy, but bats are also important – and vulnerable, both because their population growth rates are slow and because migratory animals are particularly susceptible to anthropogenic impacts. It is noteworthy that our understanding of the significance of this problem is limited by our poor understanding of bat population sizes.

If turbines are randomly sampling airspace, it might be that there are simply more bats out there than we have thought to be the case. However, if there is an attraction, then we are creating population sinks all over the continent. If this is the case then there is reason to be concerned.

The pattern of tree bats dying during late summer and autumn offers promise in that it suggests a behavioral explanation and possible solutions. However, in July of 2004, more than 50 Mexican free-tailed bats were killed at a turbine facility in Oklahoma. In conclusion, the picture as of 2004 was far from clear.

See slides #44-47 for list of unpublished references.

Response to Presentation

Question: If the Lasirius bats are in fact fall migrants, where are they migrating to, and why isn't there significant mortality in the spring?

Response: This is an excellent question. Hoary bats do very different things in spring v. autumn; this has to do with reproductive activity. Females leave southwest wintering grounds during spring about a month earlier than males. They migrate while pregnant, flying low (heavily laden) – consequently we find them in very different places and doing very different things in the spring v. autumn. During autumn, male and female ranges overlap and their behavior is more similar. As far as we know, most of the mating happens in the autumn. We see similar trends with red and silver-haired bats.

WHAT NEW STUDIES HAVE BEEN COMPLETED ON BATS AND WHAT DO THESE NEW STUDIES TELL US?

Pre-Construction Studies

moderated by
Al Hicks
New York State Department of Environmental Conservation

Patterns of Pre-Construction Bat Activity at Proposed Wind Energy Facilities [10]

Edward B. Arnett
Bat Conservation International

Key questions: Where is the "best" place to locate wind facilities to reduce bat fatalities? What is the "risk" to bats at a given site? Existing pre-construction information is not sufficient to make predictions about fatalities with desired accuracy.

Factors Influencing Pre-Construction Monitoring

There are many problems that could interfere with getting the answers we need to be able to predict bat fatality rates and risks with sufficient confidence.

- Are we asking the right questions?
- Are sampling design and methods appropriate for answering the question(s) of interest?
- How do we account for spatial and temporal variation?

Other problems to avoid include poor sample size, low power, and pseudoreplication that may lead to inappropriate statistical and deductive inferences. To date, no study has correlated pre-construction information on bats with post-construction fatality. This limits our confidence in the use of pre-construction data to make pre-siting "risk assessments."

Can Pre-Construction Study Predict Post-Construction Fatalities?

In 2005, we gathered data using acoustic detectors to develop indices of bat activity at two proposed wind energy sites with very different topography. The first site, in south-central Pennsylvania, is located on a forested ridgetop. The second site, in Southeast Wisconsin, is located in an agricultural landscape setting near the Horicon Marsh and Neda Mine.

We used met towers and "portable" telescoping towers, placing acoustic detectors at ground level (1.5 m), at 22 m (approximate height of the top of the canopy), and, in the case of the met towers, at 44 m. The portable towers were moved to different locations

[10] Edward B. Arnett, BCI; David Redell, Wisconsin Department of Natural Resources; John P. Hayes, University of Florida; Manuela Huso, Oregon State University.

with each site every 5-7 days to sample each of the proposed turbine locations. This enabled us to gather data on activity in relation to altitude, and to compare activity in relation to altitude both between the forested and open prairie sites and among species. We also gathered weather information, enabling us to look at activity in relation to variables such as temperature and wind speed.

In Wisconsin, where we sampled from mid-July to the first of October, 2005, we recorded a total of 26,495 bat calls at all towers. In Pennsylvania, where we sampled from August 1st to November 1, 2005, we recorded a total of 9,162 bat calls. Within each site, the mean number of bat calls per night per tower varied considerably from one night to the next.

Activity in relation to altitude. At the Pennsylvania site, the activity rate of high-frequency bats (>35 KHz) was 9-59% higher than that of low-frequency bats at 1.5 m. Conversely, at 44 m, the activity rate of low-frequency bats (<35 KHz) was 17-210% higher than that of high-frequency bats. At 22 m, the activity rate in forest habitat was 99-229% higher than in open habitat.

Activity in relation to temperature. At the Pennsylvania site, total bat activity generally increased with increasing temperature, but this relationship was highly variable, and differed by altitude. At 1.5 m, bat activity increased 7-13% for every 1° C increase in temperature. At 22 m, activity increased 0-7% for every 1° C increase, and at 44 m, activity was unaffected by temperature changes.

Activity in relation to wind speed. The highest average nightly wind speed recorded during the study periods was 15.7 meters/second (m/s) in Pennsylvania, and 9.6 m/s in Wisconsin. There was an inverse relationship between bat activity and wind speed, though this relationship was highly variable, and even at wind speeds above 6.5 m/s, there was still some bat activity at both sites. At the Pennsylvania site, activity was estimated to decrease 11-39% for each 1 m/s increase in wind speed. At the Wisconsin site, activity was estimated to decrease 4-13% for each 1 m/s increase in wind speed.

These patterns of activity are consistent with other studies.[11] They also are consistent with patterns of fatality that have been observed at sites such as Mountaineer, WV and Meyersdale, PA, where a large proportion of fatalities are occurring at lower wind speeds.

Next Steps

The next step is to correlate pre-construction bat activity measured at the Pennsylvania and Wisconsin sites with post-construction fatality data. This will help us to understand whether our tools have predictive capability. Numerous acoustic studies are underway at sites in Canada (Alberta), New England, Maryland, Pennsylvania, West Virginia, and Wisconsin. We will continue to do intensive acoustic monitoring at sites in Pennsylvania and Massachusetts, perhaps other sites in the future, and correlate activity with post-

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[11] D.S. Reynolds, 2006, Monitoring the potential impact of a wind development site on bats in the northeast, Journal of Wildlife Management, in press.
K. Lott, MS research in Maryland.

construction monitoring of fatalities. Other methods for determining pre-construction activity and abundance (radar, thermal imaging) also should be evaluated. Integrating different technological tools for assessing bat activity would greatly improve our understanding of bat activity at proposed wind facilities.

See www.batcon.org for results of studies, incl. 2004 and 2005 research.

Response to Presentation

Question: Would you say acoustic activity of the tree bats is more uniformly distributed at 44 meters?

Response: Yes, for the low-frequency bats.

Question: Do you find bats checking out communications towers like they seem to be doing with wind turbines?

Response: I am not familiar with the data on bats checking out communications towers. There may be an attraction to met towers and to our portable towers; our analysis assumed that any such bias was consistent across all towers in our study.

Question: I was told that Hoary bats were actually found roosting in the nacelles of the turbines at Ponnequin (Colorado) WRA. Has this been reported elsewhere? How many turbines have nacelles that bats can get inside, and do you think that bats view turbines as roosting sites?

Response: Bats getting into nacelles has been reported in Europe. A bat was found covered with what appeared to be grease at Mountaineer in July 2004; this fluid was never analyzed and also could have been fat decomposing, but also could have been grease from the nacelle. Crevice roosting bats can get into very tight spaces, including almost any nacelle I've seen. And yes, bats do respond to vertical complexity in the landscape, so turbines and other tall structures may be perceived by bats as potential roosting sites.

Question: Have there been any studies (not necessarily just wind turbine-related) relating abundance of bat prey species to bat activity across the landscape -- in other words, modeling bat habitat suitability as a function of prey habitat suitability?

Response: There have been very few studies along these lines, but it is a good question. There is a PhD study that was just completed in Oregon that addresses insect and bat activity in riparian systems in the Oregon Coast Range (Holly K. Ober, Department of Forest Science, Oregon State University). Mike Lacki has conducted some prey availability work in Kentucky, and there is an ongoing study in northeast Pennsylvania through East Stroudsburg University (Dr. Howard Whidden).

Daily & Seasonal Patterns of Bat Activity along Central Appalachian Ridges

Keith Lott[12]
University of Maryland Center of Environmental Science

The mortality events at the Mountaineer, WV and Meyersdale, PA wind turbine facilities have raised many questions concerning how such facilities may affect bats along the Central Appalachian ridges. With the expansion of the wind industry in the Appalachian region it has become particularly important to identify whether these ridges are an anomaly or whether ridges in the surrounding area have similar levels of bat activity. Our study was designed to document the following:

- Species of bats occuring along these ridgelines
- Timing of bat activity
- Inter-ridge variability
- Factors influencing bat activity in this region

Study Methods

We used Anabat II acoustic monitoring systems attached to nine fire observation towers and one guided latticework tower at heights ranging from 21 to 30 m. Systems were programmed to monitor and record bat activity from dusk to dawn from mid-April through mid-December, beginning in 2004 and continuing until winter 2006. The ten monitoring sites are located on forested ridgelines in the Appalachian Plateau and Ridge and Valley physiographic provinces of Maryland, Pennsylvania and West Virginia, at elevations ranging from 502 to 1,139 m.

The number of bat calls recorded per night will be compared to Department of Transportation weather data, which includes:

- Air temperature
- Relative humidity
- Dew point temperature
- Barometric pressure
- Average wind speed
- Wind gust
- Wind direction
- Precipitation
- Visibility

We are also looking at the percent of moon face illuminated which could potentially be important in predator avoidance and prey availability, as well as the distance from the bat detector to tree canopy.

[12] Co-author: J. Edward Gates

Preliminary Results

To date we have recorded a total of 155,625 bat detections. There is an extreme amount of nightly and between-site variability, though some landscape-level factors appear to be influencing these levels (exhibited by sites fluctuating similarly).

Average nightly bat activity ranges from 7.6 calls per night at Little Savage Mountain to 204.6 calls per night at Sideling Hill, PA. The unusually high levels of activity at the two study sites along Sideling Hill have been attributed to attractant issues (street lamps at the Maryland site and bats roosting within the tower structure in Pennsylvania). Out of the two remaining sites in the Ridge and Valley, Town Hill had significantly higher activity levels than Wills Mountain or any of the sites in the Appalachian Plateau.

There was not a sharp increase in bat activity coinciding with the time period of previously observed bat mortalities. The months with the highest bat activity were July, August and September. Activity peaked approximately one month earlier in the year at the Ridge and Valley sites.

Bat species identification. Seven species of bats have been identified so far; these include red, hoary, silver-haired, big brown, eastern pipistrelle, little brown, and northern myotis. Slide #21 shows timing of detected bat activity broken out by species. Due to the difficulty in discriminating between species, three additional categories have been created. Those include "No identification" when a detection lasted less than five echolocation pulses or when we could not be confident in assigning a species to a particular call. In cases where big brown and silver-haired bats cannot be separated, calls are identified as "EPFULANO." Finally, myotis bats in the northeast have extremely similar calls, and when calls exhibit characteristics of two or more myotis bats the call is labeled "Myotis species."

Factors influencing bat activity. Wind speed showed significant low negative correlation with bat activity; 99% of the detections were made at wind speeds of 4 m/s or less. Wind direction did not correlate strongly with activity. Several other studies have noted that bat activity drops during rain conditions, both because there are fewer prey items and because it is harder to stay warm. Our study found no strong correlation with nightly rainfall, though we are currently investigating whether the proportion of the night in which it rained may be a better indicator. Higher temperatures correlate with higher levels of activity. There appears to be some correlation between bat activity and barometric pressure; with some additional weather data we hope to elucidate this correlation.

Key preliminary findings are as follows:

- Bat activity patterns are similar among sites, though nightly activity varies dramatically.
- There is no significant difference in activity between ridges in the Appalachian Plateau physiographic province.
- Bat activity on ridges spans well beyond the 6-8 weeks of observed mortalities.

- Temperature and wind speed show definite relationships with bat activity for most species.
- There is little evidence of "lunar phobia" in northeastern bats.

The following results are still pending:

- Hourly activity (~150,000 detections graphed by hours after sunset)
- Whether distance of Anabat from canopy matters
- Species accumulation curves
- Between-year comparisons

Lower bat activity levels at certain times of the year, in different physiographic regions, and under particular environmental conditions may have important implications for mitigating bat mortality due to wind turbine operations.

Post-Construction Studies

Bat Fatalities in Southern Alberta

Erin Baerwald
University of Calgary

There are 16 wind farms in Southern Alberta, with a total of 403 turbines producing about 400 MW. Three more wind farms – approximately another hundred turbines – are going in this winter. Historically, bat fatalities have been low: fewer than 1 bat per turbine per year. However, at Summerview Wind Farm, 532 bat fatalities (~ 13 per turbine) were found in 2005, and 611 bats (~16 bats/turbine) were found in 2006. (Note that these are raw data; the numbers do not account for searcher efficiency and scavenging.)

The majority of the fatalities are hoary and silver-haired bats. (We have very few eastern red-bats in Alberta.) Summerview Wind Farm has 39 1.8-MW Vespa turbines arranged in eight vertical rows on 5,000 acres of primarily crop and pasture land. Could the Summerview Wind Farm lie within an undocumented migration corridor? Might newer, taller turbines be getting up into the airspace where migratory bats are flying?

Research Questions

We used a combination of methods – radar and acoustic monitoring along with daily and weekly carcass searches – at Summerview and three other wind farm sites to try to answer the following questions:

1. What proportion of bats migrating through wind farms are killed by turbines?
2. How does migratory bat activity and mortality vary with weather variables and time of night?
3. Why are more migratory bats killed at some wind farms compared to others?
4. Does ground-based echolocation monitoring provide an accurate index of bat activity at turbine blade height?

A literature search analysis indicates that tall turbines do kill more bats, but not more birds. (Slide shows exponential increase in bat mortality as turbine height increases between 65-80 m.) So – do ground level anabat studies tell you about what to expect? We placed Anabat detectors at ground level and at 30 m over a 200 km swath of study sites (Castle River, Summerview I and II, McBride Lake, Chin Chute, and Taber wind farms) in southern Alberta east of the Canadian Rockies.

Preliminary Findings

The Anabat monitors recorded higher levels of activity at the Summerview sites, but not enough to account for difference in per-turbine mortality. While there was a lot of variability among the sites, overall we recorded significantly more passes at ground level than at 30 m. This held true for Myotis and silver-haired bats; the reverse was true for Hoary bats, but not at a statistically significant level. (Again, there is a lot of variability among the sites.)

Scavenging from insects resulted in a significantly higher number of bat carcasses found at daily searches compared to weekly searches. (Daily searches yielded a mean 22 bats per turbine while weekly yielded a mean of 13 bats per turbine.) The only spatial pattern was that mortality rates were higher at turbines in the northern portion of the wind farm. (Mortality at the northern turbines was 16 bats per turbine in 2005 and 19 bats per turbine in 2006, whereas the mean mortality at the southern turbines was 11 bats per turbine per year.) If bats are migrating north to south, apparently they are dying most at the first turbines they encounter.

We learned a lot about patterns of migration from mortality data. Very few bats are killed during the summer, but mortality peaks sharply in August and September. We found higher mortality among adults, with surprisingly high levels of adult male hoary bats, compared to what was expected.

Conclusions

Our analysis is not yet complete; we have yet to correlate radar work with the anabat and weather data. Activity levels vary across the study area, but there does not appear to be a clear migratory corridor. There does appear to be a north/south pattern of mortality. Ground-based detection differs from echolocation detection monitoring at 30 m for some species. We are learning about basic migratory activity, particularly in terms of timing and age and sex ratios.

Further analysis will include correlations among the radar, Anabat, and weather data, a mitigation experiment, and hair and DNA analysis.

Based on Research Results: Questions to Address

moderated by
Ed Arnett
Bat Conservation International

Developing a Mitigation Strategy for Bat Impacts from Wind Power Development in Maryland

John Sherwell
Maryland Department of Natural Resources

All wind power projects licensed or proposed to date in Maryland are on the ridges of the Appalachian Mountains on the western side of the State. The experience at sites in similar geographic settings in West Virginia and Pennsylvania suggest that high bat mortality may be expected. As a part of the permit to construct new generating facilities, Maryland is proposing a mitigation strategy involving operational constraints during periods of low wind speed through the fall bat migration period. This presentation describes the risk assessment used to develop the mitigation strategy.

Role of the Power Plant Research Project

In Maryland, the Public Service Commission (PSC) is the licensing authority for electricity generation projects. Projects are licensed in an adjudicatory proceeding. The **Power Plant Research Project** (PPRP) provides expert technical support for the PSC in these proceedings. Although not a regulatory agency, PPRP supports relevant research and provides recommendations.

To date, PPRP has worked on three wind power projects, all in the Appalachians. When it became apparent that bats were an issue with wind, we came up with a quick mitigation strategy to manage tip speed during low wind conditions? We have since gone back to do some research to see whether such a management strategy makes sense.

