This Briefing Paper highlights current research and recent publications by the USGS and its partners that directly supports management of wildlife and wildlife habitat in the context of wind-energy projects.

Goals
The U.S. Geological Survey (USGS) conducts research to address wildlife concerns associated with wind energy of various Department of Interior (DOI) Bureaus, such as the Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service (FWS). The USGS wind energy and wildlife research goals focus on five main objectives.

1. Conducting pre- and post-wind energy facility construction to determine direct and indirect effects to wildlife, habitat, and the ecosystem
2. Identifying and describing known and potential wildlife, habitat, and ecosystem effects
3. Support of management efforts to improve how facilities are located, built, and operated
4. Support of monitoring and analysis to understand the effectiveness of management actions
5. Identifying and describing known and potential mitigation options and determine effectiveness

Research Focus
The wind energy and wildlife research conducted by the USGS can be categorized into four main focus areas:

- **Fatality and Injury** – Research in this area assists with siting decisions and understanding, measuring, and minimizing impacts to affected wildlife. Estimates of mortality and understanding the sources of mortality supports the permitting process
- **Habitat Modification and Loss** – Research in this area furthers our understanding of how development indirectly affects wildlife by modifying or causing loss of habitat or reduction in prey availability
- **Mitigation Options and Effectiveness** – Research in this area furthers our understanding of current and future options for mitigating the effects of wind energy resources on wildlife and develops innovative methods to reduce or offset negative interactions between wind energy and natural resources
- **Monitoring and Analysis** – Research in this area develops better tools for population monitoring through improvements in monitoring protocols, innovative software and mapping tools which increases cost efficiency
# Wind Energy & Wildlife

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Paul Cryan, USGS
**Acoustic and Ultrasonic Recorders Track Flight Activity**

The USGS and collaborators used acoustic and ultrasonic recorders to monitor flight notes of birds and bat calls at low elevations. Recorders were deployed in conjunction with ongoing fatality searches at wind facilities and at sites with a variety of landscape features. Objectives were to determine whether the recorders can be used to compare low-elevation flight activity among sites, and to relate recorder results to numbers of dead birds and bats found at wind facilities. The FWS partnered to deploy the recorders at numerous locations along the shores of several Great Lakes to estimate low-elevation flight activity of birds and bats, especially during migration periods, at sites where wind development appears likely.

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**Desert Tortoises and Wind Energy**

The USGS has studied the ecology of a population of federally protected Agassiz's desert tortoises that have co-occurred with a wind facility since 1995 on land managed by the BLM near Palm Springs, California. Almost 130 tortoises were marked between 1997-2000, providing an opportunity to examine growth, demography, habitat selection, and survivorship of this long-lived species. Continued research focuses on effects of turbine noise and vibration on tortoise behavior and activity, and the effects of turbine-induced fire on the ecology and behavior of tortoises.

**Contact:**
Jeff Lovich; USGS Southwest Biological Science Center; jeffrey_lovich@usgs.gov; (928) 556-7358

**Publications:**

*Nest guarding by female Agassiz’s desert tortoise (Gopherus agassizii) at a wind-energy facility near Palm Springs, California: The Southwestern Naturalist (2013).* http://bit.ly/1AVia5M


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**Detecting and Understanding Bat Fatalities**

Utility-scale wind turbines have the potential to detrimentally affect bat populations, but few well-developed and integrated methods exist for observing bat occurrence and behavior at turbines at multiple spatial and temporal scales. A study was conducted on north O‘ahu, Hawai‘i to simultaneously monitor bats at four turbines with thermal and near-infrared cameras and nacelle-mounted acoustic detectors to measure Hawaiian hoary bat activity. Researchers are determining if any correlation exists between hoary bat activity, fatalities recorded from daily ground searches, and weather conditions and turbine operation. Bat acoustics at over 20 locations in the leeward north Koʻolau Mountains were also monitored to assess seasonal occupancy at the landscape level. Results are being compared to observations of bat-turbine interactions at a wind facility in Indiana.

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Drones to Detect Golden Eagle Carcasses
USGS, in collaboration with Oregon State University and the Confederated Tribes of Warm Springs, is launching a new study to investigate the use of unmanned aircraft systems, or drones, in detecting golden eagle carcasses at wind power facilities. They will use change-detection software to compare ground images across flights to detect the arrival of a carcass, and will evaluate the whether detection is affected by vegetation or carcass size.

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Golden Eagle Take at Wind Facilities
The USGS, working with the FWS, has developed a predictive model of golden eagle “take” at a given wind facility. The model is based on pre-construction eagle-use surveys and design considerations. The FWS uses this modeling effort to work with facility applicants at the design and permitting stages. This model serves as the basis for the amount of compensatory mitigation that might be needed. Researchers also are helping develop eagle population models at the regional level to evaluate the effect of cumulative take on population dynamics. Both efforts explicitly acknowledge uncertainty, and by doing so, permit risk analysis and the implementation of adaptive management.

