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November 22, 2000 – October 31, 2005

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Department of Wildlife and Fisheries Sciences
Texas A&M University
College Station, Texas

Subcontract Report
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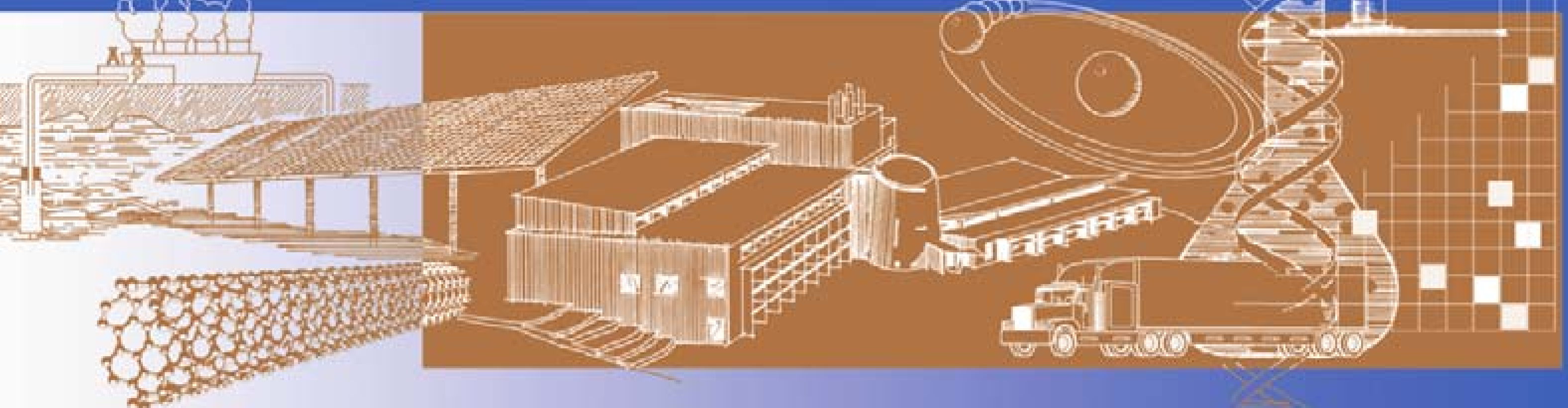

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Table of Contents

A. Introduction

The United States has high-energy demands that are for the most part satisfied by the fossil fuel industries. Fossil fuel is a finite resource that will only become more valuable as supplies inevitably become more limited and as demand increases. Wind-generated energy may represent an alternative to fossil fuels for meeting electricity needs because harnessing wind energy does not generate the pollutants that burning fossil fuels produces. Furthermore, other than constructing the facility and supporting infrastructure, ecological communities are not disturbed to the same extent as occurs when coal deposits are extracted from the earth.

Nevertheless, wind-energy facilities do impact natural resources. Although an individual wind turbine has a small footprint, wind farms consisting of dozens to hundreds or more turbines can cover hundreds to thousands of acres. The infrastructure required to install and maintain turbines in a wind farm can directly damage sensitive ecological communities through road building, clearing of tower pads, maintenance buildings, and electrical distribution lines. The presence of vehicles and personnel in wind farms may indirectly impact environmental resources through disturbance. So there is the risk of negatively impacting plant and animal communities associated with establishing financially viable wind farms. However, the primary concern associated with constructing wind farms may be the impacts that wind turbines might have on birds and bats.

The purpose of this paper is to discuss the possible impacts of wind development to birds along the lower Gulf Coast, including both proposed near-shore and off-shore developments. I do this by summarizing wind resources in Texas, discussing the timing and magnitude of bird migration as it relates to wind development, reviewing research that has been conducted throughout the world on near- and off-shore developments, and providing recommendations for research that will help guide wind development that minimizes negative impacts to birds and other wildlife resources.

1. Wind-energy status and proposed expansion

Wind power has been used commercially to produce electricity since the early 1980s, when the world's first large-scale wind development, or wind resource area (WRA), was developed in California. More than half of the United States has developed wind resource areas, and additional states are in various stages of the planning process. Wind developments are also prevalent throughout much of Europe, with most developments located relatively close to coastlines. Although the fatality rates in Europe are often higher than those in California and the rest of the United States, many European scientists have not considered this impact a significant threat to bird populations in most of Europe. This is because the number of deaths is small relative to the total number of birds using or passing through the area. Most birds killed were not raptors—they were relatively common species of passerines and waterbirds. Nevertheless, substantial kills of birds can take place if the turbines were placed in areas of relatively high bird use. Additionally, Europe has pioneered the installation of offshore wind developments, an application that is only beginning to be explored in North America.

Researchers have conducted a large number of avian fatality surveys at WRAs in the United States and Europe. There has been an emphasis on raptor fatalities, despite the knowledge that other birds have been affected. This may be because raptors receive protection under a large suite of federal and state laws and because they are symbolic and have greater emotional value. For all avian species combined, estimates of the number of bird fatalities per turbine per year from individual studies have ranged from 0 at the Searsburg, Vermont and Algona, Iowa sites to 4.45 on the Buffalo Ridge, Minnesota Phase III site (Erickson et al. 2001). A study of golden eagle populations in the vicinity of the Altamont Pass (California) WRA from 1994 to 2000 reported that 52 of 257 eagles equipped with radio transmitters were killed by wind turbine strikes. When compared with other large WRAs, it is clear that Altamont Pass supports substantially higher resident and migratory raptor populations and experiences substantially greater raptor fatality rates caused by collision with wind turbines. (See Erickson et al. 2001 for a review).