A Bat Risk Model

The collision risk model we have developed reverses the assumption that bats fly into turbines with the premise that turbines "fly" into bats. The leading edge of the blade is a line rotating in space. Collision volume (V) is given by:

$$V = n * r * \pi * T * l^2$$

Where:

- n = number of blades
- r = rate of rotation (rpm)
- T = transit time of bat past leading edge (taken as the time for the bat to fly its body length)
- l = blade length

A factor could also be added for attraction, if warranted. Any bat inside "collision volume" V would be struck by the blade.

During periods of low wind speed [typically ≤4 m/s] turbine rotation rate is generally set by maximizing the tip speed ratio [rotor tip speed /wind speed] for a given wind speed. In the model the rotation rate-wind speed function is approximated by a linear interpolation from zero to the operational rotation rate at the online wind speed. Bat population density as a function of wind speed is approximated by monitored call frequencies made by researchers at the University of Maryland Center for Environmental Science, Appalachian Lab in Frostburg, MD. (This is an ongoing study using a regional array of Anabat detectors.) The call frequency data is matched to wind speed data obtained from the state-wide network of anemometers maintained by the State Highway Department. Using the collision risk model coupled with the low wind speed turbine rotation rate and the bat density-wind speed data, it is possible to estimate collision risk as a function of wind speed. The collision risk at each wind speed is summed to give a cumulative risk over an operational range of wind speeds.

Example of collision volume model. We took some figures (typical bat dimensions, speed, etc.) and a sample turbine array (44 turbines over 8.8 mile ridge, each with 3 150-foot blades turning at 17 rpm), and used the model to come up with a predicted collision volume. We then compared the predicted probability of collision with observed risk (number of collision opportunities based on bat density estimates divided by the number of actual collisions), and came out with ratio (predicted/observed) of 0.46.

The next step is to use model to predict collision risk, assuming risk varies with abundance, and see what would happen at low wind speeds.

Tip Speed Ratio (TSR) is the ratio of actual blade tip speed to wind speed. This is an important control variable; the turbine operator wants to optimize TSR. The typical cut-in speed (below which the turbine does not operate) is 4 m/s. (Slide #10 shows the assumed wind speed-rotation rate, or TSR, for a 1.5 MW GE turbine.)

Mitigation Strategy

As wind speed increases, bat activity begins to decrease, but not as fast as tip speed increases – until you hit a wind speed at which bat activity begins to fall off. In slides #11 and 12, the area beneath the curve (to right of red line and left of blue curve) is cumulative risk. Moving the curtailment speed to the right decreases cumulative risk. Maryland has set a low wind speed curtailment at 4 m/s (the typical cut-in speed); according to the model, this curtails risk by 80%.

Any curtailment has economic implications, and there needs to be some boundary set on mitigation requirements. Looking at wind speeds for the evening hours when we think bat activity is going to be highest, we estimate that wind speed would be under 4 m/s for a total of about 400 of those hours, so that is where we set our limit – that is, we would not require curtailment above 400 hours/year.

Work continues to refine the model, gather more use and occupancy data, and participate in deterrents studies.

The MD PSC website (http://www.psc.state.md.us/psc/) has a complete history of each licensing proceeding. (Select Case Search, enter case #s: 8938, 8939, 9008.)

Migratory Behavior of Female Indiana Bats in New York and Implications for Wind Development

Al Hicks[13]
New York Department of Environmental Conservation

New York State has the 4th largest state population of Indiana bats (*M. sodalis*), about nine percent of the rangewide population. There are ten hibernacula in New York, situated mostly in the eastern half of the state. More than two-thirds of the state's Indiana bat population hibernates in a downstate cluster of three hibernacula totaling about 28,000 bats. While we know a lot about their winter distribution, and that they can migrate hundreds of miles, until this study, we didn't know where these bats went in the summer.

To find out, we caught animals as they emerged from the hibernacula in the spring for migration, and attached transmitters. We used both fixed wing aircraft (borrowed from the New York State Police), as well as people on the ground, to track the bats.

Assumptions

We had to make some assumptions about where the bats would go. One of the assumptions we made was that reproductive females would head more or less directly for their summer range. This appeared to be more or less the case. At the release night, aircraft circled at about a radius of 5 km from the release point, identifying which direction bats leaving the hibernaculum were heading, and later following them.

Another assumption was that it would be more cost effective to find a lower percentage of a large sample of targets than to find a higher percentage of a small sample of targets. One consequence of our large samples was that we often had multiple animals with the same frequency, and so could not always identify individual animals. With stereo headsets, our trackers had the potential for hearing as many as eight bats at the same time. Because we were monitoring as many as four different pulse rates per frequency, there was the potential for error in identifying signals. Also, because we were transmitting in the 150-152 range, there may have been radar interference (a pager frequency interfering with bat reception).

[13] Co-author: Carl Herzog

In 2002, 16 of 19 bats released at Barton Hill hibernaculum were found. During 2004-05, 27 of 38 bats released from the Williams hibernacula complex were located. Bats appeared to "clump" on the landscape in the same areas from year to year. In 2005, 26 of 32 bats released from Glen Park were located. In 2006, 11 of 16 bats released from Jamesville (in western New York State) were located.

Altogether we caught and released 110 bats, and succeeded in finding 82 of them at at least one roost on one day. In the case of 65 bats, we found what we assumed to be maternity colonies.

A comparison between the range if initial headings and the final headings for all detected bats supports the idea that reproductive female bats follow a more or less direct route from the hibernacula to their summer range. A comparison of the initial and final bearings of the 32 bats that could be identified as individuals also supported this idea, as did the locations of animals that were detected while en route. On three occasions, we were able to follow individual animals to their destinations.

There were some exceptions to the direct route rule. One notable exception occurred near the city of Syracuse. Bats were released just southeast of Syracuse, and they ended up northwest of Syracuse, yet the bats chose to avoid the urban area, and so appeared to be flying in directions other than where they were headed.

Implications for Wind Project Siting

Within the potential habitat for these animals, there is a clumped distribution of Indiana bats within the state of New York (see slides). By starting with the known hibernacula and using these tools to locate the summer colonies, we can extrapolate more or less the migration route.

Risks are highly localized, but can be substantial in those local areas. For example, the map of proposed wind farms in the Glen Park area (see slide) shows that proposed wind sites are practically on top of known hibernacula, which is a problem.

Bat Migratory Behaviors and Routes in Pennsylvania and Maryland

Greg Turner
Pennsylvania Game Commission

There are a lot fewer Indiana bats in Pennsylvania than in New York. We do know the location of 17 hibernacula, including one Priority 2, but with the exception of one known maternity site (in a decommissioned church not far from a known hibernaculum), we don't know where the summer colonies are.

Beginning in 2000, 4 Indiana bats were captured exiting a hibernaculum in Somerset County, where we attached transmitters and attempted to follow the migration of the bats using vehicles outfitted for telemetry. (Part of the difficulty of tracking Indiana bats in Pennsylvania is that, to attach transmitters, we have to look for individual Indiana bats tucked in with hundreds to thousands of little brown bats in the same hibernacula.) We tried to follow the bats using two vehicles leapfrogging each other to follow the bats while using GPS software to track the bat targets in real time.

We hypothesize that males don't travel far. In 2003 we tagged 11 Indiana bats from the Priority 2 hibernacula in Blair County. All the bats were eventually lost, with the exception of two males that we tracked for 13 days (until the transmitters failed) after they left the Allegheny Mountain Railroad Tunnel hibernaculum. One covered a maximum distance of only 1.6 miles during that time. The second male took about four days to get to Shawnee State Park, about 11.5 miles away from the hibernaculum.

Females, like males, worked their way east along the river. The first female we followed a maximum distance of 12.5 miles (as far as Shawnee State Park) before the transmitter failed after 13 days. A second female traveled a maximum distance of 60 miles, moving about 8-10 miles per night for 7 days until we abruptly lost her at Hwy 81. When a bat drops into a river bottom in flat terrain, it becomes very hard to get a signal.

In 2003, we started trying to follow the bats by plane. We captured 11 female Indiana bats emerging from the Priority 2 hibernaculum in the Hartman Mine near Altoona, PA. Ten of those bats were lost within two days as they headed east. We were able to track one of those bats for four days as she traveled to Juniata County where it made a 12-day stopover in a tree before continuing her migration.

Whereas in New York the Indiana bats don't seem to be traveling very far, in Pennsylvania and Maryland we're tracking bats 60 miles and then losing them.

In 2005, we re-rigged our plane with an improved switchbox to get detection profiles up to five miles off each wing (instead of mile and a half). With the new equipment, we were able to follow six radio-tagged female Indiana bats from the Canoe Creek hibernaculum to maternity colonies in Maryland. One bat was intensively followed with the ground crew and plane as it traveled 57 miles in four hours after emerging from the hibernaculum. This female continued another 35 miles the second day, eventually establishing a colony near Wentz, Maryland (92 miles from Canoe Creek), where it was joined by other bats. Additional survey work located a second bat 135 km from the hibernacula in Taneytown, Maryland. The final destination of the remaining 4 bats was not determined.

In 2006 a hibernaculum located in Luzerne County, Pennsylvania was chosen due to the installation of a new wind farm < 12 miles from two known Indiana bat hibernacula. A single female Indiana bat was captured and followed for 90 km to a site just east of Reading, Pennsylvania. (Slide shows route followed by a bat leaving abandoned anthracite coalmine near Wilkes Barre, PA, in April 2006.) We were able to track the bat at several points along the 56-mile route that it followed over a three day-period, including one 22-hour period of heavy fog when it roosted on a dead maple snag before continuing. This kind of tracking provides us with information not only about the route and destination, but also how the bats use terrain and habitat along the way. The bats we followed liked to follow trees, including riparian buffers along streams through otherwise developed areas. Bats will go out of their way to follow a tree line, avoiding open areas.

One bat that we were following flew *under* I-80, so migrating bats may be flying low. During spring and fall, temperature inversions result in cool air settling down in valleys but warm air being found higher on ridges. Bats may be following insects up with the warm air. There may also be an advantage to bats roosting in areas with higher solar exposure, near the top of the mountain rather than down in a steep river valley where they would need to use more energy to stay warm.

We went back with mist nets in the summertime to the place that looked like a maternity colony, and did in fact find some bats, including post-lactating females and juveniles. This was the second maternity site we found. We will follow bats from another hibernaculum above Pittsburgh next spring.

Evaluation of Acoustic Deterrents to Reduce Bat Fatality at Wind Facilities

Joseph Szewczak[14]
Humboldt State University

We propose an acoustic deterrent device to reduce or eliminate bat fatality at wind facilities in response to large numbers of bat kills discovered at two facilities in the eastern U.S. in 2003 and elsewhere. The development of such a device requires rigorous testing to determine its efficacy in reducing or eliminating fatalities. Previous observations have noted bats avoiding areas with high intensity ultrasound, and we know that there are moths that produce high amplitude sonar "jamming" sounds to deter bat predators. We hypothesized that there is a threshold effect, where some level of ultrasound may attract curious bats, but above some threshold bats will exhibit avoidance because the sound may hinder their perception of echo returns, causing disorientation or discomfort. If we could practically broadcast sound above this threshold, we might then be able to construct an effective deterring device.

What is the Attraction Factor?

In 2005, we measured both ambient sound power emissions and ultrasound emissions generated by turbines at Foote Creek Rim and Medicine Bow, Wyoming, and also at Somerset and Meyersdale, Pennsylvania and the Mountaineer site in West Virginia. At these sites, we found that turbines did not generate any significant ultrasound that might potentially be responsible for attracting bats. In the east, however, ridge-top turbine strings create edge habitats that may be attractive to bats as foraging habitat. The towers themselves may appear to bats as a snag that appears to be a possible roosting (or mating) spot.

It is important to note that bats have no natural ability to detect and avoid fast-moving objects such as vehicles or turbine rotors. Since we know that bats do regularly fatally collide with moving vehicles, it is not difficult to understand how bats can collide with turbine rotors that can be more than twice as large as trucks and move twice as fast.

An Acoustic Deterrent Theory

Echolocating bats depend upon sensitive ultrasonic hearing for hunting, orientation, and navigation. A typical bat emits echolocation calls at approximately 110 dB, with the echo return from an object at a distance of 1.5 m at approximately 65 dB (45 dB less). We theorized, therefore, that by generating ultrasound audible to bats at levels above 65 dB, we could create a noisescape that would be disorienting or repelling to bats.

Laboratory test. An ultrasound broadcast unit prototype was developed by Binary Acoustic Technology. We tested it first in a lab, by dividing room into quadrants. With a 25% chance of the bat landing in any quadrant, we were able to repel bats using an ultrasound-

[14] Co-author: Ed Arnett, Bat Conservation International

generating device. In trials without food, the mean percentage of landings in the quadrant with the device operating was 1.67% v. 22.39% in the control. The mean percentage of trials landing in the quadrant with the device increased to 9.4% when there was food present, but we were able to deter the bat from catching a known insect in the quadrant where the sound device was operating. In the control, 35.86% of trials resulted in the bat capturing the mealworm, but in trials with the device operating in the quadrant with the mealworm, the bat never captured the food.

Field test. To provide a confident field test of the acoustic deterrent, we sought to test the device under conditions that would best compare to conditions that would bring bats near turbines. We thus tested the effect of the ultrasoundscape on freely foraging bats at sites with consistent foraging activity. By selecting open foraging areas over ponds, we were able to test the effect of the acoustic deterrent without the confounding influence of a compulsion to reach a roost. Bats had a free choice to either occupy the airspace or move away.

Because we were testing an ultrasound-generating device, we had to rely on visual monitoring both to count bat passes (as opposed to typical ultrasonic bat detection). However, this visual method introduced the complicating factor of having to distinguish bats from insects (based on wing beats). We recorded video using a Sony DCR-TRV520 Nightshot Camera and dual Wildlife Engineering Model IRL amp6 infrared lights. A bat entering the field of view and then leaving it constituted one bat pass.

For each trial, we gathered two nights of control data (bat passes) at each pond site, and then counted bat passes on a third night at the same site with the sound device on. Data were gathered each night for one hour, at the same time of evening. A total of eight (3-night) trials were conducted.

Preliminary Findings

We detected 50% less activity when the deterrent device was operating. Over eight trials, mean passes per hour equaled 418.9 with treatment and only 238.1 for the control. It is likely that bats would learn that there was a disturbance in a particular spot and eventually avoid it altogether – essentially, we could train bats to avoid turbines.

Limited range of effectiveness. Turbines are very large, and it is not easy to load the sound for the entire rotor swept area from a single broadcast unit. The ultrasound-generating device has a modest power requirement (less than 100 W), but there are practical limitations for generating sufficient ultrasound from a single point source, in part because higher frequencies attenuate more quickly with distance than low frequencies.

Possible collateral effects. Other small mammals and birds might also be repelled by the ultrasound, as might insects. These might be considered positive collateral effects, but at this point they are speculative.

Conclusion

We now know that ultrasound can be used to influence bat behavior. Now that we have this tool, the next step is to explore its practical application and effectiveness. One possibility might be to create an "acoustic fence" around wind plants located within areas of high migratory activity. Questions that remain to be explored include: Are there certain sound patterns that are more effective than others? What are the long-term effects?

We are working on the next generation of deterrents for testing next fall (2007).

Response to Presentation

Question: If deterrents succeed in excluding bats from wind farms, wind farms may kill fewer bats, but there then will be major barriers to migration, or there may be a significant loss of habitat, especially if wind turbines continue to proliferate. Considering the example we saw earlier (in Al Hicks' presentation) of bats avoiding the urban area of Syracuse, shouldn't we consider the negative collateral effects of setting up acoustic "walls" or "fences" within migratory corridors?

Response: There are two mechanisms we are considering for deploying the acoustic deterrent devices. The primary one is to put such a device on individual turbine nacelles to prevent bats from attempting to roost there. The idea of the acoustic "wall" or "fence" was proposed specifically to prevent mortality of migrating bats flying along a specific flight route, e.g., a gap along a ridgeline. Although further investigation would be required to confirm this, we expect that deploying acoustic deterrents would simply redirect bats out of harms way at these specific locations and not prevent their migratory flights. However, as you point out, the benefit of using such an approach would have to be weighed against the cumulative consequences of setting up barriers to migration.

Bat Likelihood Assessment Protocol for Collision Mortality at Potential Wind Farms

Crissy Sutter
Pandion Systems

For bats, there is often insufficient information to estimate use and mortality rates during the initial site selection process for a proposed Wind Resource Area (WRA). An alternative to a Risk Assessment is a Bat Likelihood Assessment. The Likelihood Assessment is primarily a desktop procedure that is accomplished during the site selection process, before significant resources are committed to the development of a proposed site. The likelihood assessment described here was conducted in 2006 with the purpose of helping our client gauge the likelihood of bat collision mortality at 10 proposed wind resource areas (WRAs) each covering 60-250,000 acres. Specifically, we wanted to identify which of the proposed WRAs:

- Contained concentrations of bat resources or were within range of such concentrations
- Were utilized by bat species prone (or expected to be prone) to turbine mortality

WRAs with such characteristics were considered to have a relatively higher likelihood of high bat abundances, and a higher potential for high bat mortality.