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Golden Eagles around the AWRA
The Altamont Pass Wind Resource Area (AWRA) in California is estimated to have killed at least 1,000 golden eagles since becoming fully operational in 1987. This study aims to determine whether the population of golden eagles surrounding AWRA has the demographic resiliency to absorb estimated levels of fatality from wind turbines over time. In collaboration with FWS, scientists from USGS and their partners are using historical and current data collected on golden eagles in the AWRA vicinity to assess territory occupancy, nesting success, ranging behavior and habitat use, and estimates of survival and reproduction. This information is being used to develop a demographic model that can help predict how the local population of golden eagles might respond to different levels of wind-turbine related fatalities. Additionally, results from this study will provide an estimate of the number of breeding pairs of golden eagles required to sustain fatalities associated with wind turbines in the Altamont.

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Relationship of Bat Calls, Flight, and Fatality
Monitoring bat activity at wind turbines currently involves placing acoustic detectors, usually outside of the rotor-swept zone. Perhaps as a result of this spatial mismatch between the sampling location and the actual turbine sweep, models of the relationship between activity and fatality have been tenuous. The USGS and Bat Conservation International are collecting information about nightly bat activity measured by acoustic monitors located on turbine nacelles in the center of the rotor-swept zone. They are combining this information with measurements of bat activity using near-infrared cameras centered on the nacelle, and with estimates of bat fatality. If a direct, predictive relationship can be shown between fatality and activity, it may be useful in making pre-construction siting decisions and could suggest adaptive management techniques to reduce fatality following construction.

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Fatality and Injury

Renewable Energy Development and Nevada Sage-Grouse

Much of Nevada is targeted for proposed energy transmission corridors linking Wyoming, eastern Nevada, and the Mojave Desert. Potential paths for the corridor will dissect prime, contiguous sagebrush-steppe habitat. The USGS, in collaboration with other federal and state agencies and private industry, is conducting greater sage-grouse research to understand the implication of wind energy development and the associated powerline corridors in Nevada. The goal is to answer questions related to impacts of developing energy on sage-grouse habitat selection, population vital rates, and movement patterns. This research provides resource managers with information and tools to help develop guidelines for future renewable energy projects to minimize negative effects on greater sage-grouse populations.

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Publications:

Understanding and Reducing Bat Fatalities

Migratory bat species that roost in trees (“tree bats”) are disproportionately affected by wind turbines, in part because they appear to be attracted to these structures. The USGS is continuing work with multiple research partners to discover the underlying causes of bat fatalities at wind turbines and to devise practical new solutions to the problem. USGS research previously focused on analyzing bat migration, uncovering behaviors of bats at turbines, and developing new techniques for observing and quantifying the phenomenon. Working from this foundation, current USGS research aims to apply our new understanding of bat behaviors and perception toward efficient and effective ways of reducing the chances they will approach and interact with wind turbines.

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Using Radar Technology to Investigate Flight Paths of Bats in Wind Facilities

As part of ongoing, collaborative work to examine threats posed by wind turbines to bats during seasonal migration, scientists have collected radar data on the flight paths of thousands of bats and birds moving through a wind facility in central Indiana. The USGS researchers focused on using portable radar to determine how bats and birds respond to wind turbines - primarily attraction and avoidance - while in flight. This response is central to understanding why bat fatality at wind facilities exceeds that of birds, despite far greater numbers of birds than bats in the airspace during migration. Numerous “attraction hypotheses” have been proposed to explain the disproportionate bat fatality, yet little research has focused on if and how bats respond to wind turbines during flight. Advances in remote sensing techniques (e.g., radar, thermal imaging) continue in support of this and other research related to flying animals.

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Fatality and Injury

Wind Energy Effects on Grassland Birds
The USGS has completed a 10-year field investigation to detect and measure any avoidance of wind facilities by breeding grassland birds. This study was prompted by strong interest by the FWS, especially concerning the compatibility of wind development and the FWS’s Grassland Easement Program. This long-term study will also address questions related to habituation and delayed responses.

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Wind Energy Effects on Indiana and Little Brown Bats
The USGS is developing a quantitative framework for understanding effects of wind energy development on migratory bats by developing migratory connectivity models for the Indiana bat (listed under the Endangered Species Act) and the little brown bat. A theoretical framework provides insight into the effects of wind energy on migratory patterns and spatial dynamics of bats. Future work will focus on parameterizing and applying this model to bat populations using FWS data. The model will also consider synergistic effects of white-nose syndrome and will be expandable to assess effects of climate change and other stressors on migratory bats and other species. Long-term plans include researching which model features and attributes are necessary to assess the effects of wind energy on a suite of wildlife species.