After examining the results of numerous bird impact studies at wind farms, Erickson et al. (2001) reported that the results are probably biased towards large birds because the carcasses of smaller birds are more difficult to detect and disappear more readily to scavengers. The results from most of the studies they reviewed indicated that more than 50% of the bird mortalities detected were for raptors, while about 20% represented passerines. So the impact of wind farms on passerines may be more significant than the impact studies reveal. The primary available method for reducing the probability of avian collisions is locating wind farms in areas of relatively low bird utilization. Such pre-siting surveys are needed to appropriately locate wind farms and minimize the impacts to birds.

Currently, utility-scale wind turbines can produce electricity for $0.04 per kilowatt-hour (kWh) on Class 6 wind sites (sites with average wind speeds of 6.7 meters (m) per second at 10-m height or16 miles per hour [mph] at 33 feet). However, as more sites are developed, easily accessible prime Class 6 sites are disappearing. In addition, many Class 6 sites are in remote areas that do not have easy access to transmission lines. Class 4 wind sites (5.8 m per second at 10-m height or 13 mph at 33 feet) cover vast areas of the Great Plains from central and northern Texas to the Canadian border. Class 4 sites are also found along many coastal areas and along the shores of the Great Lakes. While the average distance of Class 6 sites from major load centers is 500 miles, Class 4 sites are significantly closer, with an average distance of 100 miles from load centers. Thus, utility access to the Class 4 sites is more attractive and less costly. Also, Class 4 sites represent almost 20 times the developable wind resource of Class 6 sites. Currently, wind energy at Class 4 sites can be marketed at prices in the range of $0.05 to $0.06/kWh (www.NREL.gov).

2. Gulf Coast/Texas development

Interest in establishing wind-generating facilities along the Lower Gulf Coast (LGC) of Texas has increased in recent years for several reasons. First, winds of sufficient magnitude to make a wind-generating facility economically viable occur at least part of every day along the Laguna Madre. Second, the terrain immediately inland consists of coastal prairie, so it is flat and has extensive open areas where wind turbines could be erected and operated on a daily basis. Third, electricity demands are evidently sufficient to operate a profitable enterprise. So the LGC appears to offer opportunities to provide competitive alternative energy sources to local consumers via wind-generating facilities. In 2005 the State of Texas began taking steps for permitting the first commercial offshore wind-energy development off of Galveston Island. Several wind energy companies have expressed an interest in Texas, in part because of the unique benefit the state offers in the competition to secure offshore wind development. In 1836, after securing independence from Mexico, Texas claimed the offshore boundaries observed under Spanish, then Mexican rule. Sam Houston, president of the new republic, successfully maintained sovereignty over all submerged lands in the Gulf out to 10.36 miles, or three marine leagues. Texas entered the Union in 1845 with its boundaries intact, and defeated an attempt at federal control of the tidelands in the 1950s. For this reason, the primary entity in Texas that an offshore wind developer must deal with is the Texas General Land Office. Also, development within the 10.36-mile limit offers proximity to the state's electrical grid to carry wind-generated power to customers.

Texas Parks and Wildlife Department (TPWD) is the state agency that oversees fish and wildlife resources out to 10.36 miles offshore, including commercial and recreational fishing, and oyster and shrimp harvesting. TPWD provides recommendations on fish and wildlife resources to local, state, and federal agencies or private organizations that make decisions affecting those resources.

Although wind turbine/bird collision studies seem to indicate that wind-generating facilities in some locations of the United States have a minor impact on birds compared to other sources of collision mortality, one cannot assume that similar impacts would occur among birds using wind-generating sites established on the LGC. Three migratory bird corridors converge immediately north of Corpus Christi, effectively funneling millions of birds along the LGC to wintering grounds in south Texas and Latin America. More than 200 species migrate along the lower Texas Gulf Coast annually, and several species on the federal threatened and endangered lists are included among these (e.g., golden-cheeked warbler [*Dendroica chrysoparia*] and black-capped vireo [*Vireo atricapillus*]). Moreover, a diverse and abundant resident bird community potentially composed of federally and state-listed threatened and endangered species will likely occur on any proposed LGC wind-generating facility site.

Consequently, the impacts of a wind-generating facility located on the LGC could be different than those at different locations throughout the United States, simply because the abundance and diversity of birds that migrate or reside on any wind-generating facility site is so much greater. Moreover, the topography and vegetation communities of the proposed wind-generating sites in the LGC are very different from those of existing wind-generating projects, and these variables would likely influence the potential impacts of the proposed wind-generating facility on the bird community. Furthermore, storms that develop in or enter the Gulf of Mexico influence the movement patterns of migrating birds, generally forcing them toward the coasts. Inclement weather events also force migrating birds to lower altitudes, increasing the vulnerability of migrating birds to wind turbines. It will be very difficult to project the impacts of a wind-generating facility on LGC bird communities unless resident and migratory bird habitat use and movements are quantified prior to construction of such a facility.

One company has recently obtained a long-term lease on a large private ranch with substantial Laguna Madre shoreline and has initiated the process of obtaining the federal and state permits necessary to begin construction of an 80- to100-turbine wind-generating facility. This company recognizes the potential impact that a wind-generating facility could have on resident and migratory birds that utilize the area encompassed by a wind-generating facility and is conducting an 8-month field evaluation to quantify the resident and migrant bird community, as well as identify important bird habitats on the proposed impact site. The company's goal is to assess the risk of constructing a large wind-generating facility on the resident and breeding bird community on the impact site.

B. Wind Potential in Gulf Coast/Texas

The Panhandle contains the state's greatest expanse with high-quality winds. Well-exposed locations atop the caprock and hilltops experience particularly attractive wind speeds. South of Galveston, the Texas coast experiences consistent strong sea breezes that may prove suitable for commercial development. The mountain passes and ridgetops of the Trans-Pecos exhibit the highest average wind speeds in Texas. Since the wind in mountainous terrain can change abruptly over short distances, the best wind farm locations in West Texas are quite site specific.