Likelihood Methodology

Risk v. likelihood. It is important to understand the distinction between likelihood and risk. ***Risk*** is the product of the usage rate and the mortality rate (with mortality rate being the number of fatalities per unit divided by abundance per unit). ***Likelihood*** focuses on the abundance part of risk equation, not the mortality piece.

Species and WRA parameters. The best available information on thirteen bat species was gathered from interviews with knowledgeable individuals and the literature. Additionally, spatial interpretation and analysis of aerial photography, vegetation classification systems, wetlands, topography, and hydrology was conducted to assess the on-site conditions of each WRA in regards to availability of bat roosting and foraging habitat. This being in the arid west (Texas), the presence of drinking water was an important habitat characteristic. Finally, based on the review of multiple sources of localities records, Texas bat species range maps were compiled for each species.

This information was compiled and analyzed to rank the likelihood of bat use and bat abundance at each of the proposed WRAs. Specifically the following parameters were evaluated:

1. Bat species geographic range
2. Roosting habitat preferences/uses and densities
3. Distance from site to known bat concentrations (usually mines or caves)
4. Nightly foraging distance from roost
5. Foraging habitat preferences

6. Foraging strategies and habits and heights
7. Habitats present on the WRA
8. Presence of suitable drinking water source on or proximate to the WRA
9. Proximity of the WRA to known bat suitable habitat
10. Species roosting behavior (solitary or colonial)

Likelihood analysis results. For each species, we developed a likelihood score for foraging and roosting as well as overall likelihood. We established a series of hierarchical disjunctive rules for adding species likelihood scores. The rules were based on the species biology and vulnerability. For example, the first rule in the hierarchy was if Brazilian Free-tailed bat colony was present then likelihood classified as high. If Brazilian free-taileds were not present then the next rule was followed and so on until all rules had been implemented.

The individual species values were then combined into an overall likelihood value for each proposed WRA. Possible values are: low, medium-low, medium, high, and very high. Given the scoring rules employed, it is not surprising that proposed WRAs within or proximate to karst regions and natural foraging habitat had corresponding high likelihood values.

Benefit of Likelihood Assessment

The real benefit of this screening analysis is that you address the question of bat use and collision mortality early in the decision-making process when there is the greatest flexibility, rather than at the middle to later part of the decision-making process. Like other types of "fatal flaw" analyses, it allows the project proponent to manage its risk of investing in a site. The screening tool is also useful for discussions with agencies on pre-construction studies and for later mitigation considerations.

It is expected that pre-development studies for at least some of the screened WRAs will undergo pre-construction bat use studies, at which time the validity of the Bat Likelihood Assessment analysis will be evaluated and the screening tool will be improved.

RESPONDENT PANEL:
WHAT NEW INSIGHTS HAVE WE LEARNED ABOUT BAT / WIND INTERACTION?

Facilitated by
Abby Arnold, RESOLVE

Reflecting on what we knew two years ago, what do you think is coming out that is different or new, or what observations do you have? Facilitator Abby Arnold asked panelists to open the conversation. Their observations were followed by responses and open discussion from the floor.

Panelists*
Jim Lindsay, FPL Energy
Bronwyn Hogan, California Department of Fish & Game
Paul Cryan, US Geological Survey

* *Tom Kunz, Boston University, had planned to participate in this panel but was unable to attend the conference*

Jim Lindsay, FPL Energy

The presentations we've seen show how far we've come in the past three years. In Fall 2003 we were in reactive mode, trying to figure out how to prevent more fatality events like Mountaineer. We had hoped that Mountaineer was an anomaly, but we have since discovered otherwise, and now that we're seeing bat fatalities in Calgary, we know that this is not unique to the Appalachian ridge sites.

Mitigation strategy. Regarding John Sherwell's presentation on the curtailment rule (curtailment at winds of 4 m/s or less to reduce mortality 80%). From an industry perspective, we appreciate how he's approached this: we understand regulations, understand permit conditions. I'm not sure, though, how you would implement the 400 hour curtailment rule – you would need to start your annual curtailment clock on June 30 or July 1; otherwise you would use up your 400 hours before you really needed them. ***Clarification*** [from J. Sherwell]: *The 400-hour curtailment rule applies to the period July 1-Nov 30.*

Migration tracking. The migration tracking work is amazing, and has produced some great information. The work that has been done to look at how bats move along ridges is useful. If we can get some good information, we may not need to survey every ridge in the Appalachians.

Deterrent research. We are seeing some very promising work in the area of deterrent research. It will be interesting to see a field assessment of the acoustic deterrent.

Screening tool. The high-level economic screening tool that Crissy Sutter presented is very useful; this is something that has been long-needed.

Some interesting points that have been raised:

- Bat activity increases as winds decrease, but bat mortality increases at lower wind speeds
- There is a difference between the impact of taller towers on birds v. bats
- Bats avoid open areas
- Turbine mortality doesn't reflect local bats – not sure what that means for pipistrelles in the Southeast; they don't migrate.

Bronwyn Hogan, California Department of Fish and Game

Mexican freetail bats. There is a recent monitoring report in California, where hoary bats represented the largest number of kills during the first year, with Mexican freetail bats the second highest numbers of fatalities. During the second year of monitoring, these positions were reversed.

Mitigation. We may be able to make use of information [about the seasonal pulse of migratory bats in fall] to reduce fall fatalities.

Use of genetic information. If we could collect genetic information from bat carcasses, we may be able to start building the broader scale picture of bat species' ranges, population distribution and genetics – without affecting proprietary info of industry.

Connecting pre- and post- studies. We need to make a connection between pre-project survey methods and post-construction fatality monitoring, combining industry, academic, and government funding to look at the impacts. Some up-front data-intensive studies would enable us to zero in on asking the right questions that give us the answers we need.

Paul Cryan, U.S. Geological Survey

I am amazed at the amount of progress that has been made since 2004. However, we still have a lot of questions to answer.

Migration. We still don't know a lot about bat migration compared to what is known about songbird migration, but we have been able to learn a lot from the people studying nocturnal avian migrants. Some of the methods we've seen in these talks are really pushing the envelope, very exciting to see. (Let's chase the hoary and red bats next year!) In 2004, we didn't know whether Mountaineer and Meyersdale were anomalies. Now we're seeing evidence suggesting they are not.

Use of echolocation. Are bats that are being killed actually echolocating while migrating? The best evidence we have indicates that bats navigate using primarily visual cues.

Echolocation is short-range, so used to feed. However, they may be feeding while migrating.

Attraction factor. If you build it will they come? If you don't find much bat activity in your pre-construction monitoring, but the presence of the turbines is actually attracting the bats, then those pre-construction surveys are not going to tell us what we need to know.

[*Ron Larkin*: The idea of attraction has come up a lot with birds. It is not a question of turbines attracting birds from a mile away. Rather, once they are in the vicinity of the turbines, it's a question of, do they fail to leave? Do they fly around the structure?]

Weather conditions. We also need to get at the question of how weather conditions affect bat mortality. How do weather conditions affect bats' ability to detect and avoid turbines?

From the Floor

Question [Abby Arnold, in response to a point raised by panelist B. Hogan]: How do we protect confidentiality while making data available that's out there?

***Response* [*J. Lindsay*]:** Most of the confidentiality issues have to do with pre-construction studies. Once a site is developed or permitted, most of the information is in the public domain. [In other words, there should be no problem with collecting DNA from bat fatalities to help build larger picture of ranges, population genetics, etc.]

***Question* [*for J. Lindsay*]:** What do you have in mind with acoustic monitoring for areas with a lot of turbines (e.g., Tehachapi WRA in California)?

***Response*:** What I had in mind was not acoustic monitoring but acoustic deterrents. Given the costs associated with buying and monitoring all this equipment – it might make more sense to take an adaptive management approach.

***Comment*:** Pre-construction monitoring at the site of the 200-turbine Flat Rock project caught very few bats in mist nets, yet post-construction monitoring shows us that now bats are dying in fairly substantial numbers (370 kills).]

***Comment*:** We have to do more to understand the relationship between bat activity and bat fatalities.

Question: When should we ask for mitigation? How many bat fatalities is too many?

***Response* [*Facilitator*]:** Let's keep this question in mind as we continue.

SESSION III:
APPLICABLE METHODS OF STUDY DESIGNS SPECIALIZED FOR BIRDS, BATS, AND COMMON TO BOTH

This session consisted of four presentations.

- Jon Belak (*EDM International*) discussed the ***Development of a Cost-effective System to Monitor Wind Turbines for Bird and Bat Collisions***.
- Wally Erickson (*Western EcoSystems Technology, Inc.*) described ***Objectives, Uncertainties and Biases in Mortality Studies at Wind Facilities.***
- Manuela Huso (*Oregon State University*) presented an ***Evaluation of Survey Protocols*** for ***Pre-Construction Acoustic Surveys for Predicting Bat Fatality at Wind Farms***.
- Ron Larkin (*Illinois Natural History Survey*) described the use of weather radar (NEXRAD) for studying ***Migration at Low Height over the Mountainous Areas of Vermont***

Development of a Cost-Effective System to Monitor Wind Turbines for Bird & Bat Collisions Phase I: Sensor System Feasibility Study

Jon Belak[15]
EDM International, Inc.

Mass mortality events occur at night or during bad weather when it is difficult to monitor what is happening. A cost-effective monitoring tool that could indicate in real-time when a bird or bat strikes a turbine blade would be useful for several reasons:

- It would provide a way to get real-time data.
- It would be more cost-effective than conducting carcass searches (fieldwork is expensive).
- It could be used to evaluate the effectiveness of mitigation options.
- It could be used to evaluate the "poofing" theory (idea that some bird or bat carcasses are never found because they are effectively destroyed by the strike), as well as to assess scavenging and searcher bias.

EDM conducted a feasibility study to identify and evaluate potential strike sensor technologies, which can be divided into two categories: contact v. non-contact sensors. Accelerometers and fiber optic sensors are in the "contact" category; they need to be installed on the rotating blades. Acoustic sensors (microphones) and visual sensors

[15] Co-authors: Dr. Arun Pandey and Richard Harness

(cameras) are in the "non-contact" category; they do not need to be installed on the blades. Radar, thermal imaging, and visible light imaging systems are excellent for documenting strike events, but are impractical for detecting strikes, and were not included in this evaluation.

Accelerometers

Accelerometer systems have been developed for other commercial applications, such as car airbags and fatigue analysis.

EDM has developed and evaluated a Bird Strike Indicator (BSI) sensor system that detects bird strikes on power lines. The entire unit weighs 2.5 pounds, and it is sensitive enough to distinguish a bird strike event from disturbance caused by weather or a bird perching on the blade. It consists of:

- a microcontroller (with built-in analog to digital converter)
- wireless radio for communicating with the base station
- battery pack power supply
- standard utility mounting hardware.

We evaluated a Bird Strike Indicator (BSI) sensor developed for power lines. The entire unit weighs 2.5 pounds, and it is sensitive enough to distinguish a bird strike event from disturbance caused by weather or a bird perching on the blade.

In field testing, BSI successfully detects bird strikes, and its battery length has exceeded expectations. It has been tested in Cold Bay, Alaska, so we know that it can function reliably in a harsh environment, requiring limited maintenance.

In a wind turbine application, the only component that would be mounted inside the turbine blades is the accelerometer sensor itself; the rest of the system would be mounted on the hub or in the base of the turbine.

Accelerometer pros and cons

PRO	CON
• **Established technology** - lower cost - reliable and durable - efficient - small	• **Mounts on blades or hub** - requires batteries - access is an issue
• **Insensitive to audible noise**	

Fiber Optic Strike Sensors

Fiber optic strike sensors represent a fairly new technology. We would most likely use a Bragg fiber optic system. Laboratory tests indicate that it is good at picking up what we want it to, and not picking up what we don't want it to. However, because it is new, it is relatively untested in the field.

Fiber-optic sensor pros and cons

PRO	CON
• **Sensitive**	• **New technology** - high cost - reliability unknown - bulky hardware - sensor density?
• **Insensitive to audible noise**	• **Mounts on blades or hub** - access is an issue - motion fatigue?
• **Insensitive to lighting**	• **Cannot be repaired**

Acoustic Sensors

The advantages of acoustic (microphone) sensors are that they use off-the-shelf components and can be mounted with no modifications to the turbine structure, hence posing no compromise to turbine design. However, the acoustic sensor approach faces significant signal processing challenges. Turbine operation noises (vibrations from blade rotation and gearbox, blade cracking, aerodynamic noise from wind blowing around the blades) are highly variable, so that the filtering system would need to be customized to the turbine. Environmental noise (including vibrations caused by rain or hail striking the turbine as well as lightning and thunderstorm activity) would also have to be filtered out.

For example, we have acoustic data from a Blue-winged teal striking a radio tower. The event was recorded by microphone, but it is not clear whether the bird (found underneath the tower the next morning) struck the tower or the guy-wires. In this example, the bird-strike event and the wind turbine noise fall within the same frequency band, presenting a challenge for filtering.

Field tests have been conducted to assess acoustic sensors' ability to distinguish between object hitting the turbine and vibrations resulting from turbine operation and environmental factors. In the Netherlands, acoustic sensors were able to distinguish the frequency response of a tennis ball hitting the turbine from turbine noise. There remains some question, however, as to whether an acoustic sensor could pick up small birds and bats.

Acoustic sensor pros and cons

PRO	CON
• **Established technology** - lower cost - reliable and durable - efficient - small	• **Sensitive to noise** - turbine operation noise - weather-related noises - complexity of filtering required (unknown)
• **Tested on turbines**	• **Sensitive to small bird & bat collisions?**
• **Non-contact sensor** - all components mount on tower; powered by low-voltage AC	

Conclusions

Based on these assessments, EDM ranks the combined feasibility and cost-effectiveness of the various sensor systems as follows:

1) Acoustic sensors
2) Accelerometers
3) Fiber optic systems

Whatever sensor type is used, it would have to be accompanied by near-infrared cameras with lights (of the type that don't attract birds) to identify the type of bird or bat that struck. Multiple camera locations may be desirable.

EDM is interested in potential venues for testing these devices.

Objectives, Uncertainties, and Biases in Mortality Studies at Wind Facilities

Wallace Erickson
Western EcoSystems Technology, Inc.

This presentation reviews methods used in design, implementation, and analysis for post-construction mortality studies of wind facilities. We identify various objectives and goals of these studies, review different study designs used to meet these objectives, and discuss concepts important to evaluating study design and results, including: *precision*, *uncertainty*, and *statistical power*. We also review field and analysis approaches used to consider and estimate key biases: *observer detection bias*, *scavenging bias*, (both of which are influenced by habitat and visibility that must be accounted for) and *plot size bias*. Case studies throughout North America in numerous habitats are included in this review, which concludes with recommendations for improving methods and where to focus future research efforts.

Fatality Monitoring Objectives

Fatality monitoring can have various objectives. Typically, such monitoring is used to determine:

- whether overall avian and bat fatality rates (or raptor fatality rates) are low, moderate, or high relative to other projects
- whether predicted mortality is a reasonable estimate
- whether a wind farm has a fatality problem.

For example, how much of the fatality at the Altamont Pass WRA is due to high raptor use v. old wind technology? Now that we have a repowered facility in the Altamont, we can compare data collected concurrently at old and new Altamont projects, as well as at other high use areas outside Altamont. In order to make comparisons, we need to look not just at the number of fatalities per year, or even the number of fatalities per turbine, but at the number of fatalities per MW per year (slide #4).

Other objectives of fatality monitoring can include:

- estimating the influence of weather on fatality levels
- comparing fatality rates to exposure or abundance (risk)
- determining the effectiveness of mitigation measures
- determining whether some turbines are "high risk"

Precision, Uncertainty, and Statistical Power

There are several sources of variation affecting estimates of mortality. These include the following:

- ***Turbine-to-turbine variation*** in observed fatalities. High variation might result in clusters of fatalities at specific turbines; low variation, which is more commonly seen, would result in fatalities spread more evenly over the facility.
- ***Scavenging rates.*** The rate at which carcasses are removed by scavengers has varied both temporarily (across seasons, across years) and spatially (among sites).
- ***Observer detection bias.*** Note that a small change in this value has a big impact on mortality estimates.