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Habitat Modification and Loss

California Condor Movement Behavior and Habitat Use
The USGS and the San Diego Zoo’s Institute for Conservation Research are collaborating on a project to model the three-dimensional home range of eagles using GPS telemetry data from tracked eagles. The primary goal is to study the movement behavior and habitat use of California condors released by the Institute in Baja, Mexico. This three-dimensional information can be used to improve the precision of space-use models of the California condor, improve assessments of condor space-use and the potential intersection with three-dimensional objects, such as buildings, and help evaluate risks from encounters with wind facilities.

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Publications:

Animal Space Use in 2D and 3D website, http://on.doi.gov/1qT0ViY

California Condor Space-Use and Wind Resources
The USGS is evaluating how wind resources in California affect patterns of condors use and movement through various habitats. Analyses and modeling are addressing variation in condor home range, habitat selection, and relationships between condor occurrence and atmospheric properties, particularly thermal and wind, throughout the annual cycle. Researchers found that condor resource selection varied relative to habitat type: dune and rock habitats along coastal areas were preferred, whereas shrubland and evergreen forest habitats were used significantly less. Differential use of habitats was often linked to proximity of release site; however, meteorological conditions, such as thermal height, thermal velocity, and wind speed, were linked to condor use of ecological sub-regions. Habitat and meteorological conditions may interact in complex ways to influence condor resource selection across the landscape.

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Publications:
Resource selection in California Condors (Gymnogyps californianus) relative to terrestrial-based habitats and meteorological conditions: PLOSONE (2014), http://bit.ly/1vZsIrH

A quantitative analysis of monthly home range size across the annual cycle in the critically endangered California Condor: Bird Conservation (In press)

Condor Flight Response to Topography and Weather
The California condor, in spite of remarkable population recovery since the 1980s, still faces a number of threats. Wind turbines pose an emerging threat with great potential to impact condors. Wind energy is among the fastest growing energy sectors in California, especially within the condor’s range. In light of the rapid growth in both condor populations and wind turbines, there is an urgent need to understand how condor flight behavior may expose them to risk from wind energy. The USGS, in collaboration with other federal and state agencies, is conducting research to understand how condor flight behavior, especially altitude above ground level, responds to variation in topography and weather conditions. The information collected will be used to generate a risk map that can assist in turbine siting and decision making.

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Habitat Modification and Loss

Does Turbine Noise Impact Diving Birds?
Construction and maintenance of wind turbines can increase in-air and underwater noise levels from pile driving, shipping of materials, turbine operation, and other activities. Introduction of new noises can mask communication, displace animals, disrupt predator-prey interactions, and cause hearing loss. In-air and underwater auditory thresholds were measured in diving bird species, using behavioral and eletrophysiological techniques. These investigations revealed that diving bird species have very sensitive hearing in the air, comparable to other bird species. Underwater auditory thresholds were measured for the first time in any bird species, and showed that long-tailed ducks have sensitive underwater hearing. These first measurements highlight the need to further understand underwater hearing mechanisms and how man-made noise sources may impact these species.

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Food Habits of Bats
The USGS is studying the diet of insectivorous bats through analyses of guano and gut contents, in part to understand the causes of bat fatality at wind facilities. These analyses help reveal the types of insects consumed, including any economically damaging pests, the habitats where these insects occur and where bats are feeding, and timing and seasonality of prey occurrence related to changes in climate. By understanding ecological relationships between insectivorous bats and their prey, it is possible to better manage areas where change might have the most effect on bats. Findings showed that most bats carcasses retrieved from wind facilities had full stomachs, indicating that they fed within minutes prior to collision with wind turbines. Hoary bats fed mostly on moths but also consumed beetles, true bugs, and crickets.

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Publications:

Geographic Context in Wind-Energy Land Transformation
Land transformation, measured as hectares of surface disturbance per megawatt, associated with wind facilities shows wide variation in its reported values. The USGS digitized land transformation at 39 wind facilities using high-resolution aerial imagery. Scientists now are studying how turbine size, configuration, land cover, and topography affect the levels of total land transformation, changes to road networks, and changes to levels of habitat fragmentation. The results indicate the geographic context in which facilities are installed affects the levels of land transformation associated with wind energy, for example flat topographies had the lowest land transformation, while facilities on mesas had the largest. This creates opportunities for wind energy production that minimizes land-cover change through effective siting. The next phase will look at the role of geographic context on how road networks change and how this impacts habitat fragmentation around new facilities.