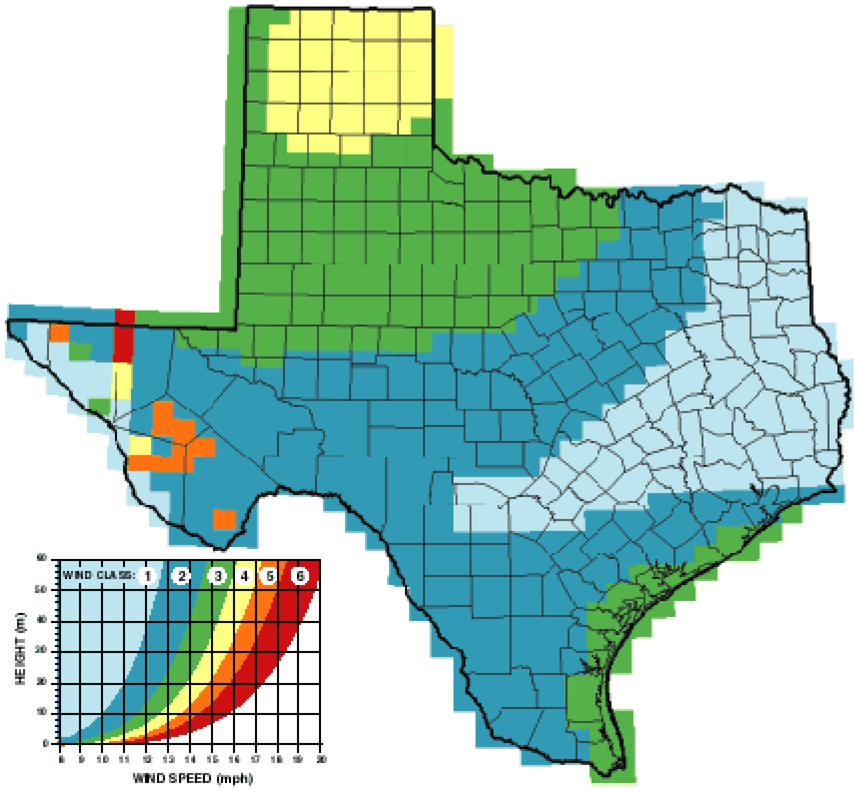

Figure 1. Potential wind production in Texas (1995 Texas Renewable Energy Assessment, Texas State Energy Conservation Office)

The Texas map identifies three major areas with good wind power potential: the Great Plains, the Gulf Coast, and specific ridgetops and mountain passes throughout the Trans-Pecos. The electric generation potential of the windy areas of Texas is summarized in Table 1, below. These values reflect exclusions for various technical and environmental constraints. The table points out that Texas contains enough class 4 resource to produce all of the electricity currently consumed in the state. Even when utilizing only class 5 and 6 lands, wind power could generate a significant portion of the state's electricity.

Table 1. Potential electricity production on windy lands in Texas

WIND POWER CLASS	AREA (km^2)	PERCENT OF STATE LAND	POTENTIAL CAPACITY (MW)	POTENTIAL PRODUCTION (Billion kWh)	% OF TEXAS ELECTRIC CONSUMPTION
3	143,400	21.13%	396,000	860	371%
4	29,700	4.38%	101,600	231	100%
5	5,000	0.74%	21,600	48	21%
6	300	0.04%	1,600	4	2%
Total	178,400	26.29%	520,800	1,143	494%

km^2 = square kilometers

The potential of a location to produce energy from wind on a commercially viable scale is classified by "Wind Power Class," which is based on averaged sustained wind speed:

- Wind Power Class 1—very poor
- Wind Power Class 2—poor
- Wind Power Class 3—marginal (wind speed >14 mph)
- Wind Power Class 4—good
- Wind Power Class 5—very good
- Wind Power Class 6—excellent (wind speed >18 mph)

With the development of wind turbines that can operate at lower wind speeds, Wind Class 3 locations are now considered commercially viable. In fact, NREL is supporting research to develop wind turbines that would be economically viable in Class 3 wind regimes.

C. Bird Movements and Behavior

1. Bird migration along the Gulf Coast

Radar studies have indicated that the flight pathway of the majority of trans-Gulf migrants in spring is directed toward the coasts of Louisiana and Texas (Gauthreaux 1970, 1971, 1992), and thus over Gulf waters in which are located the majority of offshore oil and gas production facilities. Offshore platforms, which house production equipment and living quarters for personnel, have played a central role in the development of oil and gas resources in the Gulf of Mexico. The history of offshore platforms in the Gulf has been short but dynamic. The first offshore platform was installed in 1947. The first multi-platform complex was installed in 1960. By 1974, 800 platforms had been installed in the Gulf. As the number of platforms grew, so did the geographic extent of their distribution offshore. Fixed platform installation depth reached 30 m in 1955, 60 m in 1962, and 300 m in 1978. Production began in waters exceeding 600 m in 1984, and in waters exceeding 1,500 m in 1997. The thousands of platforms now located on the continental shelf of the northern Gulf of Mexico make up the largest artificial island system in the world.

One of the most important components of birds' migration strategies is their use of local habitats for resting and refueling while en route. In light of the absence of natural islands or other terrestrial habitats during crossings of the Gulf of Mexico, it seems inevitable that the installation of thousands of artificial islands in the northern Gulf must affect migrants in some fashion. However, before 1998 few systematic studies had examined the influence of Gulf platforms on trans-Gulf migrating birds. From 1998 to 2000, Russell (2005) studied the ecology of trans-Gulf migration and the influence of platforms on migrants using a team of field biologists stationed on an array of platforms across the northern Gulf.