Precision examples. Slides #7 and 8 show how different factors affect the precision of mortality rate estimates. Note that doubling the number of turbines searched (from 25 to 50) does improve the confidence interval (CI), but not as much as you might think. Improving some of the other variables has a greater impact on precision. For example, lower scavenging rates and higher searcher detection rates give greater precision improvements. This is partially explained by the fact that corrections for scavenging and searcher efficiency are in the denominator of the estimate.

Why not do intensive searches all the time? Slide #10 shows the number of search hours required for more and less intensive searches (search intervals are given as the number of days between searches, for both migration and non-migration periods). Searches are very labor-intensive. For example, assuming that 2 hours are required to search a turbine, searching 60 turbines with one-day intervals during migration and seven-day intervals during the non-migration seasons would require over 17,000 labor hours.

For medium to large sized raptors, we are able to get reasonable estimates with relatively infrequent searches in most cases because the scavenging rates have typically been low for these large birds.

Statistical power case study. In an experiment designed to test the effectiveness of seasonal shut-downs at Altamont, we assume that each turbine is an independent experimental unit. To test for effectiveness of this management measure, a large sample is needed. Note that, while the cumulative mortality at Altamont is high, the collision of a raptor with an individual turbine is quite low (approximately 1 raptor per turbine every 10 years). This means that, over a two-year period, we have to sample 2,000 turbines.

Potential Biases

There are a number of potential biases which can skew fatality study results.

Missed fatalities. One of the problems encountered in fatality studies is that some casualties or injured specimens may land outside the search area. This may be a larger bias at a forested ridge site than at a flat, open site like Nine Canyon. Bats tend to be found closer to turbines, possibly because bats have been shown to be killed during nights of lower wind speeds. They may also be flying lower. There are two possible solutions to this problem. If you believe it to be a small percentage of the total fatalities, you can choose to ignore it, in which case your estimates will be biased slightly downward for this factor. The other option is to estimate the percentage of fatalities that are landing outside the search area. Slide #16 shows percentage estimates of missed fatalities based on the distribution of distances from identified bird fatalities to the nearest turbine.

Inaccurate measures of searcher efficiency. Another source of bias is that experimental carcasses used in searcher efficiency trials may not represent actual wind turbine casualties. Feather spots may be more or less visible than intact carcasses used in trials. Placement, type, and number of carcasses used in trials may not be representative of real mortality. Factors to consider include:

- How many carcasses to put out at one time?
- Whether to use target species carcasses or surrogates
- Whether to use fresh or frozen carcasses.

Sample sizes should be adequate to account for variation by season, habitat, and space.

Reference mortality. Studying reference or background mortality is time-consuming, but may be worthwhile. At Buffalo Ridge, Minnesota, for example, estimates of fatality rates at plots without turbines was one-third of the estimate of fatality rates with turbines. It should be noted that bird use is likely higher without the turbine. Other examples of reference mortality studies include studies conducted at the Harmata site in Montana, San Gorgonio, California, and Buffalo Mountain.

Summary / Implications for Future Research

- The objectives of the study are the key to study design.
- If you are trying to answer a broad set of objectives, we recommend a mix of intensive searches at a sample of turbines with less intensive searches at other turbines.
- We need more research in these areas:
  - modeling/study of effective plot size (especially for birds);
  - finishing simulations to understand variance components (i.e., the optimal design for a given fixed cost); and,
  - relative effectiveness of using fresh v. frozen birds, surrogates v. target species.

Response to Presentation

***Question*:** What are chances of identifying major mortality events with greater than 7-day intervals?

***Response*:** If you are using a seven-day search interval, you don't want to search all of the turbines on the same day. Rather, you want to spread the sample across the turbines. So, for example, you might search four turbines one day, four the next, and so on, coming back to search the first set of four turbines after seven days. Mountaineer had high scavenging rates, which would have been a problem with searching all turbines every 7 days.

***Question*:** Can costs be reduced by randomly sampling transects?

***Response*:** This has been done at the Top of Iowa site, but I wouldn't sample transects randomly, I would do it systematically based on where fatalities are likely to fall around the turbines.

***Question*:** Assuming that most carcasses are scavenged quickly, and that the rest dry and rot, those that are not scavenged quickly are not likely to be scavenged or removed for a long time. In this case, the mean time a carcass remains on the ground would be heavily right-skewed, and would be very different from the median time a carcass remains on the ground. Consequently, the use of the mean time for carcass removal is not justified, and using it would lead to fatality estimates that are biased low, because the carcass removal compensation factor is biased low.

***Response*:** In our earlier formulas we used the search interval divided by mean removal time, this "skewness" was an issue. We now use a new formula that takes the skewed character of scavenging removal into account.

Pre-Construction Acoustic Surveys for Predicting Bat Fatality at Wind Farms: an Evaluation of Survey Protocols

Manuela Huso[16]
Oregon State University

Bat activity rates at proposed wind power generation sites may provide an indication of potential future mortality at these sites. To assess this relationship, activity rates and eventual mortality rates must be accurately measured. But protocols for collecting activity data with acoustic detectors are not well established. To assess the adequacy of various protocols, we took continuous acoustic data collected daily over a 90-day period from two proposed wind facilities (in South-central Pennsylvania and Southeastern Wisconsin), and re-sampled this data according to protocols reflecting different spatial arrangements and temporal periods used in the field.

Acoustic Dataset

Pennsylvania. The South Central Pennsylvania site included a string of 23 proposed turbine locations, ten of which were monitored using Anabat detectors mounted on "roaming" towers for seven days every other week at two heights (1 m and 20 m). Four of five permanent met towers at the site were monitored continuously for 72 days (August 1-October 12, 2005) at three heights (1 m, 20 m, and 40 m). Four towers is not a very big sample size, so we used small sample size correction factors in our estimates.

Wisconsin. The Southeast Wisconsin site consisted of a scatter of (34) proposed turbine locations, with three permanent met towers among them. We measured bat activity using Anabat detectors positioned at two heights (2 and 22 m) on roaming towers, for two five-day periods during the season. As with the PA site, we positioned detectors at three heights on the met towers (2, 22, and 48 m), and measured continuously for 78 days (July 27-October 12, 2005). Again we used small sample size correction factors in our estimates.

Effect of Different Resource Allocations

Our study was intended to give some guidance for where to focus our efforts if we don't have enough resources to monitor all locations at multiple heights continuously over the migration season. By re-sampling the data at the PA and WI sites, we can examine how different allocations of resources affect both the accuracy (how close we come to the true mean) and the precision (how big a bracket do we put around our estimate) of our measures of bat activity. Specifically, we looked at the impact on accuracy and precision of sampling:

- at only one height
- at two of the three heights
- at all heights, but at only two of the four towers

[16] Manuela Huso, Oregon State University; Ed Arnett, Bat Conservation International; David Redell, Wisconsin Department of Natural Resources; John Hayes, University of Florida.

Sampling at fewer heights. In Pennsylvania, we used the data from 72 nights at the four met towers as our "population" and then re-sampled. The average activity rate over all towers during the period of measurement was 9.5 bat calls per tower per night.

- By sampling only at 2m we overestimate this by 5.7/3.17 = 1.80 => overestimate by 80%.
- By sampling only at 20m we overestimate this by 2.0/3.17 = 0.63 => underestimate by 37%.
- By sampling only at 40m we overestimate this by 1.8/3.17 = 0.57 => underestimate by 43%.

If we place detectors only at the lowest height (1 m), our estimated average activity rate would be 5.7 bat calls per night per tower, an overestimate of 80%. If we place detectors only at one of the higher heights, we underestimate activity by 37% and 43% for the 20m and 40m heights, respectively. We do better if we sample at two of the three heights, particularly if one of them is near ground level. Sampling at 1 m and 20 m, we exceed the average (two-thirds of 9.5) number of bat calls per tower by 22%. Sampling at 1 and 40 m, we exceed the average by 18%. Sampling only at the 20 m and 40 m heights, we underestimate the average by 40%.

Results from Wisconsin were very close to what we found in PA: If we measure only at the lowest height, we overestimate the number of bat passes by 59%. If we measure only at the higher heights, we underestimate (by 37% and 23% for the 22m and 48m heights, respectively. Sampling at two heights produces somewhat smaller biases (+11% at 2 and 22 m, +18% at 2 and 48 m) when the lowest height is included, and moderately high bias (-30%) when we sample at 22 and 48 m.

Sampling at fewer towers. While sampling at only one height or two heights results in biased estimates of total bat activity, we wanted to explore whether there is enough spatial variability that sampling at fewer sites would also result in bias? We examined effects on our estimates of bat activity of monitoring at all heights, but at only two towers rather than four. For the Pennsylvania site, there is so much variability that our estimates are both inaccurate and imprecise. For the Wisconsin site, estimates based on sampling at two towers are somewhat more accurate, but are still very imprecise.

Sampling for a portion of the season. Finally, we looked at the impacts of sampling only a portion of the season. We re-sampled our data to see what measures of bat activity we would come up with if we sampled for only 4 weeks, or for only two weeks.

Slide #15 graphs the moving average of four-week sampling periods within the 72-day season at the Pennsylvania site. If we were to take a four-week sample early in the season, we would tend to overestimate bat activity. Towards the end of the season, we would tend to underestimate. Overall, 43% of the 4-week samples capture the "true" mean of 9.5 bat calls per night per tower. If we monitor over a two-week period, we actually get better estimates – 48% of our 2-week samples capture the "true" mean – but there is still a lot of variability.

Likewise, there was a lot of variability when four-week and two-week samples were taken at the Wisconsin site. Four-week samples captured the total seasonal average 22% of the time, while two-week samples captured the total seasonal average 27% of the time.

At Pennsylvania, “roaming” towers were used to measure half of ten proposed turbine locations during alternate weeks. (Data from three of these locations was later dropped because the towers were located in uncleared forest, not indicative of future site conditions). Overall, data from the two groups of roaming tower (proposed turbine) locations were consistent with each other, but significantly overestimated the met tower measurements. The two samples are representing different things.

Measuring bat activity from a given set of roaming towers for a single week period resulted in variable accuracy from one sample to another and erratic precision in the resulting estimates. Taking the same measurements for two one-week periods improved precision, but the accuracy of the measurements remained variable. Taking four samples for each set of roamers while varying the length of the sampling period (one, two, three,…, seven days) resulted in improved precision as the length of the sampling period increased, although for the second set of roamers precision remained stable after five days.

Conclusion

Although the Pennsylvania and Wisconsin sites were very different from each other, the results were consistent one with another. In general, as sample size increases, variance decreases, as would be expected. At six or seven days, the coefficient of variation (CV) drops to 20-30% from 100% CV at one-day sample. This is still pretty high from a statistician’s viewpoint. Other conclusions:

- **Sample size really does matter.**
  Monitoring at two to three towers, even continuously, is not enough; there is too much turbine to turbine variation around the site.
- **Monitoring at only one or two heights can lead to biased estimates.**
- Alternating sample locations weekly resulted in consistent estimates but did not represent the met tower data, due to high spatial variation in activity within the site.
- Sampling for 5+ consecutive days improves precision.
- Sampling for only one week gave relatively unbiased but imprecise estimates.
- Sampling for two weeks improved precision.

Migration at Low Height over the Mountainous Areas of Vermont

Ronald P.Larkin
Illinois Natural History Survey

In the Eastern United States, wind power facilities are being sited on high elevation ridges. A site in northern Vermont has come under particular scrutiny as a location where information about nocturnal flying birds and bats is needed to make regulatory decisions. A WSR-88D (NEXRAD) radar just north of Burlington in Colchester, Vermont, provides data on flying vertebrates over nearby mountainous areas in various wind and weather conditions. The WSR-88D radar is not well-suited to surveying low-height migration in flat areas, because of the Earth's curvature. However, because the KCXX radar station is located at 731 m above sea level (ASL) in an area of high topographic relief, it provides a direct "view" of nearby elevated areas so that direct radar observations of targets traveling over ridges are possible.

Objectives

We examined NEXRAD data from several spring and fall migration seasons. Nights with instructive or typical migration patterns were analyzed with the goal of learning how flying birds and bats cope with mountainous terrain in this area, and - in particular - their response to windy ridges. Specific objectives of this analysis were as follows.

1. Determine the feasibility of using inexpensive NEXRAD data to characterize migration of birds and bats in mountainous Vermont terrain.
2. Identify which National Weather Service NEXRAD (WSR-88D) radars are useful over Vermont.
3. Examine selected nights over a three-year period.
4. Concentrate on nights with the highest migratory activity.
5. Analyze speed, location, direction, height, volume, and patterns of bird migration.

General Methods

We surveyed a roughly circular area above Burlington, Vermont, using the KCXX WSR-88D radar located just north of the city. Our survey comprised a total of six migration seasons, spring (30 April to 21 May) and fall (24 August to 15 October) over three years (2003-2005). Of a total of 202 nights surveyed, we discarded 87 nights. In most of these cases (69 nights), data were discarded because precipitation (rain or a storm front) complicated the images, making them difficult to interpret for our purposes. (Other nights were discarded because some or all data were missing from the KCXX archive, or because there were few or no echoes.)

There are no local wind data available. For nights when sonde data from Montreal, ONT and Albany, NY were in agreement, we assumed similar wind conditions for the Burlington area. When necessary, we attempted to resolve inconclusive events with calculations of averaged reflectivity and velocity. We used Level III for surveying nights, and Level II for detailed inspection. (For a description of what is included in Level II and

Level III data, see: http://www.ncdc.noaa.gov/oa/radar/radarresources.html.) These regional wind data were not useful for estimating local winds; therefore, we could not use speed of flight (ground speed minus wind speed) to classify echoes as arthropods (insects) vs. vertebrates (bats and birds).

Of the 202 nights surveyed, 115 provided useful data. Nearly half (55 nights) showed seasonally-appropriate movements of animals. (Note that one limitation of using the NEXRAD data alone is that we had to assume that targets were animals. Because of the topography, no target aspect is available, and there is no way to tell bats from birds this way). On 13 nights, we observed scattered movements (usually light and slow) in the reverse direction. There were nine nights with an observable wind-shear; here we suspect that lower targets were insects, while the higher targets were vertebrates (birds and bats). The remaining 38 nights were ambiguous and have not yet been classified, but showed some interesting complexity which merits further analysis.

Limitations and Possibilities

Despite several serious limitations, NEXRAD does offer several possibilities for learning about how flying vertebrates respond to windy mountain ridges during migration.

Limitations. As has been noted, the lack of wind data means that identification of targets to phylum is mostly subjective, especially with wind shear. Even when we can be reasonably sure that targets are flying vertebrates, there is no way to distinguish birds from bats. (People commonly use target velocity to distinguish flying insects from flying vertebrates; however, this requires having wind speed data, which is unavailable at the Vermont site.) Other limitations:

- The limited scope of this type of analysis dictates a case study approach.
- There is no dual-Doppler.
- Beam blockage limits the geographical extent at low height (the lowest radar elevation is 0.5 degrees). In particular, areas such as East Haven are not visible at useful heights above the ground. Height is important for wind turbine applications but is poorly estimated by NEXRAD at useful ranges in Vermont.
- There was no attempt to relate WSR-88D data to three studies done with smaller radars.

Possibilities. This is the first WSR-88D study of details of response to mountainous terrain. When you're looking at flat earth, can't see very low because earth curves. But over mountains, flying animals are having to fly higher, so can pick up more of these high-flying animals with radar. The beam of KCXX is very high over the northern mountains, and, in particular, over East Haven, Vermont. These higher beams (elevation angles) can show the height of echoes at close range. Some migrants encounter their first mountains near Colchester, Vermont. The topographic features near the Colchester NEXRAD reveal behavior that may apply generally where birds and bats are migrating across mountain ridges. NEXRAD radar KENX, located in Albany, NY, is capable of "seeing" birds in southwest Vermont; however, the large diameter of the Albany radar beam at those ranges does not permit one to tell whether birds flying over Vermont would be at the height of the proposed wind turbines, or far above them.

Interpreting the WSR-88D Data

Slides showing base velocity data: blue indicates targets moving toward radar; yellow to red targets are moving away from radar.-Observations:

- We could watch animals going through mountain passes, but the radar beam bends due to refraction in the deep valleys, and because we don't know how much the radar beam has bent, we cannot tell how high animals are flying beyond the mountain valleys.
- Selective "bright areas" above particular mountain ridges indicate an area where things are moving but not in one general direction. We suspect that this may be trees moving back and forth in the wind that are breaking through the clutter map.

Compression over ridges. It does seem to be the case that birds are compressed (more animals per unit area, probably closer to the ground) over ridges when winds are not favorable.