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Golden Eagle Conservation in San Diego County
In California’s San Diego County, rapid expansion of business and housing has substantially altered the number and distribution of nesting golden eagles, and might affect habitat resources required to support immature eagles and the survival of adults that cannot find suitable foraging and nesting areas. Furthermore, eagles using San Diego County likely may range into the adjacent Desert Renewable Energy Conservation Plan area and become affected by development there. The USGS is working with San Diego County to provide resource managers with information on factors affecting territory occupancy, use of foraging habitats, and genetic structure of golden eagles so that potential threats can be identified and managed accordingly.

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Jeff Tracey; USGS Western Ecological Research Center; jtracey@usgs.gov; (619) 225-6422
**Golden Eagle Late-Summer Occupancy**
The USGS is developing golden eagle habitat-occupancy models and maps to overlay with maps of potential energy development, including wind energy. Models and maps will highlight biological strengths and weaknesses (high- and low-quality habitat) across the landscape. Map overlays explicitly delineate opportunities for conservation (high-quality habitat, low energy potential), and imminent threats (high-quality habitat, high energy potential). These tools can guide resource managers in their efforts with industry concerning siting for energy development and the identification of areas for off-site mitigation.

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**Golden Eagles in California and the Central Appalachian Mountains**
Development of wind energy resources has the potential to impact golden eagles at all stages of their life history. There is a known history of golden eagle conflict with wind energy plants, primarily through direct mortality from collisions. USGS is collecting information related to habitat use, home range, and population dynamics in the central Appalachian mountain region, northeastern California, and the Mojave and Sonoran Deserts using various methodologies including: GPS-GSM telemetry, standard GIS analyses, nest visits, and non-invasive genetic monitoring. The data collected will be used to create risk models to assist resource management agencies in evaluating management options for this species. Data will be combined with other similar projects’ datasets to create a framework and baseline to build an effective long-term golden eagle monitoring program to support adaptive management.

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**Golden Eagles in New Mexico**
The BLM manages large areas in New Mexico that have a high potential for wind energy development. The USGS is conducting research to assess the risk that proposed wind energy developments in southeastern and south-central New Mexico may have on resident and migratory golden eagles. The study will assess habitat and space-use of migratory and resident golden eagles; identify nest sites, estimate productivity and survival, origin, and migration patterns; and determine the drivers for golden eagle distribution in southeastern and south-central New Mexico. The results of the study may be used to inform the development of mitigation strategies that will reduce potential negative effects from proposed wind energy developments.

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Habitat Modification and Loss

Habitat Occupancy and Population Trends of Bats
The USGS developed an innovative statistical approach to monitor trends in bat activity and occurrence in comparative studies of habitat use. The approach has been successfully applied by the USGS at large (island-wide) scales to the echolocation calls from species with very different life histories. These include the endangered Hawaiian hoary bat, a relatively uncommon but widely distributed and solitary tree-roosting generalist, and the Pacific sheath-tailed bat, a colonial cave-roosting species with restricted habitat requirements and an extremely limited distribution. The metrics generated by this analytical approach may provide a quantitative baseline for status assessments following regional changes in habitat due to management activities, such as wind-energy development, or other factors, such as disease.

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Publications:

Habitat Prioritization for Wyoming Raptors
The goal of this project is to develop predictive models of the relationship between available raptor (golden eagle, ferruginous hawk, northern harrier, and prairie falcon) habitat and habitat use in Wyoming. This project has created models and maps that identify priority habitat areas, which will assist resource managers in effective raptor conservation by helping guide siting of wind power infrastructure and informing prioritization of locations for strategic and focused conservation efforts.

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Integrated Assessment for Southwest Wyoming
The USGS is providing an integrated assessment of the effects of energy development on Wyoming Landscape Conservation Initiative focal ecosystems to inform planning and decision-making in southwest Wyoming. The project evaluates the natural, economic, and social context for energy development and other land uses, and focuses on informing conservation actions and decisions. Specifically, the assessment will identify areas with high conservation and restoration potential, and with high development potential on the current landscape. This assessment includes conventional and renewable energy resources, with special attention to wind energy.

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Habitat Modification and Loss

Mapping Wyoming, Colorado, and New Mexico Wind Turbines

The USGS has created a database for wind turbine information which includes locations of wind turbines as of 2009, with an update underway to include data for 2010. Each documented wind turbine is assigned to a wind facility, with associated information, including potential megawatt output, rotor diameter, hub height, rotor height, land ownership, county, wind-farm power capacity, the number of units currently associated with each wind farm, wind turbine manufacturer and model, wind farm developer, wind farm owner, current purchaser of power, year the wind farm went online, and status of operation. The locations are derived from true-color aerial photographs and have positional accuracy of approximately five meters.