In addition to the censuses of birds stopping over on the platforms, visual surveys of the airspace around platforms were used to assess the volume of flyby migration traffic and to quantify the flight behavior of trans-Gulf migrants. The researchers also compared their platform-based results to results of land-based radar (NEXRAD), including 10 radar sites that provide a nearly complete observational network around the northern Gulf Coast from Brownsville, Texas, to Key West, Florida. I summarize some of the findings of the Russell (2005) study below because of its importance in understanding specifics of bird migration along the lower Gulf Coast. (The Russell report presents a detailed presentation of data and should be reviewed for additional information.)

Prior to this study, the conventional wisdom had been that spring trans-Gulf migration involves a roughly straight-line, shortest-distance flight from the Yucatan Peninsula to the upper Gulf Coast. Results of Russell (2005) support parts of this scenario but also indicate that the situation is considerably more complex. Backtracking from radar images and arrival times on platforms indicates that most spring migrants initiate their flights from the Yucatan Peninsula and/or the northern coast of the Isthmus of Tehuantepec. Radar and direct observational evidence indicate that most trans-Gulf migration takes place over the western Gulf and suggests that the migrants' route is curvilinear and divergent, veering from a probable mean heading of northwest at points of origin, to north off the south Texas coast, to northeast off the Upper Texas Coast and Louisiana.

Large flights are usually associated with Eastern Continental High (ECH) or Bermuda High (BH) synoptic weather patterns, in which winds similarly veer clockwise around the western Gulf. It appeared that the route of trans-Gulf migrants is influenced by the availability of tailwinds, with migrants attempting to minimize the time or energy expenditure required for crossing. This hypothesis is strengthened by the finding that centers of migrant offshore abundance as well as areas of eventual landfall varied in concert with synoptic weather. On ECH days when winds typically had a stronger westward component over the southern Gulf and often maintained a westward component over the northern Gulf, migrants were most abundant on platforms in the far western Gulf, and landfall was usually along the Texas coast. In contrast, on BH days, when winds had a weaker westerly component over the southern Gulf and usually an eastward component over the northern Gulf, peak offshore abundance shifted eastward and landfall was more likely to take place farther east along the northern Gulf Coast, occasionally as far as the Florida Panhandle. All available evidence indicates that the main migration stream is at least partially "steered" by synoptic-scale winds.

Spring migration over the northern Gulf began between early morning and early afternoon, peaked 3 to 4 hours after first detection, and continued until 7 to 12 hours after first detection. Patterns of diel timing varied geographically and were related to weather, again consistent with a strong synoptic steering influence on migration routes across the Gulf. The bulk of spring trans-Gulf migration detected by radar occurred between March 25 and May 24, but very large flights (>25 million migrants) occurred only in the 3-week period from April 22 to May 13. Waterfowl and herons peaked by early April. Shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April. Theoretical analyses of radar data yielded total seasonal estimates of 316 million trans-Gulf migrants in spring

1998 and 147 million trans-Gulf migrants in spring 1999. Radar-observed spring migration was characterized by a series of pulses and tended to be “all-or-nothing”; that is, either significant trans-Gulf migration was evident on radar or else it was essentially absent. Dramatic hiatuses in radar-observed migration were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf. Conversely, radar-observed migration peaks were almost strictly associated with ECH and BH days.

Fall trans-Gulf migration was more difficult to study because the extensive presence of aerial insects precluded quantitative interpretation of radar imagery. In addition, one of the two field seasons was partly compromised by prolonged absences from the platforms caused by tropical weather systems. Nevertheless, Russell (2005) thought that the heaviest trans-Gulf migration traffic in fall originates from the stretch of the northern Gulf Coast running eastward from Alabama.

Southbound “fall” migrants were observed as early as May 20 and as late as January, but the vast majority of the migration occurred from mid-August to early November. There seemed to be several phases in the fall migration. During the early fall, migration by long-distance migrants appeared to be obligate (i.e., required) and was not strongly influenced by weather. Later in the fall, major trans-Gulf movements of shorter-distance migrants were generally associated with cold fronts and northerly winds. Direct observations at the eastern-most platform indicated that the direction of flight was most often due south but varied from south-southwest to south-southeast. As with spring, variation in the direction of travel was clearly influenced by wind. Russell and associates also detected considerable fall migration over the far western Gulf, where flight direction usually had a westerly component. The western-Gulf route was used by a high proportion of juveniles, and appeared to represent a risk-averse migration strategy favoring a shorter, less risky overwater flight leg at the expense of a more circuitous overall migration route. The researchers suspected that many of the adults traveling over the western Gulf were individuals that reached the northeastern Gulf Coast with inadequate fat stores for a direct trans-Gulf flight and worked their way westward along the coast, perhaps stopping over along the way.

2. Potential environmental issues

In specific situations, wind power developments have been shown to cause environmental impacts, including impacts on animal habitat and movements, noise pollution, visual impacts, biological concerns, bird/bat fatalities from collisions with rotating blades, and health concerns. Of all the potential environmental impacts, biological concerns regarding birds and bats have, to date, been discussed and studied the most. Various other issues associated with resource developments in general may also be of concern with wind developments; however, issues that are common to most if not all developments, such as soil erosion and water quality, are not addressed in this report. Morrison and Sinclair (2004) summarized many of the potential environmental concerns surrounding wind-energy development.