Migratory take-off. We can use the radar to show where flying animals have chosen to stop over during the day by looking at where they take off at dusk. (Slide showing birds taking off at dusk.) One does not necessarily expect geographically uniform synchronous take-off, but because birds (for instance) are mostly found at lower heights during the take-off period, we have a brief opportunity each evening to selectively examine animal behavior when they are all (or mostly all) at low elevations.

Complex pictures. In some cases, we see a spiraling effect in the velocity diagrams, suggesting a great deal of complexity - i.e., animals going different directions and different speeds at different heights. It may be that there is an opposing air flow at lower elevations, causing invertebrates to travel north in the fall while larger targets (birds, bats) are flying in a seasonally-appropriate direction because they are able to take advantage of favorable winds at higher altitudes.

Future Investigation

Questions that we would like to investigate using NEXRAD include:

- Why are echoes sometimes stronger to the south than to the north of KCXX in the fall?
- What accounts for big stationary patches of echo, especially in the Adirondacks?
- How frequent is the low-level jet (LLJ) in these mountains?
- Is there a dawn ascent over Lake Champlain?

Acknowledgements

Supported by a contract with US Fish and Wildlife Service Region 5, Alex Hoar Project Officer.

The National Weather Center office in Burlington VT (Paul Sisson and Brook Taber).
NOAA Natonal Climatic Data Center.

Response to Presentation

Question: Can you quantify compression above the ridges?

Response: No. It is not possible to quantify using this data, because we don't know how high the animals are flying, or how many, or what kind, or over what time period. We are looking at snapshots, and so are only able to take a case study approach.

SESSION IV:
MITIGATION OF WIND ENERGY IMPACTS

This session focused on the Mitigation Toolbox, a new product being developed by the NWCC Mitigation Toolbox Subgroup. Lynn Sharp (*Tetra Tech EC*) presented the first draft of the Toolbox. Her presentation was followed by a respondent panel, moderated by Ms. Sharp, in which panelists commented on the first draft and made suggestions for refining this work product.

Presentation of Mitigation Toolbox
(prepared by the NWCC Mitigation Toolbox Subgroup)

Lynn Sharp
Tetra Tech EC, Inc.

A five-fold increase in wind development is expected by 2020, and a number of agencies are developing mitigation guidelines and policies to address wildlife and other environmental concerns. What kind of research-related information is available to support these mitigation policies?

Purpose and Goals

The NWCC Mitigation Toolbox Subgroup was formed to provide direction for future wind development efforts by:

- researching existing mitigation policies and guidelines
- investigating scientific bases of strategies promoted within guidelines
- examining the effectiveness of methods to avoid, minimize, or compensate for direct and indirect wildlife impacts

The Toolbox Subgroup's goals are to identify gaps between policies and research, identify future research needed to address those gaps, and provide a suite of tools to meet stakeholder needs. Our plan is to update the document periodically as new information becomes available.

Toolbox "Drawers"

Our research began with a literature review of existing policies, guidelines, and available research. We interviewed biologists, developers, and conservation organizations, and organized the information we collected by review process and topic area. We created a "gaps" matrix, and put together the start of what we hope will become a larger body of case studies.

Policies and guidelines. We compiled a matrix of existing policies and guidelines pertaining to wind development and mitigation efforts, including those developed by:

- States: WA, CA, KS, MD, MA, MI, MN, NY, OR, SD, VT, WI
- US Federal agencies: BLM, USFWS, USFS, FAA

- Other national governments: Australia, Canada, UK
- Non-profit environmental organizations: American Birding Conservancy, Washington Audubon Society

This compilation revealed several common themes.

- Importance of pre- and post-construction assessments, which may make use of existing agency knowledge.
- Preference for locating turbines on altered landscapes, avoiding fragmentation of native habitats
- Need to identify and avoid disrupting important seasonal behaviors, such as breeding and migration.

Annotated bibliography. The Toolbox includes an annotated bibliography, organized by type of tool, including tools used for other types of projects that might be applicable to wind. The bibliography covers 71 studies on the effects of wind project alterations on birds/bats, or on general habitat mitigation measures possibly applicable to wind development. The literature is categorized by primary topic of mitigation effort or research.

Gaps matrix. A "gaps" matrix lays out existing policies/guidelines with related research, if any, and – where mitigation measures have been studied – identifies whether the research supports the policy. One purpose of this matrix is to identify gaps and overlaps between policies and supporting studies. Like the bibliography, the matrix includes examples not from wind that may be relevant.

Case studies. We set out with the goal of building a large library of case studies, including laboratory test information where available. The case studies include anecdotal information as well as large, formal BACI-design studies. A sample of study objectives includes:

1) Monitoring and evaluation of efforts to relocate a Caspian tern colony to reduce predation on juvenile salmon in the Columbia River
2) Testing of carcass search protocols and fatality estimators, and examination of the effects of weather, turbine conditions, and lights on bats and birds
3) A pair of related studies, one evaluating the visibility of various blade patterns, speeds, and tips, the other examining the effect on bird use and mortality of painting turbine blades with UV-reflective gel.

Case studies currently in progress include: Hart Mountain (Earnst et al. 2004), Blade Painting (Hodos et al. 2003 and Young et al. 2003), Straits of Gibraltar (Barrios & Rodriguez 2004).

Next Steps

We could find few well-verified tools available, but there is hope. We need input on the case studies, including results from The Nature Conservancy, land trusts, state and federal agencies and tribal habitat improvement projects. We will need to update the information we have now on pre-construction data with post-construction monitoring results. Ideally, we would like to see more collaboration, like the work the Bat-Wind Energy Collaborative is doing to test theories and tools.

We have additional funding from the American Wind Energy Association Siting Committee to take next steps. Specific objectives include:

- Extend research on mitigation strategies to additional classes of wildlife, international efforts, and habitat mitigation efforts
- Obtain feedback to identify gaps/future directions
- Conduct economic analyses comparing various mitigation options
- Obtain and review more case studies.

We need your input. The draft toolbox is posted on the NWCC website[17] – please submit information (case studies, ideas) and comments.

MITIGATION TOOLBOX RESPONDENT PANEL

Facilitated by
Abby Arnold, RESOLVE

Recognizing that this draft of the Toolbox represents a "first stab" at a product proposed at the last meeting, facilitator Abby Arnold asked panelists to open the conversation with comments and suggestions regarding the draft. Their observations were followed by responses and open discussion from the floor.

Panelists:
Michael Fry, American Bird Conservancy
Alex Hoar, US Fish and Wildlife Service
Greg Hueckel, Washington Department of Fish and Wildlife
Stu Webster, Clipper Windpower
Lynn Sharp, Tetra Tech EC

Michael Fry, American Bird Conservancy (ABC)

This is a good start at organizing the available information, but right now our toolbox is pretty empty. As Crissy Sutter mentioned, there is value to doing habitat/sensitivity analysis early on – just doing the paper analysis early on is important. ABC is developing a process to go along with the toolbox. The focus of our effort is on siting to minimize risk by overlaying GIS maps of important bird areas, bat hibernacula, migration corridors plus local planning (as at Foote Creek Rim, where turbines were moved back from edge of rim) to limit potential impact.

Operational tools. If wind energy is to become 20% of US energy resource, we cannot rely

[17] http://www.nationalwind.org/default.htm

entirely on avoidance. We need to look at operational tools. Seasonal shutdowns are one example; we need to get the investors in on this at the early inception of the project, so that the funding mechanism accounts for it. An example of this can be found in Oaxaca, Mexico, where 8 GW of wind power are being developed in an area (the Isthmus of Tuhuantepec) where raptors migrate. The World Bank is being clear up front that there will need to be monitoring, and seasonal shut downs to avoid raptor mortality.

Repowering. Altamont Pass is incredibly important. Secrecy and in-fighting and discrediting of people's work – that has to stop. The wind industry is going to suffer if it cannot deal with Altamont Pass problems constructively.

How much is too much? If there is unavoidable take – we have to answer the question, how much is too much? If mitigation means compensating for the take, then economics will set limits on offsite conservation banking, habitat restoration, raptor breeding programs, etc.

The Federal Energy Plan calls for 20% of our energy from wind. This means the federal government is going to have to come up with funding for mitigation. The federal government supports fossil fuel producers and has for a long time – with all kinds of subsidies and property rights that the wind industry does not have benefit of. If wind is to make a more substantial contribution to our energy demand, there needs to be a level playing field with oil and gas.

Alex Hoar, U.S. Fish and Wildlife Service

I commend Lynn Sharp and Jenny Rectenwald for taking this on – the Mitigation Toolbox is a monumental task, and we'll have to keep working hard to go from here.

That there are no well-studied tools is not that surprising; it is no different from hydro. USFWS favors bat- and bird-friendly projects – that statement comes from Matt Hogan, our Interim Director. However, USFWS has not favored a "build-and-study" approach. We don't know if we are avoiding bad sites. There's been slowness to address problems at some sites once site is built.

There are a number of ways identified to avoid bad sites. The company that hired Crissy Sutter, Pandion Systems, to do the up-front risk assessment has taken a leadership step. I want to see more in the way of low-cost tools that fit into the process from early planning through permitting, tools that help us avoid "red" sites and pursue "green" sites.

What is needed is a "three-stage consultation process" that involves all interested parties in: 1) scoping; 2) studies based on issues raised in scoping; and, 3) recommendations based on results of studies. It's important that we better define what it is we need to study, and what we're looking for in the way of results. Also needed is a clearinghouse for making results available, drawing in relevant information from other kinds of projects.

Greg Hueckel, Washington Department of Fish and Wildlife

We need to take a lot of the science we've heard about, and put the tools on the ground – make them part of the regulatory process so that they make a difference.

Washington State's experience. Four years ago Washington Dept. of Fish and Wildlife put our first set of guidelines out. The idea was to put the best available science into the form of guidelines that could become part of the regulatory process. Three of the eight projects that have been developed using the Washington guidelines are on cropland. The other five are on 1,000 acres of native habitat, and their impacts have mitigated by doing restoration on 3,000 acres of land.

We have used the money from our mitigation fund to acquire 5,100 acres of shrub-steppe habitat that would tie up that native habitat in perpetuity. In developing the infrastructure at a state level we are trying to develop consistency. Among other things, experience has shown us that the non-regulatory provision of guidance (through technical assistance) is often more effective at getting people to do the right thing using the best available science.

Also, it should be pointed out that guidelines do age, so we are now revising our guidelines with information that we didn't have four years ago. This includes information that supports the idea of seasonal shutdowns.

Need for national guidance. The Toolbox leaves it up to the individual states or counties that are permitting projects to decide what's acceptable. Yet there is a need to provide some national guidance as to what is acceptable. For example, cropland mitigation – my biologists are telling me that there is habitat value in cropland, and we shouldn't just "give it away." Each state is different, just as all my biologists are different. Providing guidelines at national level would provide some level of certainty for industry, and would establish greater consistency.

I would like to see a single forum that takes this leadership to the national level (NWCC is a good forum because it is independent, and includes academic, industry, regulatory agencies, etc.) Nobody should get a better deal. If the wind industry continues to get inconsistent guidance from different states, we may not be able to achieve what we want for wind.

Stu Webster, Clipper Windpower

What's been compiled here is fantastic. A lot of improvements could be made (as other people have just pointed out), but there is a plethora of knowledge out there from other industries – especially with regard to habitat fragmentation – that we can use. For example, the forest industry has likely addressed endangered habitats and possibly on and offsite mitigation measures they have incorporated may prove useful. Additionally, transmission line and road corridors would seemingly face habitat fragmentation issues and therefore may prove a useful resource. The general idea of the toolbox is to have a compilation of ideas and techniques where various stakeholders can find mutually beneficial and consistent means of assessing impacts and mitigation.

The significance and importance of this resource tool lies in its accessibility to all stakeholders (and, more importantly, where all stakeholders share responsibility for nurturing its development), and is best exemplified in contrast to the common course of development activities in the absence of such a resource. Industry realizes that environmental issues and concerns are to be addressed fully, but cautions that such assessments need to be contained within the context of economically viable limits.

We have to beware the "Bermuda triangle" of communication among stakeholders (NGOs, industry and the regulators). Regulators of wind industry have a mandate to protect wildlife but also a mandate to support renewable energy. NGOs advocate that the wind industry properly address issues and concerns pertinent to their given interest (e.g., understanding avian and bat impacts) and yet understand the significance of this industry. Industry needs certainty and transparency within a competitive market in order to encourage participation and efficiency.

Broadening the avenue of communication is important for these reasons, with the intent that a resource such as the mitigation toolbox provides all stakeholders the means to agree upon what is necessary and/or appropriate given what has worked (and not worked) in the past. As an industry representative (but speaking only for Clipper) I feel we need to be able to support the advance of scientific knowledge of these environmental issues; there is no reason not to do so. The alternative historically has been shown to be rules that are onerous to comply with and interpret, crafted without meaningful upfront engagement by industry in the policy making process, that ultimately become less effective and more expensive than more robust alternatives such as what this toolbox can provide.

Comments and Discussion from the Floor

***Facilitator* [*A. Arnold*]:** what we really need more than a conversation about the policy piece, is to please give us concrete input on the Toolbox.

***Comment* [*A. Manville*]:** I liked Greg's comment about national guidelines. We're about to go into a Federal Advisory Committee Act (FACA) process to update USFWS guidelines. This is a perfect opportunity – we've got good minds on this, we've got the process – let's take advantage of it. USFWS provided a draft guidance document in 2003, opened for comments, closed in July 2005. Came up with group of stakeholders, and to avoid a lawsuit, and are going through the FACA process to come up with revised guidelines (probably voluntary) to address to issues in our guidelines.

Response* [*G. Hueckel*]*: Once USFWS guidelines are developed, those guidelines will have the agency's stamp on it. Still, I think it's important for NWCC as an independent forum to adopt a set of national guidelines.

***Comment* [*R. Manes*]:** It is very encouraging that we've got the right people involved in creating this toolbox. My concern is that as we develop the Mitigation Toolbox, we are still focused far too little on habitat issues. The Washington State guidelines do a good job of addressing this. But from what I've been hearing here, I'm concerned that habitat loss deserves far more attention than the direct impacts (collision mortality).

***Response* [*M. Fry*]:** Compensation of unavoidable take addresses the habitat issue. But there is also a need to address the issue of transmission corridors. Wind will be built where the transmission corridors are.

***Response* [*P. Cryan*]:** Regarding habitat suitability with respect to bats. We've now seen a couple of major mortality issues in cropland. We may have a habitat mimicry situation here – bats may be mistaking wind turbines for trees.

***Response* [*A. Hoar*]:** With regard to what Rob said, there are three issue areas: water quality, terrestrial habitat, and air as habitat. We need to identify tools with regard to each of these areas. My anticipation of the toolbox as a finished product is that it ought to deliver information about *tools* ("hammers and saws"). I think we need to define what we mean by tools. This definition is not in the document now, or else it is not clear.

If this is a living document, we need to paint a picture of where we want to go with this, so that people can be constructive in their contributions. The individual pieces that were done for this working draft were done very nicely, but there are gaps, and it isn't clear what they are.

***Comment*:** To say that this can be done without taking policy in consideration is to say it can be done in a vacuum. Regulatory agencies are looking for guidance. The fossil fuels and hydro were developed pre-NEPA. This is a resource that is being developed post-NEPA, and that puts its development under an entirely different set of constraints.

***Response* [*Facilitator*]:** It is not that the Mitigation Toolbox doesn't happen in a policy context – that's what Al Manville is talking about – but rather that the Toolbox group is focusing on the tools themselves. All of $5000 has been spent to put this draft together, and another $5000 has been raised. That is very little money, so if this is important to you all, you all need to come up with the resources.

Facilitator concluded the discussion by inviting people to come up with specific suggestions to add to the Toolbox.

Lunch Address: Documenting the Effects of Wind Turbines on Bat Populations Using Genetic Data

Nancy Simmons
American Museum of Natural History

How are wind farm kills affecting bat populations? Locally? Regionally? Or on continental scale? What research questions do we have to ask to address this? (Note that the methods described in this presentation could be applied to birds as well.)

Preliminary Questions

To begin to determine how wind farm fatalities affect bat populations, we must ask questions that address the genetic structure of the populations in question:

1) How large are bat populations?
2) How much genetic diversity is there?
3) How is this genetic diversity structured geographically?

Genetic diversity provides the building blocks for helping animals respond to changes. Yet just as animals are not uniformly distributed around a landscape, genes are not uniformly distributed among populations of a species. So, in addition to knowing about the abundance of a species across its range and the genetic diversity within that population, we also have to find out how that genetic diversity is structured geographically.

If there is enough gene flow among sub-populations of a patchily distributed species, that species may act like one large population. In this case, we can take out a few individuals and the overall genetic diversity does not change. But if there is less gene flow, we may find that different sub-populations have a different genetic heritage. In that case, the same number of fatalities could have far greater impacts on the genetic diversity of the species.