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Publications:

Modeling Squirrel Habitat in the Mojave Desert

Mohave ground squirrels are small, ground-dwelling rodents that have a highly restricted range in the northwest Mojave Desert, California. Wind and solar resources for renewable energy have the potential to reduce existing habitat further. USGS built a potential-habitat model to assess whether proposed energy development areas overlap with potential habitat. They also used maximum-entropy habitat models to estimate current potential habitat in the context of proposed energy development in the region. While 16 percent of the species’ historic habitat has been lost to urbanization already, an additional 10 percent may be affected by renewable energy development. Additionally, models show that habitat suitability is higher in areas slated for renewable-energy development than those in surrounding areas. Maps could be used to help resource managers develop sampling designs, evaluate conservation corridors, and inform development planning. Additional models are being created to forecast habitat shifts under climate change and energy development.

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Publications:

Wildlife Genetics to Reduce Impacts

Population genetics is an informative way to assess habitat importance because genetic diversity within animal species provides the raw material for adaptation and evolution. When a geographic region shows spatial overlap in high genetic diversity and divergence for many species, it can be considered an “evolutionary hotspot.” USGS has identified 10 such hotspots in the Mojave Desert, and have assessed whether they overlapped with proposed renewable energy developments. Researchers mapped the population genetic structure for 17 animal species across the Mojave Desert, including four species that are listed or of special concern. Results showed a 17 percent overlap of hotspots with planned renewable energy project footprints, when transmission corridors are included. Resulting maps can be incorporated into management and planning efforts and can identify specific regions where further studies may be needed to discern and rank the potential effects of development to animal populations and connectivity.

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Publications:
**Habitat Modification and Loss**

**Wind and Wildlife Interactions in Airspace**
Knowledge of airspace use is fundamental for assessing risks of wind energy development to wildlife. Specifically, a wind farm located where few animals fly is likely to result in few, if any, fatalities; whereas, a wind farm located where flight activity is intensive may pose severe risks to those animals. Knowing where flight intensity is high, and where wind development has occurred or is likely to occur, could greatly facilitate risk assessment. A USGS study will evaluate the potential for development and use of tools to determine the intensity of low-elevation flight of birds, bats, and other flying animals. Information derived from use of such tools could be used in combination with knowledge of wind resources and likely wind development sites to facilitate the assessment of wind development effects on wildlife.

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**Wind Energy and Lesser Prairie-Chickens**
The USGS is investigating using habitat-suitability modeling with maximum-entropy modeling to develop maps that could be used in the siting of energy development. For a case study, scientists chose the lesser prairie-chicken, which occurs on the southern Great Plains of North America. Populations of this species have been declining and are potentially susceptible to harm from energy development. Scientists used lek locations in Kansas, along with several environmental and anthropogenic parameters, to successfully characterize the probability of lek occurrence across the landscape. The models with anthropogenic parameters performed slightly better than those without, an indication that anthropogenic features may negatively affect lek habitat suitability for lesser prairie-chickens. This method may help guide the siting of energy development and help standardize and quantify the effects of development on at-risk species.

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**Wind-Energy Disturbance Mapping**
The USGS is quantifying surface disturbance associated with the development and operation of wind facilities for the BLM Wyoming Renewable Energy Office. The study quantifies all infrastructure associated with wind-energy development, surface disturbance, and re-vegetation or reclamation following initial wind-facility development. Results will document the amount and pattern of disturbance over time during the development and operation of facilities in Wyoming. This information will be useful for planning and assessment of future wind projects.

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Mitigation Options and Effectiveness

Curtailment Strategies to Reduce Bat Fatality
Wildlife fatalities due to collisions with wind turbines have sparked efforts to reduce the number of deaths through operational management. Recent studies have shown altering turbine operations when winds are below certain speeds can decrease the number of bat fatalities, but questions remain regarding optimal management. In a new study, USGS and colleagues are modeling the proportion of bat fatalities occurring under varying meteorological conditions at Iberdrola Renewable’s Blue Creek Wind Farm Ohio to identify conditions under which both bat fatalities and energy production loss can be minimized. The scientists will also investigate whether accurate and precise estimates of fatality can be derived from carcass searches conducted only on easily searched areas, such as roads and pads below turbines.