3. Impacts on habitat and animal movements

The term habitat refers to the specific configuration of environmental features (e.g., vegetation, rock outcrops, water) that an animal uses at any point in time. Habitat is a species-specific concept—every animal species uses a different combination of environmental features. Therefore, no specific area is "good" or "bad" habitat unless it is assessed in relation to a specific species. Thus, what is "good" for one species might be "poor" for another species.

For wind developments, issues of habitat involve (1) outright loss because of development, (2) indirect impacts because of disturbance (i.e., the animal will no longer reside near the development), and (3) disruption in animal passage through or over the development because of the addition of towers and turbines. This definition also applies to offshore situations, and is applicable to foraging areas for birds, marine mammals, and fish.

Because wind developments often stretch for many miles, the turbines, along with the associated infrastructure (especially roads), can impact animal movements. No quantitative work has been done on the impacts of wind developments on animal movements. It is unlikely, however, that onshore, inland wind developments will cause wholesale disruption in migratory movements of birds and other vertebrates. This is because wind developments are seldom, if ever, introduced into pristine environments. Migrating or dispersing animals do encounter a host of potential obstructions not necessarily associated with wind development, including highways, power line corridors, housing, farm fields and pastures, and people. Analysis of the impacts of a wind development on movements of terrestrial animals, therefore, would usually focus on the additional impacts that the wind development would have on animal movements. There are also numerous methods available to lessen potential impacts to animal movements that were developed for highways and other human developments, which could apply to wind developments. Such strategies would include widely spacing turbines in certain locations, restricting travel along roads within wind developments (e.g., for inspection and repair only) during specific times of year (e.g., during ungulate [i.e., large mammals such as deer] migration), and providing appropriate habitat between turbines to facilitate animal movements.

The ground disturbance associated with placing a turbine, especially road cuts and cuts used for turbine pad placement, can actually attract certain species. Most notable are burrowing animals, such as gophers and ground squirrels. In some locations, these species are rare or legally protected. In most areas, the attraction of these animals to turbines likely enhances the area for foraging raptors, thus raising the likelihood of raptor collisions with rotating blades. As such, wind developments must consider the potential for attracting species of concern and creating conditions in which birds could be killed. At Altamont Pass, for example, research has shown that the abundance of rodent burrows is highest near turbine strings (Smallwood and Thelander 2005).

A major concern with offshore developments is the impact that boat and air (helicopter) traffic to and from the wind development might have on animal behavior and movements.

Here again, little is known about such impacts. The primary concern is that human activity in support of the development (e.g., supply delivery and maintenance crews) could have negative ramifications on animal behavior that extend far outside the boundaries of the turbines. Russell (2005) found that migrants would sometimes arrive at certain oil platforms shortly after nightfall and proceed to circle those platforms for variable periods ranging from minutes to hours. Circulations were highly variable in size and composition. The numbers of birds involved varied from a single individual to many hundreds. Although a wide variety of species was recorded in circulations, herons, shorebirds, swallows, and warblers were the dominant components. This behavior, if repeated around offshore wind turbines, could raise the risk of collision with the tower or the blade. Russell (2005) concluded that this circling behavior was related to attracting the birds to platform lights.

Commercial turbines now commonly produce 1.5 to more than 2 megawatts (MW) of power, are three bladed, have a rotor-swept diameter of 70 m, and are placed on a tower 80 m tall. Modern commercial wind turbines, therefore, have a maximum height measurement from ground level to the tip of the blade of 120 m (≈375') or taller. Many offshore developments have proposed turbine-tower combinations that are near or exceed 160 m (≈500') in total height. As a result, turbines can be highly visible from many miles away. Larger turbines result in fewer turbines in an observer's field of view, although the land area covered for a given wind farm megawatt capacity is approximately the same as for smaller turbines. In some locations, aircraft warning lights may be required by the Federal Aviation Administration (FAA), which adds another dimension to visual considerations.

4. Bird fatalities at land-based sites

Researchers have conducted a large number of avian fatality surveys at WRAs in the United States and Europe. In most cases, several factors have made it difficult to compare results from one study or one site to another. First, survey methods vary, and very few of these studies have been peer reviewed and published in scientific journals. Second, turbine designs and wind farm layouts vary considerably from site to site. Third, the wide climatic and topographical differences and range of bird species present in different locations make it extremely difficult to draw concrete conclusions from the available literature. Fourth, it is difficult to make statistical comparisons because the relatively low number of fatalities causes inadequate sample size. In addition, there was an initial focus on raptor fatalities, at least in part because raptors receive protection under a large suite of federal and state laws and because they are symbolic and have greater emotional value. Beginning in the late 1990s, increased work has been placed on evaluating the potential impacts to all bird species. A sampling bias toward raptors and other large birds also occurs because small birds are more difficult to detect and scavenging of small birds can be expected to occur more rapidly relative to larger birds. Impacts to some passerines, including neotropical migrants, may warrant more careful scrutiny because most of them are protected under the Federal Migratory Bird Treaty Act and because some are experiencing regional population declines.

A study of golden eagle populations in the vicinity of the Altamont Pass WRA from 1994 to 2000 reported that 52 of 257 eagles equipped with radio transmitters were killed by wind turbine strikes. When compared with other large WRAs, it is clear that the Altamont Pass supports substantially higher resident and migratory raptor populations and experiences substantially greater raptor fatality rates caused by collision with wind turbines. Although it remains inconclusive whether the eagle population in the Altamont region is declining due to turbine kills, these eagle fatalities may cause many direct and indirect impacts on the area's bird population. Direct impacts include a decline in the population size and change in age structure. Indirect impacts include a reduction in the number of birds that are available to disperse to other regions.