To summarize, a large population with high diversity and little geographic structure is less likely to be impacted by fatalities, but a small population with low genetic diversity and a high degree of geographic structure is more likely to be affected.

Mapping Genetic Structure of a Population

Haplotypes. DNA sequence data can be used to determine the genetic structure of a population. All genes are made up of a series of four bases.[18] A pattern of bases makes up a gene sequence, and a pattern of gene sequence bases makes up a *haplotype,* the genetic constitution of an individual chromosome. By comparing haplotypes, we can determine what percentage of the gene sequence is different. (Slide #32 shows two haplotypes, H1

[18] A=Adenine, C=Cytosine, G=Guanine, T=Thymine

and H2, which differ at 6 out of 24 sites, a 25% sequence divergence.) A network of haplotypes shows graphically the relative difference among haplotypes (H1-H6) within a species (Slide #34) as contrasted with the haplotype from a different species (H7, slide #35).

> ***Example (Slides #36-37):*** A field vole map of Europe shows that there are three different sub-species (Eastern, Western, and Southern). The Eastern and Western sub-species have many closely clustered haplotypes. The Southern sub-species has fewer haplotypes, but is very different from the Eastern and Western sub-species.

We can more simply show the relationships among haplotypes using a tree diagram (slides #39-40). In slides #41-43, a tree diagram of H1-H6 shows how the similarity of haplotypes is related to geographic structure. When the most closely related haplotypes are found closest geographically, this suggests a lower gene flow. By contrast, if closely related haplotypes are found in very different geographical areas, this indicates a high level of gene flow.

> ***Example (Slide #45):*** In a similar tree diagram mapping the geographic distribution of Mexican free-tailed bats, we see the extreme case of no geographical patterning whatsoever. The entire continental population is acting as a single genetic population, so that removing all the animals from one geographic location would not effect population genetics.

Slides #48-49 use a pie diagrams to depict haplotype diversity and geographic structure. These illustrations are called *minimum spanning network* diagrams. Each circle represents a haplotype. The size of each circle reflects how common the haplotype is (larger circles = haplotype found in more individuals). Colors indicate geographic localities.

Slides #50-51 shows the mitochondrial gene sequences for two species of bats from Samoa and Fiji shown using minimum spanning networks. From these diagrams we can see that *P. samoensis* demonstrates high degree of geographic structure – wiping out the population on one island would reduce the genetic diversity of species.

Actual v. effective population size. When we talk about population size, we have to specify whether we are referring to the *actual population* size (census, or N) or the *effective* population size (N_e). The latter is concerned only with reproductive males and females. An uneven sex ratio or uneven reproductive success results in reduced effective population size. Any crash in population size is going to reduce genetic diversity (bottleneck effect), simply by eliminating rare genes by chance. When a population begins to recover, its genetic diversity does not necessarily recover – or not as quickly, at any rate.

The relationships among genetic flow, diversity and geographic structure are very complicated.

Coalescence theory. Slides #64-68 use different colors to represent different alleles (different versions of the same gene, part of a haplotype) We can track lines of descent of alleles from the past to the present generation. At each new generation, there is a possibility of extinction and of mutation. Coalescence has to do with where (how many generations back) different lines split or come together.

Using Genetic Data to Learn about Populations

Using complex mathematics, these kinds of data theoretical frameworks (phylogenetic trees and coalescence theory) can be used to estimate population sizes from raw genetic data (haplotype/allele frequencies and distribution).

How do we know this stuff works? How do we know that population estimates based on genetic data have any bearing on reality? These approaches have been tested with simulations. The estimation techniques turn out to be remarkably robust, and they are being used with a lot of different types of species, in major peer-reviewed journals. These are tools that have become accepted by scientific community. There are several examples of the way these tools are used.

> ***Example:*** Slide #73 shows a phylogenetic tree of the Hepatitis C virus. The availability of genetic material from 100s and even 100,000 year-old samples has enabled us to trace the population size change of this virus over long periods of time.
>
> ***Example:*** We can also use these kinds of studies to compare populations of different species. Slide #75 shows how three species of whales have all declined, but humpback and fin whales have declined to greatest degree.

Back to the bat question… The North American population of Mexican free-tailed bats is huge (N_e for females = 417.8 million) and has grown over time (from historical N_e = 16.7 million). The whole continent is one population, and its growth is associated with the development of agriculture in N. America – insect population has increased, and bats feeding on them have increased.

How to Make Use of these Tools

What about other bat species (Hoary, Eastern red, silver-haired, Indiana)? When carcasses are found at wind farms, freeze them and send them to large research institutions like the American Museum of Natural History. We take DNA or tissue samples from material that comes in. Technology developed for medical purposes is used to freeze the DNA samples. We also maintain an online searchable database.

We are working with various researchers, including Tim King from US Geological Survey, who is developing a nuclear marker technique using mitochondrial markers (DNA). The different techniques are easier for different things. For example, it is easier to get DNA from rotted carcasses than to get the nuclear markers, which are only available from certain tissue under certain conditions.

The time factor is a powerful aspect of this kind of research tool. We have 100-year old specimens of several species of bats. We can also look at where things are going five, ten years into the future, using baseline data. However, we need a minimum of ten bats per species per site and at least 25 sites broadly distributed across a species' geographic range to be able to build the kind of database that will prove powerful in looking at how wind farm fatalities are affecting species.

The following link provides more information about donating dead bats or tissue samples from wind farms for this project: http://research.amnh.org/mammalogy/batgenetics/

SESSION VI:
RISK ASSESSMENT, MANAGEMENT AND WIND POWER IN THE UNITED STATES

Facilitator Abby Arnold introduced this session by noting that, two years ago, the Wildlife Workgroup of the NWCC decided to form a risk-assessment subgroup. The first presentation of the session summarizes the work this group has been doing.[19] One of the things the Subgroup has discovered is that different people use the term "risk" in different ways, and so we need to clarify what we mean by risk. Moreover, the question of risk is often multi-layered: is it project-specific risk? or is it risk from a regional or population impact perspective?

Finally, there is the larger context of wind power-related risks. If you don't build wind, and continue to meet energy demand using existing energy resources, what is the relative risk to wildlife? What about climate change? How do we assess, manage, and communicate relative risk, or put these risks into the larger context, particularly given all the inherent uncertainties?

Dr. Rebecca Efroymson (*Oak Ridge National Laboratory*) will present the work of the NWCC Risk Assessment Subgroup. Dr. Terry Root (*Stanford University*) will talk about climate change, and the relative risk of wind power v. other alternatives to meeting energy demand.

Ecological Risk Assessment for Wind Energy Facilities

Rebecca Efroymson
Oak Ridge National Laboratory

Ecological risk assessment (ERA) takes place within a number of frameworks – from pesticide use to military activities to wastewater treatment. It can also be applied to energy development projects such as hydropower and wind energy. In the case of wind energy development, potential drivers for using ERAs include:

- State siting guidelines (ERAs under consideration for California and New York)
- Environmental Impact Assessments (e.g., NEPA requirements)
- Incidental take permits (ITP) and habitat conservation plans (HCP) under the Endangered Species Act
- Avian Protection Plans

[19] An initial working draft of the Risk Assessment Subgroup's White Paper is included in the Research Meeting notebook. The White Paper is currently undergoing revisions based on feedback from the San Antonio meeting; a revised draft will be posted on the NWCC website in the second quarter of 2007.

Key Questions

The White Paper poses these key questions:

- Is a framework needed as guidance for conducting environmental assessments of wind energy facilities?
- Might such a framework be responsive to regulatory agency needs and flexible in terms of data requirements and expense?
- Is an ecological risk assessment framework appropriate for wind energy assessments?
- To what extent are previous environmental assessments of wind energy facilities consistent with an ecological risk assessment framework or its components?

Two additional questions we considered it necessary to address:

- How might exposure and effects (consequences) of wind energy be characterized in an ecological risk assessment?
- What should be the context of results of a risk assessment? Should it:
  - Include background risk?
  - Assess relative risk of alternative energy technologies?
  - Assess relative risk of alternative land uses?

Current Scope of the White Paper

Currently, the scope of the White Paper includes: vocabulary; the concept of "tiered" analysis; broad stakeholder involvement; the stages of risk assessment; the concept of stressors; the concept of assessment endpoints; concepts of measures of exposure and measures of effects; and potential advantages of an ERA framework.

Defining vocabulary. One of the first steps the sub-group took was to define the terms we use so that everyone can be using a common vocabulary.

The U.S. Environmental Protection Agency developed an Ecological Risk Assessment (ERA) Framework in the late 1980s. We are using the EPA's definition of ecological risk assessment: "a process that evaluates the likelihood that adverse effects may occur, or are occurring" [in this case] to individual birds or bats, or populations of birds or bats, as a result of stressors (turbines, habitat disturbance) caused by wind power generation. "Process" is a key word in this definition, as is "likelihood." We can't always be so precise as to come up with an exact probability; we may have to say "likely" or "probable."

Concept of tiered analysis. The Australian Wind Energy Association has developed an ecological risk assessment framework using a tiered approach. Within this framework, analysis can range from a qualitative screening to a very quantitative analysis.

Problem formulation. Slide #9 diagrams the EPA's ERA framework. The problem formulation is a planning step This is a crucial step, in which scientists and planners work out the scope of the assessment and what is needed from the results. This planning stage also provides the opportunity for input from stakeholders, possibly in the form of a facilitated discussion of data needs and assessment designs. Note also that there is ongoing discussion between the Risk Assessors (scientists) and the Risk Managers (planners), shown to the upper left of the diagram.

Potential stressors. Within the context of wind energy, potential stressors include:

- collision with moving turbine blades
- habitat stressors, including removal, fragmentation, and edge effects
- human activity resulting in disturbance.

Potential assessment endpoints. The selection of assessment endpoints is a function of several criteria. Endpoints must be:

- of biological or regulatory importance
- focused on species that are highly susceptible or highly sensitive
- of appropriate spatial scale
- practical for assessment
- identified with either individuals or populations.

Advantages of ecological risk assessment. A well-defined ecological risk assessment process that encourages input from all stakeholders and facilitates discussion of data needs and assessment designs offers many advantages. A structured process using consistent metrics and a common language produces consistency among assessments, making possible the development of a base of common knowledge which can be applied to other projects. Selection of well-defined, susceptible, valued wildlife species, appropriate properties, and critical levels of effects facilitates the evaluation of uncertainty and helps to focus decision-making.

Characterization of Exposure

Exposure is defined as *contact or co-occurrence of stressors with wildlife at a wind project site.* There are several methods for characterizing exposure. To some extent, the method used depends on the type of stressor under consideration. Methods for assessing risk associated with collision, for example, differ from methods used to assess the risk associated with habitat loss or fragmentation.

Exposure to collision. One approach to assessing collision risk is to measure species' utilization of the wind resource area or of the "risk" area (more narrowly defined in terms of the rotor swept height of the turbines). Examples of methods include:

- Abundance in the risk area divided by total abundance (ENE and Pandion 2004)[20]
- Exposure index: proportion of all flight observations in which individual was observed flying within the rotor-swept height of the turbines (WEST, Inc.).

Examples of methods used to measure exposure to collision include:

- Utilization divided by avoidance-mortality (Ecology and Environment and Pandion Systems)

[20] Slide #13 lists the parameters used to estimate raptor utilization below maximum turbine height for the Chautauqua Windpower draft assessment.

- Avian Risk of Collision model, in which collision flight paths are divided by total flight paths, based on flight and turbine characteristics, and the design of the wind farm (Podolsky).

Exposure to habitat and distribution impacts. Methods used to measure exposure to habitat removal and fragmentation include quantifying total acres removed or total acreage affected, and quantifying the effect of development on the landscape pattern. Methods of measuring spatial and temporal distribution of wildlife include: field surveys, radar studies, thermal cameras, echolocation detectors, mist nets, telemetry, and weather models to estimate the timing of migration. Exposure to noise from turbine operation can be measured objectively. Other sources of disturbance (i.e., from human activity related to facility development, operation, and maintenance) are harder to quantify.

Characterization of Effects

The characterization of *effects* is defined as a *description of the effects* and a measure of *how they change with varying stressor levels*. Exposure-response relationships may be empirical or mechanical.

Collision effects. Methods used to characterize collision effects include fatality counts (adjusted for searcher efficiency and carcass removal biases), and collision modeling (exposure = effects). Slide #17 shows an example of a regression plot in which (adjusted) raptor fatality rate is plotted against raptor use (bird count per 20-minute survey).

Habitat removal effects. Methods used to characterize habitat removal effects include: abundance surveys, reproductive measures (such as nest counts), population models, predator-prey models, and measurements of nest parasitism and predation.

Potential Next Steps

The Risk Assessment Subgroup would like to get feedback on what would be most helpful for finalizing white paper on risk assessment. Possible steps include:

- Include more case study information from previous environmental assessments?
- Clarify the term “risk” by using examples, distinguishing “risk” from other measures such as “likelihood,” “probability,” etc.?
- Provide examples of various stages of risk assessment, including characterization of exposure and of effects, as well as risk characterization?
- Describe how ERA framework might be used differently in different contexts (e.g., siting assessments, permitting assessments, post-construction assessments, impact-reduction studies)?
- Describe risk management considerations?
- Describe risk perception and communication issues?
- Provide additional discussion of assessment or management goals (e.g., how relative risk assessments might be different from assessments focused only on wind energy)?
- Conduct additional discussions of risk perception, risk communication, or relative risk at a subsequent Wildlife Workgroup meeting?

Possible Ecological Consequences of Not Kicking Our Fossil-Fuel Addiction

Dr. Terry Root
Center for Environmental Science and Policy, Stanford University

[Note: this presentation summary has not yet been reviewed by Dr. Root]

Is global warming an important piece of what participants attending this research meeting are concerned with? [A substantial show of hands affirmed that many meeting participants feel that it is.] One of main reasons I'm here is that I've spent most of career looking at how global warming would affect biodiversity. The Intergovernmental Panel on Climate Change (IPCC) has mapped anticipated global temperature increases we can expect over the next 100 years, given scenarios ranging from "business as usual" to a "highly cooperative sharing of technology" to reduce fossil fuel emissions. At this point, we cannot avoid an increase of 2 degrees C. Unless we can manage to avoid going up 4-6 degrees C, I believe that we are right at the edge of a major extinction event.

To avoid such a major extinction event, however, we have to stop letting fuel emissions go up. Slide #4 graphs the difference between "business as usual" increases in fossil fuel use and a stabilized level of annual carbon emissions projected over the next 50 plus years.[21] We can take this "stabilization triangle" and divide it into wedges, each of which represents a way to cut back on additional CO2 emissions. Wind is very important in this picture! Replacing coal power with wind power is one such wedge, but it would require 50 times our current wind energy capacity – equivalent to adding 2 million 1 MW-peak capacity wind turbines.

Slide #8 graphs departures from 1990 temperature (C) observations for North America from the year 1000 to 2000. What we see is a "hockey stick" curve: essentially horizontal over the first 900 years, and then veering sharply up. Slide #11 compares differences in temperature forcing from 1860-2000 between actual observations and what would be predicted based on modeling of natural v. anthropogenic causes. The combination of natural causes and human activity accounts for the change in observed temperatures. However, the model for natural causes alone has weak predictive value; modeling human causes produces a much closer match.

Impact on biodiversity.

What types of impacts are we seeing on biological species, as a result of increasing global temperatures? We are seeing a variety of impacts, including:

- Range shifts
- Phenology shifts
- Other shifts
- Extirpation and extinction

[21] S. Pacala et al.(2004), Science 305: 968-972.

Range shifts. There is evidence that the ranges of species are changing, shifting both towards the poles and up in elevation. Slide #17 shows northward shifts in the average latitude of occurrence for three species of warbler from the early 1970s to the early 1990s. Biotic interactions between species that now share range but are differentially affected by temperature will be affected as some species shift and others don't. It is hard to put a value on the consequences of such shifts, they could be good or bad depending on a host of other factors.

Phenology shifting. Phenology refers to the timing of events, such as spring and fall migration. A meta-analysis of 61 studies affecting 694 species around the northern hemisphere show that spring migration is occurring earlier – on average about five days earlier over a ten-year period.[22]

Other shifts. Other types of shifts – in densities, in genetics, in behavior, and in morphology – all point to the impact of temperature change.

Extirpation and extinction. Extirpation and extinction of species is not a matter of conjecture, they are already occurring. Impacts are compounded by synergisms. Consider what happens when species moving north and are compressed against developed areas. For example, butterflies trying to move north from Baja California are being compressed against Tijuana and San Diego. In this situation we have to physically move animals to prevent their extinction.