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LEAP (Landscape-scale Energy Action Plan)
The USGS is developing tools to: 1) assess landscape-scale vulnerability to energy development; 2) provide field staff with web-based data and tools for site specific assessments and planning; and 3) deliver web-based information to assist in project-siting proposals that avoid or minimize effects to important resources. The tools and assessments collectively will serve as a Landscape-scale Energy Action Plan (LEAP), which will use the FWS Information, Planning, and Conservation system as the web-based platform. LEAP is a set of spatial and non-spatial products and tools that will help energy projects avoid, minimize, or mitigate effects to natural resources. LEAP will also evaluate various resource management scenarios to determine the best possible project siting alternatives, will provide a centralized repository for spatial data needed to conduct project assessments, and will provide maps of potential resource conflicts and mitigation opportunities.

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Ultrasonic Acoustic Deterrent for Reducing Bat Fatalities at Wind Turbines
The USGS participated in a study that evaluated the effectiveness of devices that emit ultrasonic sound to deter bats from wind turbines. Researchers compared average per-turbine bat-fatality rates at 10 turbines fitted with deterrent devices with rates at 15 other turbines without deterrents. The study occurred at a site in Pennsylvania during summer and fall of 2009 and 2010. The results, published in 2013, indicated that hoary bats had fewer fatalities at turbines with deterrents in both years, and silver-haired bats showed a similar response in 2010, suggesting that ultrasound broadcasts may discourage some bats from approaching sound sources. Researchers noted that variations in turbine and deterrent design and environmental conditions may influence deterrent effectiveness.

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Publications:


Behavior of bats at wind turbines: Proceedings of the National Academy of Sciences of the United States of America (In press)
**Accounting for Fatalities Falling in Unsearched Areas**

An important source of detection bias in current protocols to estimate turbine-caused wildlife fatality is the configuration of the area searched for carcasses beneath wind turbines. Search plots large enough to detect all fatalities are uncommon because they are expensive to search and may not be accessible. USGS is comparing several models of relative carcass density, some of which can provide accurate estimates of the proportion of carcasses falling in unsearched areas. Accounting for this source of detection bias results in accurate estimates of fatality at wind-power facilities will allow comparisons of rates among turbines, sites, and regions. Focusing search effort on areas of high carcass density, where probability of detection is also often highest, could result in accurate and precise estimates of fatality while reducing monitoring costs.

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**Publications:**

**Airspace Use by Migrating Landbirds at Lake Erie**

Interest is growing to develop wind energy capacity along Great Lakes shorelines both onshore and off shore. With this growth, comes the consideration of potential impacts to the large concentrations of landbirds that use the southern Lake Erie shoreline during spring and fall migration. Using two marine radars operated simultaneously at paired sites (shoreline and inland at three or 15 miles), USGS is collecting data to: 1) describe movement patterns of night-migrating landbirds in terms of azimuth, altitude, and intensity; 2) estimate ascent and descent flight profiles for night migrating landbirds in relation to distance from the southwestern Lake Erie shoreline; and 3) estimate intensity of nightly bird movement using radar and relate results to banded birds.

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**Bird Migration in the Central Appalachians**

Concerns about potential effects of wind power development in the Appalachians on migrating birds and bats have resulted in questions about distribution and flight characteristics of migratory species. During five migration seasons, USGS and collaborators studied nocturnal bird migration in the Central Appalachians of Maryland, Virginia, and West Virginia. Calls of migrating birds in flight were recorded to index the birds’ spatial and temporal distribution patterns. Portable radar sampling was conducted concurrently with sound recording to corroborate the patterns observed and to provide information about the altitudinal distribution of migrants. In both spring and fall, nearly 30 percent of birds or bats were within 200 m of the ground, the altitudinal zone sampled by the sound recorders. The flight call data are being used to model the effects of weather, topography, and other variables on migrant abundance to identify where or when migrants are likely to be abundant.

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Eagle Survey, Monitoring, and Distribution

The USGS and FWS are developing comprehensive survey and monitoring plans to quantify the distribution and status of golden eagles at project, regional, and continental scales. They are developing sample designs and field procedures estimating the occupancy of golden eagles at sample areas throughout the western United States and identifying important geographic areas and habitats during the breeding seasons. They also are studying ways to predict where golden eagles are likely to spend the winter season. Results can be used to decide where to focus eagle surveys to delineate areas of high eagle occurrence, and thus, potential for focused management and areas of low eagle occurrence, which are potentially better suited for wind development.

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Energy Development in the Rocky Mountains

The USGS is developing a framework for evaluating the spatially explicit environmental effects of the development of various energy types in the Rocky Mountain area, including wind energy. The framework will allow decision-makers to evaluate the cumulative environmental effects for a particular stage of the energy life cycle and integrate assessments of risks for priority biological and hydrological resources. This approach will provide a common currency for comparison of various energy types to facilitate analysis of trade-offs among energy development alternatives.