Results of numerous studies in the United States at sites outside of California have indicated that the rate of raptor collisions in California, particularly at the Altamont Pass WRA, is considerably higher than in other WRAs. Passerines composed the highest percentage of fatalities in the non-California studies. Reports from these studies indicate that the levels of fatalities are not considered significant enough to threaten local or regional population levels, although overall cumulative effects of human-induced bird fatalities are unknown. A major difference between the Altamont Pass WRA and other WRAs is that many other areas lack the dense populations of raptors and diverse topography of the Altamont Pass WRA and the large number of turbines sited. The high number of fatalities at the Altamont Pass WRA has created awareness of potential siting problems and, in some cases, more regard has been given to the level of raptor and other bird species use prior to construction.

a. Body of evidence from Europe

As reviewed below, offshore developments have been established throughout Europe, and there is now a body of evidence about potential ecological and human impacts from 1-2 years of operation of the largest projects in Europe and about 280 studies of various types and scientific credibility. Most of these developments are small relative to onshore developments, although two larger projects are now operating in Denmark.

There is a body of evidence in Europe regarding the potential environmental impacts from an offshore wind project because operating wind farms in the ocean have existed since the early 1990s. There are now over 280 studies relating to environmental and human effects research from offshore wind installations in Europe. There have been, however, concerns about the adequacy of this knowledge base as most of these projects had few turbines (less than 10), did not conduct rigorous BACI studies, and were not peer reviewed. In order to tackle this uncertainty and shape a credible story, the EU sponsored two major projects, Concerted Action for the Offshore Wind Energy in Europe (CA-OWEE) and Concerted Action for the Deployment of Offshore Wind (COD). In 2005, COD compiled the available studies in a searchable electronic database and summarized their findings in a final report. "The COD work on the establishment of an environmental body of experience has brought an important overview of the present state of knowledge in this up to now unknown field" (COD 2005, 2).[1] Two Greenpeace International reports summarized environmental impact assessment studies in Europe prepared by Deutsches Windenergie Institute (2000) and Deutsche WindGuard GmbH (2005), respectively.[2]

The major risks from offshore wind turbines to sea birds and resting birds are:

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

Of these, assessments suggest that collisions and disturbance have the main impacts on sea birds and resting birds (COD 2005, 23). Collisions of birds with wind turbines in offshore wind farms, in most cases, are only a minor problem (but with exceptions in some poorly-sited land-based facilities) (Greenpeace International 2000, section 5.3.3). Quantitative risks estimates for collision risks are difficult due to the facts that:

- Impacts are highly site dependent;
- Inadequate data exist on bird migration routes and flight behavior (Exo, Huppop, and Garthe, 2003, 50);
- Impacts vary for different bird species;
- Measurements address only found bird corpses; and
- Results thus far are often contradictory between studies (Desholm and Kahlert 2005).

Still a number of studies thus far for offshore facilities suggest little or no impact on bird life (COD, 2001, 7-5). On the other hand, relatively high collision mortality rates have been recorded at poorly sited land-based wind farms in areas where a large concentration of birds are present, such as Altamont Pass and Tarifa (Birdlife International 2003). By contrast a recent study of 1.5 million migrating seabirds from Swedish wind farms in Kalmarsund concluded that the fatality risk to passing seabirds was only one in 100,000 passing seabirds (Eriksson and Petersson 2005).

In Denmark, radar studies have shown that migrating birds avoid flying through the Nysted wind farm. These studies reveal that 35 percent of the birds fly through the area at baseline, but only 9 percent after construction. Monitoring at the operating Horns Rev wind farm in Denmark found that, "…most bird species generally exhibit an avoidance reduction to the wind turbines, which reduces the probability of collisions (Elsam Engineering and ENERGI E2, 2005, 45).

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

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

Thus far, the risks of habitat loss and barrier effects for birds have not been quantitatively estimated. The avoidance behavior of birds is significant in these risks. Such avoidance behavior is species-specific and the overall availability of suitable areas is important. Large offshore wind farms may diminish foraging and resting conditions and so assessment of cumulative effects is needed. Sea birds and resting birds appear to be less at risk than migrating birds (COD 2005, 32), as they may adapt better to offshore wind farms.

Despite the lack of evidence to suggest a major overall risk to birds, this issue remains high in public concern and in European priorities. It is important to note that while further studies are needed to better define the risks, precautionary measures to reduce and mitigate such risks exist. For example, careful siting of wind farms away from bird migratory paths, bird habitats, and large concentrations of species at higher risk is possible.

From preliminary Danish monitoring results, it appears that offshore wind farm-induced effects are less severe than might have been anticipated. However, knowledge gaps and uncertainties on cumulative effects from other sea users suggests that further work and, in the meantime, careful assessment and monitoring, is merited. As to the impact on fish, it appears that no significant adverse effects from the building and operation of wind turbines has been demonstrated. It is generally believed that wind farm areas may have positive impacts as these may serve as a refugium for fish. There appears to be no common expert opinion on how offshore wind farms effects benthos communities (especially the long-term impact on composition of benthic species and communities).

Most of the European studies focused on solitary or small groups of turbines. Therefore, it is difficult to compare data with U.S. studies that focus on larger groups of turbines. Many of the European studies were based on coastal sites where waterfowl and migratory bird issues were not comparable to those in the California studies. Although the fatality rates in Europe are often higher than those in California and the rest of the United States, many European scientists have not considered this impact a significant threat to bird populations in most of Europe because the number of deaths is small relative to the total number of birds using or passing through the area. Most birds killed were not raptors—they were relatively common species of passerines and waterbirds.