I surveyed approximately 3,000 studies on species and climate change, and found a total of 143 studies that met criteria for a meta-analysis of all types of change (range, phenology, etc.) from all parts of the world except Africa. (Studies in Africa focused on precipitation rather than temperature, and my meta-analysis focused on impact on plant and animal species of temperature change.) This analysis looked at more than 1,859 species. About 20 % of the data were not changing. Of the 1,473 species showing change, 20% (>277 species) are changing in opposite direction from what you'd expect from global warming, but 80% (>1196 species) of the data are changing in the expected direction.

Where do we go next?

We have to make the shift from fossil-intensive to non-fossil intensive technologies (i.e., wind rather than coal). If global temperatures rise more than 3.5 degrees, the impacts on the natural world will be catastrophic. Slide #36 projects the likelihood that we will see a temperature increase of this magnitude at some point during this century, under the worst (fossil-intensive) and best (technology-intensive) case scenarios. Even under the best-case scenario, there is a ten percent chance that global temperatures will rise 3.5 degrees C before mid-century; under the worst-case scenario, however, there is a 50 percent chance of crossing that threshold by 2075 – whereas the best-case scenario offers a 50 percent chance that we will be able to curtail global temperature increases before we reach that

[22] Root et al., 2003. Nature 421: 271-260.

tipping point.

Slides #38-39 show how much farther north the ranges of several species would have to move over the next 50-100 years under the best-case (non-fossil technologies) and worst-case (fossil-intensive) temperature change scenarios. In reality, if all those species tried to move that far north, many would go extinct.

Finally, I want to emphasize that atmospheric CO_2 concentrations, temperatures, and sea level all continue to rise long after CO_2 emissions peak. Slide #41 illustrates the lag in response of these conditions to the reduction in emissions – from 100-300 years for atmospheric CO_2 concentrations to a few centuries for temperature stabilization to several millennia for sea levels. We must start by shifting to wind *now* to get up the curve to where we will start seeing a major difference by 2050.

Discussion following Presentations on Risk

***Comment* [*B. Ram, Energetics*]:** What can this group do to address the issues Terry and Rebecca have raised? Risk assessment is quite an advanced scientific framework (nuclear, chemical industries have developed highly complex risk frameworks). Dr. Root's presentation raises the larger risk issue.

***Comment* [*T. O'Leary*]:** In a project Shell Renewables recently had approved in Iowa, the EIS included several options, including the option of not building the wind plant. Where would the coal come from? Where would you put the rail lines to bring the coal? What impacts would these actions have? I would ask folks here today to work with us – not asking you to ignore the wildlife impacts of wind energy, but for all of us to keep our eyes on the prize.

***Question*:** What about cropland – food sources must shift north as well, which in turn will affect habitat.

***Response* (Terry Root):** Croplands *are* moving north – and they are shrinking while populations are growing.

Comment [*T. Younger*]: We're looking at what's happening on the Great Lakes as a result of global warming. The water supply could be going down anywhere from 1-8 meters over next 50-100 years, reducing hydroelectric power capacity, which we will have to make up as well.

TELECAST ADDRESS:
Adaptive Resource Management

Jan Beyea
Consulting in the Public Interest

"Adaptive management" (AM) is a very popular phrase these days. While a formal set of AM principles have been developed (based on the work of Carl Walters and disciples), people use the phrase to refer to a wide range of approaches, from simple trial-and-error (or "wait and see what happens, then react,") to "squeezing" an operator step by step, to a more rigorous joint fact-finding effort that fits within the larger conceptual framework of a structured decision process involving stakeholders.

Adaptive management is only one of many possible approaches to managing risk. Others include:
- Deferring action (wait for uncertainties to resolve; follow "standard operating procedures");
- Taking a biological risk-averse approach (e.g., facility shut-down);
- Falling back on a dogmatic approach (either "do not disturb" fixed policy positions, or – all too often – a "winner-take-all" fight between antagonistic stakeholders).

What is an appropriate formulation of AM in the context of wind energy? At a minimum, AM requires:

- That we learn from management decisions (which requires monitoring)
- That management is adjusted based on what we learn ("closing the loop")

This minimum formulation of AM is not too different from the "wait and react" or "trial and error" approach. The problem with "trial and error" is that it generates unclear results. The basic idea of AM is management as a kind of experiment, combined with the idea of iteration, converging on an optimum management strategy. AM is an attempt to go beyond trial and error to facilitate systematic learning. While AM is not easy to accomplish, if you can do it, it offers some real advantages over the other options. It can:

- Get rid of bad hypotheses (and prevent bad hypotheses from arising)
- Resolve disputes between stakeholders promoting different theories
- Provide more useful research opportunities than academic research in situations where academic-style research results would be difficult to extrapolate to real world conditions

Essential AM Components

It's important to be careful of abuse of AM. One cannot just say, "well, I'll build this facility, and we'll see what happens." That is not adaptive management.

Clear objectives. Essential to any AM plan is the establishment of one or more clear objectives. Some authors claim that the various players must *sign off on the objectives*, but this raises the question of which players? Developer and regulatory agency? A broad group of stakeholders? Some authors claim that the objective must be *quanitifiable*.
One challenge is that objectives may change as new understanding is gained. (This can create difficulties if a broad group of stakeholders needs to sign off on the objectives.)

In order to establish an objective or objectives, several questions must be answered.

- What is being managed?
- Who is doing the management?
- Is the monitoring focused on the objectives?
- What are the politics involved?

These are some examples of objectives that might be appropriate in the wind energy context.

- Maintain (and possibly help) populations of threatened and endangered species.
- Reduce turbine kills by some percentage.
- Minimize kills (e.g., per peak kW-hour generated).
- Devise a pre-siting protocol that best predicts post-construction bird/bat fatalities.

Bear in mind that, if the objectives are vague, with details "left to be worked out," it is unlikely that the management loop will be closed.

Management options. The AM framework tests multiple, competing models, as opposed to testing each idea sequentially against the null hypothesis. In the context of wind energy, these may include: modifications to the design and placement of turbines on the landscape; modifications to operations, such as rodent control or time restrictions on turbine operation; offsite mitigation. Some of the management options are tricky. For example, rodent control could hurt the species you are trying to protect by reducing its prey.

Closing the loop. That systematic learning takes place is one key assumption of AM; another is that management action will be taken in response to what is learned. It has been observed that "there are startlingly few examples in wildlife management in which the adaptive management 'loop' has been completed" (Gibbs et al., 1999). An important question, therefore, is who is responsible for closing the loop? In the context of wind energy, it may be state wildlife or natural resource agencies, it may be USFWS, or it may be the facility operator, under agreement with agencies or other stakeholders.

Bayesian v. Non-Bayesian Approaches

There are two schools of AM. The first is the non-Bayesian school, or hypothetico-deductive approach. The second is the Bayesian school, or model weighting/evaluation approach. Both can have models, with parameter fitting.

Hypothesis formulation and testing. The non-Bayesian approach is well-understood by all researchers. It is perhaps most appropriate when you have an opportunity for multiple treatments and replication. However, because deductions and interpretations are subjective, this approach is susceptible to politics.

Model weighting. The Bayesians are model evaluators. Recognizing that "science is contested territory," they search after probabilities to assign validity to theories or models. Model weighting requires both *prediction*, and the *assignment of uncertainty* to that prediction. It is perhaps most appropriate when you have only one "ball game" – as for example, with waterfowl harvest regulations – with limited treatments/replication opportunities. It may also be appropriate when you have contesting stakeholders.

Limitations and advantages of the Bayesian approach. The Bayesian approach is not as familiar as the non-Bayesian, and some statisticians don't like it. It is highly mathematical, and there are few computer programs yet available for Bayesian AM.[23] If there are multiple outcomes, treatments, or objectives, different models may be found to perform better on different parts of the field data. This can potentially lead to paralysis in decision-making or review bodies. Nevertheless, it does offer many advantages. It allows anyone to propose or champion a favorite theory, as long as uncertainty is assigned to its predictions. Regulatory agencies have to start the ball rolling by picking the initial "best" management option, but the agencies can then stand above the fray as competing theories are evaluated based on how well they predicted the field results.

Site-specific AM Proposals

Examples of non-Bayesian AM proposals within the context of existing or proposed wind energy developments include Massachusetts Audubon's proposal (Allison 2005) for the Cape Wind project[24] and two proposals (WEST, Inc., and Smallwood, both 2005) for studying management actions at Altamont Pass WRA.

Cape Wind. Cape Wind is an off-shore project. Key bird species at the Cape Wind site (and at New York off-shore sites) are the roseate terns and piping plovers. Mass Audubon's (non-Bayesian) AM plan is to be presented to the operator, state government agencies, and to the US Corps of Engineers and Marine Minerals Service (as a recommended permit condition). Possible "loop-closing" actions include: reduction in avian mortality; seasonal shutdown; offsite mitigation; and establishment of an independent mitigation fund Mass Audubon's Cape Wind AM goals are to:

- Correct any unanticipated and ecologically significant collision mortality
- Correct any ecologically significant loss of habitat due to wind farm avoidance

The strengths of this plan are that the goals are tied to larger issues, and (with the exception of seasonal shut-downs), the operator's responsibility for management actions is largely pre-determined by the fund. Limitations of the plan include the fact that "ecologically significant" is left to a review panel to determine, that it is not yet clear who will trigger which actions and in what sequence, and that the lack of a Bayesian component

[23] A new piece of software (called WINBUGS) makes dealing with complex models in AM highly feasible (Dorazio 2003).
[24] For a more stakeholder-oriented proposal for the Cape Wind development, see Ashcraft, undated.

could lead to paralysis within the decision-making group over data interpretation.

Altamont. For Altamont Pass WRA there exists a large base of research from which to choose response actions. Both WEST's and Smallwood's AM proposals for Altamont include a commitment to management as hypothesis-based experiment, and both have a lot of ideas to test, with well-defined mortality-reduction goals. Neither proposal has a Bayesian component (assignment of likelihood numbers to contesting theories or models). As a result, both are vulnerable to political paralysis within the decision-making group due to the subjective nature of data interpretation within the deductive method.

WEST has proposed goals of a 35% reduction in golden eagle, red-tailed hawk, and burrowing owl combined mortality within three years of implementation. However, the connection to population impacts not made. (Note that many California stakeholders are concerned with absolute kill rates, regardless of population impacts.) Also, this goal is modified by the phrase "if not prohibitively expensive" – which does not set a lower bound on the financial responsibility of the owners.

Smallwood has set a goal of 50-80% reduction in mortality within 3-6 years, using offsite mitigation t bring net reduction to zero. This goal does not set an *upper* bound on the financial responsibility of the owners.

Example of Successful (Bayesian) AM

In 1995, the USFWS embraced adaptive management for regulating the harvest of mid-continental mallards. The objectives are to maximize current and future harvest as predicted by a weighted sum of models. This is a good example of successful Bayesian AM approach.

USFWS AM Methodology. There are three basic steps to the mallard harvest AM program.

1) <u>Compare the predictive abilities of the (4) candidate models.</u> Each model expresses a different hypothesis about *survival* (compensatory v. additive mortality) and *reproduction* (strong v. weak density dependence).

2) <u>Update the management "weight" assigned to each model.</u> Each spring, the weight assigned to each model is updated according to how well its predictions match observed population size through use of a Bayesian probability distribution.

3) <u>Make predictions of present and future value of harvests.</u> Predictions are made for a range of regulatory options using each of the four models. A weighted sum of harvest predictions is then made, using model weights for each option. The management option that maximizes the weighted sum is then chosen.

Other planned and proposed uses. AM proposals are being planned or considered for Florida Everglades Reconstruction and for a Pennsylvania deer management program.

Fights over water in South Florida make fights over bat and bird impacts look trivial! It took decades of head-butting to get to AM, but the South Florida Water District has data-driven conceptual models of the system that can be used to make and test predictions.

In Pennsylvania, managers want to know whether deer browse or acid rain is responsible for loss of vegetation understory, and what level of deer density reduction is needed to restore system structure and function.

AM Advice from the Literature

The AM literature is filled with advice. Define your terms, including the AM approach that you are taking. Start simple and involve stakeholders in multiple aspects, encouraging informal networks as a way to help generate creative ideas. Lay out a wide range of management options, and be explicit about management responsibilities from the start. Try to get agreement on goals, and remember, the more explicit (and preferably quantifiable) your objectives, the better.

Getting agreement on objectives. There is not always initial agreement on objectives, metrics, or long-term goals. In this case, try to find objectives that all parties can agree on, even if they differ on long-term goals. A list of key management questions may be a good place to start. Are there questions that all parties want answered? Looking at successes and failures at the site (or at other sites) can also provide a starting point for coming up with objectives.

The literature also advises that you work with multiple, competing predictive models with quantified uncertainties, so that models can be quantitatively tested. If possible, include multiple treatments and replication – for example, by installing different risk-avoiding turbine designs.

Importance of monitoring. Monitoring is key to the success of AM. Both the policy and the research community must agree on the relevance of the monitoring to the objectives, as well as on the scientific adequacy of the monitoring effort. Without agreement on the monitoring protocol, models cannot be tested, and nothing useful will be deduced. The literature advises involving review committees with a wide range of experts.

Conceptual models. Conceptual models link species to ecological parameters and form the basis for identifying adaptive management actions. The following examples illustrate two conceptual models:

1) Conceptual model #1 assumes that the post-construction collision rate (C) is a function of pre-construction flux, the number of turbines, the rotor-swept area, and turbine-specific hit probability. The effective death rate is a function of the Collision rate, accounting for any compensatory mortality and unanticipated side-effects of operations. An error rate must be assigned, perhaps based on data from older sites.

2) Conceptual model #2 is simpler. Bird impacts are based on a simple score function determined from a pre-siting inspection and knowledge of migratory flight patterns. Again in this case the error rate is assigned based on analysis of data from older sites.

Implications for Wind Energy Community

AM could be useful to the wind energy community for testing and refining the idea that pre-siting studies predict post-construction impacts. Aside from site-specific applications, the wind energy community might work together to:

- Develop conceptual impact models – e.g., for offshore wind impacts
- Commission development of predictive models with uncertainty ranges
- Establish a joint insurance policy for operators that would:
  - Pay for offsite mitigation at sites where problems develop and persist
  - Ensure closure of the management "loop"
- Support monitoring that has value beyond a particular site
  - In effect, compensate operators for experiments (such as turning off rotors at the ends of turbine strings)
- Increase the tool set for data analysis – for example, with:
  - Kinetic models of collisions
  - Infrared cameras on blades
- Case-control methodology for better statistical handling of rare events

Case-control methodology is widely used in epidemiology. In this context, when a dead bird is found near a turbine, the following steps would be taken.

- Study that turbine and its surroundings intensively, measuring prey density, bird abundance, scavenging rates, and other covariates that are expensive to measure for site as a whole.
- Pick a "control" tower at random and study it intensively.
- Examine differences between case and control towers to identify associations with mortality.
- Output is odds ratio of fatality given covariate value

What is an appropriate AM program for wind? An appropriate program would consist of competing models within a structured decision framework. It would involve multiple stakeholders and an iterative approach. In a contested situation (or if only a few treatments are possible), it would take the Bayesian approach of assigning likelihoods to models.

When could such a program be instituted? It took decades of fighting to arrive at AM in the Altamont and in the Everglades. If stakeholders buy in and there is a political or legal "hammer" available to close the loop, AM is very appropriate at contested sites.

AM on a National Basis?

AM could be used at the state and national levels as a way of testing conceptual models that can support generic planning and siting policies. On a national level, AM could be used to confirm the value of pre-siting studies. The objective might be to find the best model (or model weights) for predicting post-construction kill rates of all birds and bats (or of birds and bats of greatest concern to USFWS). Competing hypotheses might include the following:

1) Pre-siting studies predict post-construction impacts (within a predicted error rate)
2) Post-construction impacts are dominated by drifts in migratory pathways (within a projected error rate)
3) Post-construction impacts are dominated by changes in habitat and prey base (within a projected error rate)

Step 1: Bring together stakeholders. The first step would be to bring stakeholders together to:

- explain the process,
- identify hypotheses of greatest concern and competing conceptual models;
- identify modeling needed to test the alternative hypotheses;
- get views on objective functions and error rates
- understand developer constraints on modeling
- identify other objectives.

Step 2: Compare field data to models. The next step is to compare data from the field to the conceptual models. Do the models do a better job than the null hypothesis? Can data be used to fix the parameters of the models? If so, adopt the best values to compute next year's kill rates.

Step 3: Collect data and iterate. As with the mid-continental mallard harvest example, the third step is to collect the next year's data and iterate.

Step 4: Close the loop. The final step in the sequence is to close the loop. Are there any conceptual models or parameter sets that work better than others at predicting kill rates? If so, the NWCC would recommend using them in future siting analyses. You might end up with a combined (weighted) model for use at future sites.