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Energy Futures for Wyoming

As part of the Wyoming Landscape Conservation Initiative, the USGS is mapping the locations and extents of potential electricity-generating resources in Wyoming. This work includes mapping resources, such as natural gas, coal, wind, and hydropower, as well as transmission and transportation corridors. Results of this work will be used in the Wyoming Landscape Conservation Initiative and other energy-related studies. More broadly, the work is developing an energy-assessment framework and methods that can be used in other regions.

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**Monitoring and Analysis**

**Estimating Total Population Abundance**
An important component to understanding the effects of wind power development on wildlife is accurate and precise estimates of fatality. The USGS is working with other researchers to refine a statistical method that was developed to estimate fatalities from carcasses found at wind farms. They also will develop new methods to extrapolate results beyond the searched plots. The project will result in new scientific information useful to natural resource management agencies, conservation organizations, and other stakeholders who need accurate and precise scientific information for understanding the effects of wind power development on wildlife.

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**Evidence of Absence or Absence of Evidence?**
The statistical tools for estimating fatality from bird and bat carcasses observed below turbines are fairly robust when fatality levels are high, but often no carcasses are observed for rare and endangered species, rendering these tools ineffective. No carcasses would be observed either if no deaths occurred, or if the probability of detecting a carcass was so low that they were missed during searches. USGS developed a method to estimate the number of carcasses that could have been missed, even when none were found. To make this work accessible to managers, the method has been packaged into a decision support tool that will help resource managers evaluate whether permitted “take” is likely to have been exceeded and to design monitoring protocols that can be optimized for detecting “take.”

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**Publications:**
*Estimating the Abundance of an Animal Population When the Total Observed Count is Zero: Ecological Applications (In press)*

*Evidence of absence software user guide: USGS Data Series 881 (In press)*

**Examination of the Biology of Summer-Roosting Indiana Bats Using Genetic Tools**
Range-wide, populations of Indiana bats have declined by approximately half since listing under the Endangered Species Act in 1967. The decline has been particularly steep in the southern portion of the species’ range where managers lack basic information about Indiana bat populations during summer months. Traditional tracking techniques have not enabled researchers to regularly monitor individual bats throughout a field season. Recent advances in genetic techniques have made it possible to uniquely identify animals using DNA in mark-recapture studies. Preliminary work by the USGS has shown that DNA can be extracted from Indiana bat fecal pellets collected beneath roost trees. It is now possible to explore the relatedness of Indiana bat-colony members using genetic information and to estimate population sizes using DNA. Accurate demographic and relatedness information is essential for the management and recovery of the Indiana bat.

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Monitoring and Analysis

Golden Eagle Monitoring Protocol for the DRECP
The California Desert Renewable Energy Conservation Plan (DRECP) was developed to provide protection of Mojave and Colorado desert ecosystems, while allowing for the appropriate development of renewable energy projects. Effective surveys for golden eagles and monitoring of their status are needed to assess the effects of energy development. The USGS, with support from the California Energy Commission, is leading a new effort to develop survey sample designs and field procedures for protocols to determine the distribution and demography of golden eagles in the DRECP area. The protocol will be designed to provide information required to promote golden eagle conservation and compatible renewable energy development. Information collected will be especially critical in determining whether regulatory requirements and goals of the conservation plan are being met.

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Golden Eagles in the Mojave Desert
The USGS is conducting research to inform energy and land-use planning by providing information to prevent the loss of important foraging and nesting habitat of golden eagles from proposed alternative energy developments within the California DRECP area. The study will determine home ranges and core use areas of golden eagles in the Mojave Desert in Nevada, relate golden eagle habitat use and movement patterns with prey availability, and assess whether size and spatial use of home range vary seasonally or are correlated with habitat quality, specific habitat features, human activities, wind patterns, or other factors. The study will also identify the habitats associated with most critically important golden eagle migration, wintering, and breeding areas in southern Nevada and California.

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Landscape and Airspace Use of Waterbirds
USGS and FWS partnered to collect data on foraging locations (systematic roadside surveys) and flight patterns (using marine radar) of fall refuging sandhill cranes within the Horicon Marsh landscape which includes an 86 turbine wind energy development. A three-dimensional movement model of cranes is being developed based on habitat use probabilities, turbine avoidance probabilities and flight profiles of cranes. The model can be refined with further data collection and validation with other species in select landscapes. The model framework can be used to estimate landscape and airspace use of refuging waterbird species in different areas to evaluate placement options for wind energy projects and transmission lines.