A summary of bird-wind interactions in Europe found that overall kill rate was low. It was noted, however, that 2 to 3% of birds passing a windfarm at rotor height were killed. It has been concluded that disturbance and habitat loss effects associated with wind developments were probably much more important than direct bird kills due to collisions. In Spain, however, relatively high levels of kills were sometimes evident. Research in Europe has indicated that individual and single rows of turbines in areas with small bird populations provide the best landscape for wind farms (e.g., Winkelman 1995).

J. Winkelman conducted a series of studies examining the impacts of on-land but near-shore wind developments on birds; several of these studies are reviewed below. Winkelman (1994) provides an overview of research carried out in Europe with special emphasis on the results of the two most in-depth studies (Winkelman 1992 parts 1-4). Winkelman provides data and tables that are not available in any of the English summaries of these reports. Up to 1994, 14 studies have been finalized in Europe, covering 108 different sites. Most studies include small, solitary turbines (100 to 150 kW). Studies on bird collisions were mostly carried out by searching for dead birds. The proportion of birds colliding in relation to the total number passing the wind turbines was studied at 13 sites. Estimates of the total number of bird deaths could only be made in two studies. At the 108 sites, 303 dead birds were found, of which at least 41% were proven collision deaths. Of 14 collisions visually observed, 43% were caused by birds swept down by the wake behind a rotor, 36% by a rotor, and 21% unknown. The author states that total numbers likely to be killed per 1,000 MW of wind power capacity are low relative to other human-related causes of death. Findings on disturbance and the effect of turbines on flight behavior, which were investigated in most studies, were summarized. Up to a 95% reduction in bird numbers has been shown to occur in the disturbance zones (250 to 500 m from the nearest turbines). From the European point of view, in most circumstances disturbance and habitat loss is thought to be of much more importance than bird mortality. New or ongoing research in Spain, The Netherlands, and Denmark was also mentioned.

Winkelman (1992) presents the first of a four-part series of reports showing the results of a continuing study to determine the impact of an experimental wind park on birds and reports results of searches for birds that died or were injured by collision with turbines and meteorological towers from 1986 to 1991. Seventy-six injured or dead birds were found, representing 25 species. Of these, 36% were certainly or very probably killed as a result of collision with turbines, while 17% were injured. Fewer birds probably collided with the middle row of wind turbines. Consequently, Winkelman suggests that a cluster formation of turbines may cause fewer impacts than a line formation. All birds that were thought to be killed by turbines were found in the area behind the rotor or on the right front side of it. Most deaths were found after nights with both poor flight and sight conditions. On average, less than 0.01% of the birds passing the wind park during nocturnal or diurnal migration collided with an obstacle in the wind park. Lighting of wind turbines is believed to be harmful rather than beneficial, particularly when weather and visibility are bad.

Winkelman (1985) studied the possible danger to birds of medium-sized wind turbines (tower height 10to30 m) situated on six small windfarms located along or near the Dutch coast. The main points addressed by the study were the flight behavior of birds approaching turbines in daylight, the number of birds killed at night, and the possible loss of breeding and feeding habitat around turbine sites. Diurnal migrants seemed to respond more to operating turbines than local birds. An average of 13% of migrating flocks and 5% of local flights showed a change in flight behavior that could be attributed to the turbines. The results suggest that local birds habituate to wind turbines. Within 12 species groups during diurnal migration, the greatest response to operating turbines was shown in ducks and geese. Of the diurnal migrants, 3% of the flocks came within reach of the rotor and 1% showed a panic reaction. At present sites, the disturbing effect of turbines on breeding and feeding habitat of birds has been negligible. No collisions with turbines were recorded. However, there were no data on carcass removal by scavengers and sites are situated in areas of low bird life. The study concluded that the chance of collisions of birds with medium-sized turbines in daylight and in weather with good visibility is almost zero. The author advised caution that the study does not indicate the danger of collisions at night or in poor visibility, by large groups of turbines, and by turbines at sites in the open field.

Winkelman (1990) deals with the behavior of birds approaching wind turbines during day and night conditions. Specific questions include how many birds pass the turbines at tower height and what proportion of these birds have collided with the turbines. Specialized equipment (search approach radar, passive image intensifiers in combination with infrared lights, and thermal image intensifiers) was used to determine abundance, behavior, and height of birds flying at night or during poor visibility. Ninety-two percent of birds approached the rotor without any hesitation during the day compared to 43% during the night. Most of them did approached the rotor with strong wing beats or a fluttering flight, particularly when there were head winds compared to tail winds. During high-use nights, 56 to70% of the birds passed at rotor height (21 to 50 m). More birds collided with the rotor at night and twilight than during the day. Of 51 birds recorded trying to cross the rotor area during twilight and total darkness, fourteen (28%) collided. During daylight, only one of fourteen birds (7%) collided. Bird accidents were not always real collisions. In 43% (6 of 14) of the nocturnal accidents observed, the birds were swept down through the wake behind the moving rotors during tailwinds. Half of these birds recovered soon after these collisions. The report also compares flight heights of birds during day and night conditions. Based on the number of birds passing at rotor height and the proportion of birds colliding, an estimated 1 out of 76 birds passing the towers at night was expected to collide mortally with the turbines when the park was fully operational.

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

b. Turbine and wind farm characteristics

Various design features, such as perch availability, rotor diameter, rotor-swept area, rotor height, rotational and tip speeds, and fixed versus variable turbine speed have been evaluated to determine whether they contribute to bird collision risk. Although at one time workers suggested that lattice towers might encourage birds to perch and thus come into close proximity of rotating blades, recent studies have failed to confirm a correlation between tower type and fatality rates.

The issue of rotor-swept-area and blade-diameter effects on avian collision risk with turbines is important because wind developers are in the process of repowering or replacing existing, less efficient turbines with a smaller number of new, larger, and more efficient turbines. Existing studies concerning fatalities in relationship to increased rotor-swept area are inconclusive, and further research is needed.