Having such a model could have a positive impact on wind development.

References

See slides for extensive set of references included with this presentation.

Questions and Responses following Telecast

***Question*:** Do you see AM as helpful for habitat impacts as well as for bird kills?

***Response* [*J. Beyea*]:** Yes, absolutely – as long as you put probabilities on your model.

***Comment* [*A. Linehan*]:** There is a lot that is really positive in this presentation: post-construction monitoring does need to be done regularly and for a period of years. For developers, however, this can be very expensive ($40-300,000 / year)…

***Response* [*J. Beyea*]:** Yes, but if unexpected problems come up at a site, that's where having a fund, a joint insurance pool that all developers contribute to would be useful. Such a pool would minimize impact on individual developers while making sure that AM gets done.

***Comment* [*M. Fry*]:** I like the idea of an insurance pool, with matching funds from federal agencies.

***Response* [*J. Beyea*]:** Yes, and foundation support as well, particularly in the global warming context.

***Question*:** How important to the process is the assigning of probabilities – and whether there is agreement on those probabilities?

***Response* [*J. Beyea*]:** You don't have to assign probabilities, particularly if you have managers who have the freedom to make decisions on their own. The Bayesian approach comes in when there are bitter battles and you want to avoid gridlock. [Note added after the presentation: Agreement on assigning probabilities is not necessary. Probabilities, except for the first year, are assigned mathematically based on the results of monitoring. The first-year probabilities would be assigned by the convening party or by a regulatory agency.]

***Question* [*C. Braun*]:** Mitigation is a major issue – how to fund the huge costs?

***Response* [*J. Beyea*]:** We're not always sure that mitigation will work, we may have to test mitigation options. We don't have easy answers.

***Question* [*L. Spiegel*]:** Are there any examples where the case control methodology was applied and it worked?

***Response* [*J. Beyea*]:** Case control methodology is used *all the time* in human epidemiology – it is the standard approach for dealing with rare diseases. The same methodology is applicable for species with low numbers of collisions

Question: Help us define a "case." Are we talking about a low mortality project or a project experiencing high mortality, or what?

***Response* [*J. Beyea*]:** I was thinking of a single species at a single site, but you could do it across sites. I was thinking of huge area like Altamont; there are certain factors you can try to assign as causal agents, but you don't have to measure them at every turbine, only where there's a kill rate… I would need to work more on this to make it clearer.

***Facilitator*:** We will raise this with the Wildlife Workgroup – whether NWCC wants to do an AM pilot, as with Grassland Shrub-Steppe Species pilot.

SESSION VII: IDENTIFYING AND ADDRESSING CRITICAL RESEARCH PRIORITIES RELATED TO WIND PROJECT DECISION-MAKING

Participants broke into small groups to consider, in light of all known research, the draft list of research priorities developed by the NWCC Wildlife Workgroup. Facilitator Abby Arnold of RESOLVE then moderated a plenary discussion of comments on the draft list, making it clear that the purpose was NOT to try to reflect every research question that might be addressed, but rather, to try to develop some categories and identify some of the ideas that we could address in the short term. The Wildlife Work Group Core Group met following the conference to discuss participant comments and revise the draft list of research priorities. (See Appendix C.)

Reporting out of groups

Comments are summarized by topic rather than by group.

Overarching Issues

- In general, the research needs are well-covered in the draft research priorities list, but there are serious organizational problems with the draft. There are a lot of overlapping issues, with no clear differentiation between birds and bats. The need to address the direct impact of fatalities is hard to pick out.
- It is important to focus on research that will lead to better siting decisions. The draft list includes many interesting research questions, but if we want to make a dent in climate change, we need to look at good wind sites near the grid with good transmission system, and then ask how does the way birds utilize that airspace bear on developing those sites?
- We need to reconsider whether and when studies should be required to meet permitting conditions. Sometimes permit applicants are being required to do studies when they could use data from other studies and put research dollars into something else. What are appropriate levels of pre- and post-construction studies, and who should be responsible for funding and carrying out those studies?
- Permit applicants are not given clear guidance from the agencies as to what research they will need to do. Criteria are inconsistent, making it hard to compare data and do meta-analyses.

Mitigation

- We do not know very much about mitigation techniques because, either for operating wind projects or for new/proposed projects.
- We need to figure out whether it is economically feasible to set up experiments to test feathering.
- Use Bayesian approach to look at probabilistic questions.
- The current list does not include any conservation priorities (e.g., for offsite preservation).

- Deterrent methods bear further research: we may not need to worry about how many bats if we can deter them. On the other hand, we also have to look at the broader impacts – the research question is not just "does a deterrent work in a specific place?" but "how does that impact other parts of the site or larger area?"
- There hasn't been enough experimentation. Almost everything on the draft research priorites list – lack of opportunity or unwillingness to do experiments on any of the mitigation features, whether turbine operation or habitat mitigation.

Modeling & Data Issues

- The predictive models we have now are not very well developed, not very powerful – and because we don't have well-developed models, we don't necessarily gather the right data (a chicken-and-egg problem).
- In the case of bats, we need to know whether or not bats are being attracted to wind turbines. Pre-construction surveys suggest very few bats, but then we have fatalities.
- Bird researchers advise the bat researchers: try to use less data-intensive methods.
- We should be analyzing NEXRAD data past and present and correlating it with marine radar data.
- We need to integrate monitoring techniques, e.g., acoustical with infrared, perhaps radar as well.
- GIS and ecosystem impact modeling should be added to Section A [of the draft].
- Archiving of data. How long is it important for companies to hold pre-construction data proprietary? In Canada, once construction is started, pre-construction data (not just analysis, but the raw data) are requested and archived for purpose of comparisons, meta-analyses, etc.
- There should be more emphasis on cumulative impact analysis; models needed to estimate cumulative impact (focused on species-specific level).

Types of Impacts (habitat and population)

- Besides potential impacts, factors like aversion and avoidance in areas like grasslands should be included in Section B.
- Historically, wind project have not focused on habitat impacts. These are more important than some of the less applied topics on the list.
- Understanding habitat impacts means looking not just at wind turbines but all along the transmission corridors – e.g., nesting sites at substations, transmission lines, etc.
- Yes, but it is not just a matter of measuring habitat impacts, it's a question of translating local habitat displacement to regional population abundance changes – in other words, how important are the habitat displacement impacts?
- Likewise with fatalities: fatality counts don't tell us much unless we can get population context – what do these fatalities represent?
- There was general agreement that understanding population impacts should be a "high" (rather than "medium-high") priority, and that DNA studies may be valuable in this regard.

Putting Wind Energy Impacts in Context

The Facilitator raised the larger question of energy policy: the NWCC Steering Committee has asked RESOLVE staff to look into alternative energy, and will have an issue brief. Should the Wildlife Workgroup be working on this topic?

- We should wait for a NYSERDA report (should be out next fall) looking at cradle-grave impacts of wind v. other energy resources.
  - Will NYSERDA report just deal with NY or nationally?
  - It will be looking at energy use of NY as a whole, but some of that is regional.
  - The National Academy of Sciences will have something out in December. USFWS feels it's nice to know about this but off the topic.

- As Terry Root told us, this [climate change] is the elephant in the room. My sense is that we need to pay some significant attention to it one way or another.
  - We have to pay attention to global climate change issues, but this group may not be equipped to deal with it. Our focus should be on direct mortality and habitat impacts.
  - Agreed. There's going to be wind energy, so we should continue focusing on doing it right.

- There should be a mitigation toolbox for coal and oil and other fossil fuel industries – and they can use wind as a mitigation tool!

- The Workgroup doesn't have to research the alternative impacts of various energy resources. Given the urgency of the issue, we have to make tough choices about the speed of permitting v. the risks. How does that impact the way you make choices about what key issues are, what are the research priorities?

- We need to provide impacts on wildlife to compare with impacts from other energy resources.

APPENDIX A
FINAL MEETING AGENDA

Monday. November 13, 2006

6:30 – 7:30 pm **Pre-registration**

Tuesday, November 14, 2006

7:30 am **Registration & Continental Breakfast** *Location: Salon De Gala*

8:00 **I. Welcome and Introductions**
Abby Arnold, RESOLVE
- Review meeting purpose
- Review & adopt agenda and groundrules

8:15 **II. Interaction of Wind Power Facilities and Birds**

A. Overview of What We Know About Avian/Wind Interaction

#1 Summary of study results up to November '04
Dale Strickland, Western EcoSystems Technology, Inc. (in collaboration with Doug Johnson, US Geological Survey)

8:45 **B. What New Studies Have Been Completed on Birds and What Do These New Studies Tell Us**
What New Insights Have We Gained Since November '04?

i. Pre-construction
Session Moderator: Michael Green, US Fish & Wildlife Service

New techniques and study results (since Nov '04)

#2
- **How to See the Invisible: Remote Techniques for Study of Offshore Bird Migration**

  Dr. Ommo Hüppop, Institute of Avian Research "Vogelwarte Helgoland"

#3
- **Designing Nocturnal Bird Migration Studies for Proposed Wind Energy Developments**

  Todd Mabee, ABR Inc. Environmental Research and Services

- **Radar & Thermal Imaging Techniques for Assessing the**

#4 **Environmental Risks of Wind**

Sidney Gauthreaux, Clemson University

#5
- **Toward Prediction of Bird-Rotor Collision Mortality**

  Robert McFarlane, McFarlane & Associates

10:20 **Break**

10:40 **ii. Post-construction**

Estimates of fatalities and injuries from study results (since Nov '04)

#6
- **The Genetic Consequences of Wind Power Development on Greater Prairie Chicken Leks of Eastern Kansas**

  Andrew Gregory, Kansas State University

11:05 **iii. Based on Research Results, Questions to Address**
Session Moderator: Kathy Boydston, Texas Parks and Wildlife Department

#7
- **Effects of Wind Power Development on Sage-grouse**

  Michael Schroeder, Washington Department of Fish and Wildlife & Clait Braun, Grouse, Inc.

#8
- **Impacts of Wind Power Development on Mountain Plovers at Foote Creek Rim**

  David Young, Western EcoSystems Technology, Inc.

#9
- **What Have Marine Radar Surveys Taught Us About Wildlife Risk Assessment**

  David Young, Western EcoSystems Technology, Inc.

12:05 **Lunch** *Location: Aztec Room*

12:50 **iii. Based on Research Results, Questions to Address *(continued)***

#10
- **Assessing Bird Movement Patterns on Cape May Peninsula Using Marine Radar**

  David Mizrahi & Robert Fogg New Jersey Audubon Society

#11
- **Effects of Modern Wind Turbines on Birds: Results of Field Studies on Collision Victims & Nocturnal Flight Patterns in the Netherlands**

  Karen Krijgsveld, Bureau Waardenburg

1:40 **C. Respondent Panel:**
What New Insights Have We Learned About Avian / Wind Interaction?
Facilitator: Abby Arnold, RESOLVE
Respondents and open discussion from the floor.

(1) Panelists:
Andy Linehan, PPM Energy
Rob Manes, The Nature Conservancy, Kansas (invited)
Al Manville, US Fish & Wildlife Service
Linda Spiegel, California Energy Commission
Dale Strickland, Western EcoSystems Technology, Inc.

2:30 **Break**

2:45 **III. Interaction of Wind Power Facilities and Bats**

A. Overview of What We Know About Bat/Wind Interaction
#12 Summary of study results up to November '04
Paul Cryan, US Geological Survey

3:15 **B. What New Studies Have Been Completed on Bats and What Do These New Studies Tell Us**
What New Insights Have We Gained Since November '04?

i. Pre-construction
Session Moderator: Al Hicks, New York State Department of Environmental Conservation

New techniques and study results (since Nov '04)

#13
- **Pre- & Post-Construction Surveys for Predicting Bat Fatality at Wind Facilities**

  Ed Arnett, Bat Conservation International

#14
- **Daily & Seasonal Patterns of Bat Activity Along Central Appalachian Ridges**

  Keith Lott, University of Maryland Center of Environmental Science

4:10 **ii. Post-construction**

Estimates of fatalities and injuries from study results (since Nov '04)

#15
- **Bat Fatalities in Southern Alberta**
  Erin Baerwald, University of Calgary

4:35 **Break**

4:45 **iii. Based on Research Results, Questions to Address**
Session Moderator: Ed Arnett, Bat Conservation International

#16
- **Developing A Mitigation Strategy for Bat Impacts from Wind Power Development in Maryland**
  John Sherwell, Maryland Department of Natural Resources

#17
- **Migratory Behavior of Female Indiana Bats in New York & the Implications for Wind Development**
  Al Hicks, New York State Department of Environmental Conservation

#18
- **Bat Migratory Behaviors & Routes in Pennsylvania & Maryland**
  Greg Turner, Pennsylvania Game Commission

#19
- **Evaluation of Acoustic Deterrents to Reduce Bat Fatality at Wind Facilities**
  Joseph Szewczak, Humboldt State University

#20
- **Bat Likelihood Assessment Protocol for Collision Mortality at Potential Wind Farms**
  Crissy Sutter, Pandion Systems

6:30 **Adjourn to Reception / Poster Session** *Location: Lobby / Foyer*

Wednesday, November 15, 2006

7:30 **Continental Breakfast**
Location: TBD

8:00 **C. Respondent Panel:**
What New Insights Have We Learned About Bat / Wind Interaction?
Facilitator: Abby Arnold, RESOLVE
Respondents and open discussion from the floor.

(2)

Panelists:
Paul Cryan, US Geological Survey
Bronwyn Hogan, California Department of Fish & Wildlife
Tom Kunz, Boston University
Jim Lindsay, FPL Energy

8:45 *(incl. break)* **IV. Applicable Methods and Study Designs Specialized for Birds, Bats, and Common to Both**

- **Development of a Cost-Effective System to Monitor Wind Turbines**

#21 **for Bird & Bat Collisions Phase I: Sensor System Feasibility Study**

Jon Belak, EDM International, Inc.

#22

- **Objectives, Uncertainties, & Biases in Mortality Studies at Wind Facilities**

#23 *Wallace Erickson, Western EcoSystems Technology, Inc.*

- **Pre-Construction Acoustic Surveys for Predicting Bat Fatality at Wind Farms: An Evaluation of Survey Protocols**

#24 *Manuela Huso, Oregon State University*

- **Migration at Low Height Over the Mountainous Areas of Vermont**

  Ronald Larkin, Illinois Natural History Survey

10:20 **V. <u>Mitigation of Wind Energy Impacts</u>**

Presentation of mitigation toolbox prepared by the NWCC Mitigation Toolbox Subgroup. *Lynn Sharp, Tetra Tech EC*

Respondent panel to follow, covering one or more of the following:

- Mitigation processes
- Identification of mitigation measures
- Implementation of mitigation measures
- Measuring effectiveness of mitigation measures
- **(3)** Approaches to focus mitigation development
- Translating study results into project siting decisions in various parts of the country and/or at specific sites (e.g. siting of wind farms in native prairie of the plains)

<u>Panelists</u>:
Michael Fry, American Bird Conservancy
Alex Hoar, U.S. Fish and Wildlife Service
Greg Hueckel, Washington Department of Fish and Wildlife
Kevin Rackstraw or Stu Webster, Clipper Windpower
Lynn Sharp, Tetra Tech EC

11:20 **Pick Up Box Lunches**

11:35 **<u>Lunch Address:</u>** *Location: Salon De Gala*

#25

Documenting the Effects of Wind Turbines on Bat Populations Using Genetic Data
Nancy Simmons, American Museum of Natural History

12:20 **VI. <u>Risk Assessment, Management & Wind Power in the U.S.</u>**
Abby Arnold, RESOLVE

#26
- **Evaluate the priorities of the Risk Assessment Subgroup white paper & add exposure / consequences to the ecological risk assessment**
  Rebecca Efroymson, Oak Ridge National Laboratory

#27
- **Relative risks to the ecology from different energy sources**
  Dr. Terry Root, Center for Environmental Science and Policy, Stanford University

#28
- **Context of relative risk & next step ideas for the NWCC**
  Bonnie Ram, Energetics

1:30 **Break**

1:45 **VII. <u>Adaptive Resource Management Telecast</u>**
#29 *Jan Beyea, Consulting in the Public Interest*

2:30 **VIII. <u>Considering All Known Research, Identifying and Addressing Critical Research Priorities Related to Wind Project Decision-making</u>**
(Wildlife Workgroup present a list of research priorities for review and
(4) *comment from participants)*

- What are the critical scientific needs?

4:10 **Wrap-up**

4:30 **Adjourn WL Research Meeting VI**

NWCC Wildlife Workgroup Core Group Will Meet on November 16, 2006

APPENDIX B
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