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Main Hawaiian Islands Seabird Tracking
The Main Hawaiian Islands (MHI) and associated offshore islets (i.e., Moku Manu, Lehua, and Molokini) provide substantial breeding habitat for more than 19 seabird species. The Bureau of Ocean Energy Management (BOEM) and the State of Hawai‘i have received proposals to develop offshore renewable energy related projects within waters surrounding the MHI that have the potential to negatively affect seabirds which have been documented to interact with wind-turbine structures, lighted facilities, elevated power lines on land, and lighted ships off Hawai‘i. The USGS, in collaboration with other entities, is conducting at-sea tracking studies of MHI seabirds to provide information to assess potential risks posed by proposed offshore energy developments. Information collected include intra-seasonal and inter-colony differences in foraging behaviors and variability in sea habitat use and ranging behaviors of various MHI seabird species, including those listed under the Endangered Species Act.

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Marine Mammal and Seabird Aerial Surveys
Understanding critical marine habitats, including seabird and marine mammal hotspots at sea will help inform offshore energy siting along the U.S. Pacific Coast. USGS conducts seabird and marine mammal surveys for the BOEM Pacific Outer Continental Shelf (OCS) Region to inform future alternative energy plans. Named the Pacific Continental Shelf Environmental Assessment, the primary survey area extends from Fort Bragg, California to Grays Harbor, Washington. Marine spatial planning, including potential site selection for offshore energy development, requires updated information on of recent species-specific community patterns and distributions. Manned aircraft surveys are used to conduct seabird and marine mammal counts and to operate oceanographic remote-sensing equipment to record habitat features throughout this span of the Pacific OCS region.

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Publications:

Onshore Industrial Wind Turbine Locations
In 2014, USGS completed and released a national dataset of onshore, industry-scale wind turbines in the United States (http://erscmap.usgs.gov/windfarm/). The dataset contains turbine locations, through July 2013, that have been collected, digitized, spatially verified, and internally quality controlled. Windmills from the Federal Aviation Administration (FAA) Digital Obstacle File, were used as the primary source of turbine data points. In addition, turbines without FAA Obstacle Repository System numbers were added to the collection. Turbine position was verified using high-resolution aerial imagery with a final locational error of less than 10 m. Technical specifications such as height, blade length, rotor swept area, model, and size were attributed for the majority of turbines based on a variety of sources. We are currently working on an update of the dataset that will include turbines constructed through March 2, 2014.

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Monitoring and Analysis

Tracking Offshore Use of Diving Bird Species
To evaluate the potential for detrimental effects to marine birds posed by wind turbines in Federal waters, we need information on the distribution and behavior (e.g., flight pathways, seasonal use timing) of birds in these areas. Platform terminal transmitter satellite tracking tags are being used to determine fine-scale occurrence and local movement patterns of red-throated loons, surf scoters, and northern gannets in Federal waters of the mid-Atlantic U.S. during migration and winter. Preliminary results indicate that gannets from different age classes in major breeding areas in the Gulf of St. Lawrence and eastern Newfoundland use habitats of the U.S. eastern seaboard in winter. Loons relied heavily on offshore areas within 100 km of the coast during migration and utilized several stopovers along the east coast. Scoters stay within 10 nm of the coastline and may not be influenced by the proposed wind energy areas controlled under BOEM jurisdiction, but state plans may have an impact on this species.

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Wind Energy Development and Operation on Non-flying Terrestrial and Marine Wildlife
USGS scientists published the first global review of the effects of wind energy development and operation on non-flying terrestrial and marine wildlife. The review addressed land-based and offshore wind energy development. Known and potential effects of utility-scale wind energy development and operation on terrestrial and marine non-flying wildlife include direct mortality, environmental effects of destruction and modification of habitat including effects of roads, and offsite effects related to construction material acquisition, processing and transportation. Known and potential effects due to operation and maintenance of facilities include habitat fragmentation and barriers to gene flow, as well as effects due to noise, vibration and shadow flicker, electromagnetic field generation, macro- and micro-climate change, predator attraction, and increased fire risk. The scarcity of before-after-control-effects studies hinders the ability to rigorously quantify the effects of wind energy development on non-flying wildlife. The authors conclude that additional empirical data are needed to fully assess the effects of wind energy development and operation on non-flying wildlife.

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Publications:

Wind Energy Effects on Birds and Bats
The USGS has developed a cost-effective system for detecting and imaging bats and birds flying at night near industrial-scale wind turbines. Each system consists of a video surveillance camera that is highly sensitive to low-light conditions and a near-infrared laser illuminator, which emits light not visible to birds and bats. The system is coupled with motion analysis to identify specific events of interest, such as turbine strikes by wildlife, while ignoring other moving objects, such as turbine blades. The system also efficiently filters large volumes of digital video and reduces labor costs associated with imagery review. A key feature of the monitoring system is its capacity to detect infrequent events not readily sampled by other methods. Digitally tracking motion can also provide information about behaviors, such as social interactions and foraging, and bat occurrences around turbines.

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