It has been speculated that overall bird fatalities will be higher at taller turbines because of an increased potential for collisions by neotropical migrant species. It is well known that migrating songbirds are frequently killed at tall communication towers. This was attributed to higher-flying, non-raptor nocturnal migrants that often constitute the greatest percentage of fatalities. Behavior differences among raptors indicate that there may be some trade-offs in benefits. For example, one species may benefit from blade tips being further from ground level, whereas others may be exposed to greater risk from blades that reach a greater overall height. Further research is needed to determine the impact that the newer, taller turbine towers have on bird kills. Rotor velocity and a corresponding increased tip speed have been correlated with fatalities. Faster turbine rotor speeds kill more raptors than would be expected by chance.

c. Offshore oil platforms

Russell (2005) documented a total of 787 cases of migrant mortality on or near oil platforms during the three spring seasons of study. Starvation was the most common cause of death (46% of deaths in which a cause was assignable), followed by collision (34%), and predation (14%). Among the total of 780 cases of migrant mortality documented on or near platforms during the two fall seasons of study, collision was the most common cause of death, accounting for 48% of deaths in which a cause was assignable. Predation was relatively more common in the fall (36% of deaths, compared to 14% in spring). However, starvation was uncommon in the fall, with only 76 documented cases in the 2 years. Collision deaths revealed that most occurred very early in the morning with strong winds from the south, when the vanguard of northbound migrants actually reached platforms before the onset of daylight. In contrast to spring, starvation was relatively rare and collision was the most common cause of death in the fall. Starvation was rare in part because the platforms are much closer to points of departure in the fall (i.e., migrants arriving on platforms have had less time to deplete their fat stores). Collision mortality is more significant in the fall because most migrants in that season are aloft over the northern Gulf during hours of darkness. Based on the seasons with heaviest observed collision mortality (spring 1998, fall 1999), Russell (2005) concluded that an average Gulf platform may cause 50 deaths by collision per year, suggesting that the platform archipelago may cause roughly 200,000 deaths per year. This number may be biased low because some birds that collide with platforms undoubtedly fall into the sea and avoid detection.

5. Bat fatalities

Until recently, little research has been conducted to determine the impacts of wind farms on bats. A few bat carcasses were found during earlier bird fatality studies; however, recent surveys at some newer sites have discovered higher mortalities than reported previously. To better discern the level of collision impacts on bats, researchers have initiated studies at some of these sites. These studies include analysis of environmental features in and around wind farms that could attract bats, such as roosting sites, availability of surface water, and riparian foraging areas.

Erickson et al. (2002) included a summary of bat fatalities at wind farms. The researchers found that some bat mortality can be expected at most wind plants, with a very large majority of the fatalities involving migratory tree and foliage roosting bats such as hoary and silver-haired bats in the western United States, and hoary and eastern red bats in the Midwest and eastern parts of the country. Bat collision mortality during the breeding season is virtually nonexistent, despite the fact that relatively large populations of some bat species have been documented in close proximity to wind plants. These data suggest that wind plants do not currently impact resident breeding bat populations in the United States. All available evidence indicates that most of the bat mortality at U.S. wind plants involves migrant or dispersing bats in the late summer and fall.

Bat echolocation and collision mortality studies indicate that only a small fraction of detected bat passes near turbines result in collisions, and that there appears to be little relationship between bat activity at turbines and subsequent collision mortality (Erickson et al. 2002). This relationship may not exist because many of the migrant species involved may either not be echolocating, or they are flying too high for the bat detectors to record, but still may be within the zone of collision risk. One of the largest estimates of bat fatalities is from the wind plant at Buffalo Ridge, Minnesota. Preliminary data from this site collected during a 5-year study suggest that the number of bats susceptible to turbine collisions is large, but the observed mortality is not sufficient to cause population declines of potentially affected bat species, based on relatively stable fatality rates over time. However, the effect on migrant populations of sustained collision mortality over several years is not known.

Arnett (2005) studied the relationships between bats and wind turbines at the Mountaineer Wind Energy Center in West Virginia, and at the Meyersdale Wind Energy Center in Pennsylvania. Fatality searches located a total of six species at Mountaineer and seven at Meyersdale during the 6-week sampling period: hoary bats, eastern red bats, eastern pipistrelles, little brown bats, silver-haired bats, big brown bats, and northern long-eared bats (only found at Meyersdale). Fatalities were distributed across all turbines, although higher-than-average numbers of bats generally were found at turbines located near an end or center of the string at both sites. Of the 64 turbines studied, one was nonoperational throughout the study period and this was the only turbine where no fatalities were found. Bat fatalities were not different between turbines equipped with FAA lights and those that were unlit at both sites. The majority of bats were killed on low wind nights when power production appeared insubstantial, but turbine blades were still moving, often times at or close to full operational speed. Fatalities tended to increase just before and after the passage of storm fronts. Daily searches at Mountaineer yielded an estimated 38 bats killed per turbine and a daily kill rate of 0.90 bats per turbine. The total number of bats estimated to have been killed by the 44 turbines just during this 6-week period was 1,364 to 1,980. At Meyersdale, an estimated 25 bats were killed per turbine based on daily searches, yielding a daily kill rate of 0.60 and a total of 400 to 660 bats killed by the 20 turbines during the 6-week study.

D. Potential Bird-wind Interactions along the Gulf Coast

1. Bird migration

Texas in general is considered part of the Central Flyway. The Central Flyway merges toward the east with the Mississippi Flyway and is bounded to the east by the Missouri River. The Central Flyway runs through western Missouri, Arkansas, and Louisiana, and then follows the Gulf coast of Mexico southward (Figure 2).

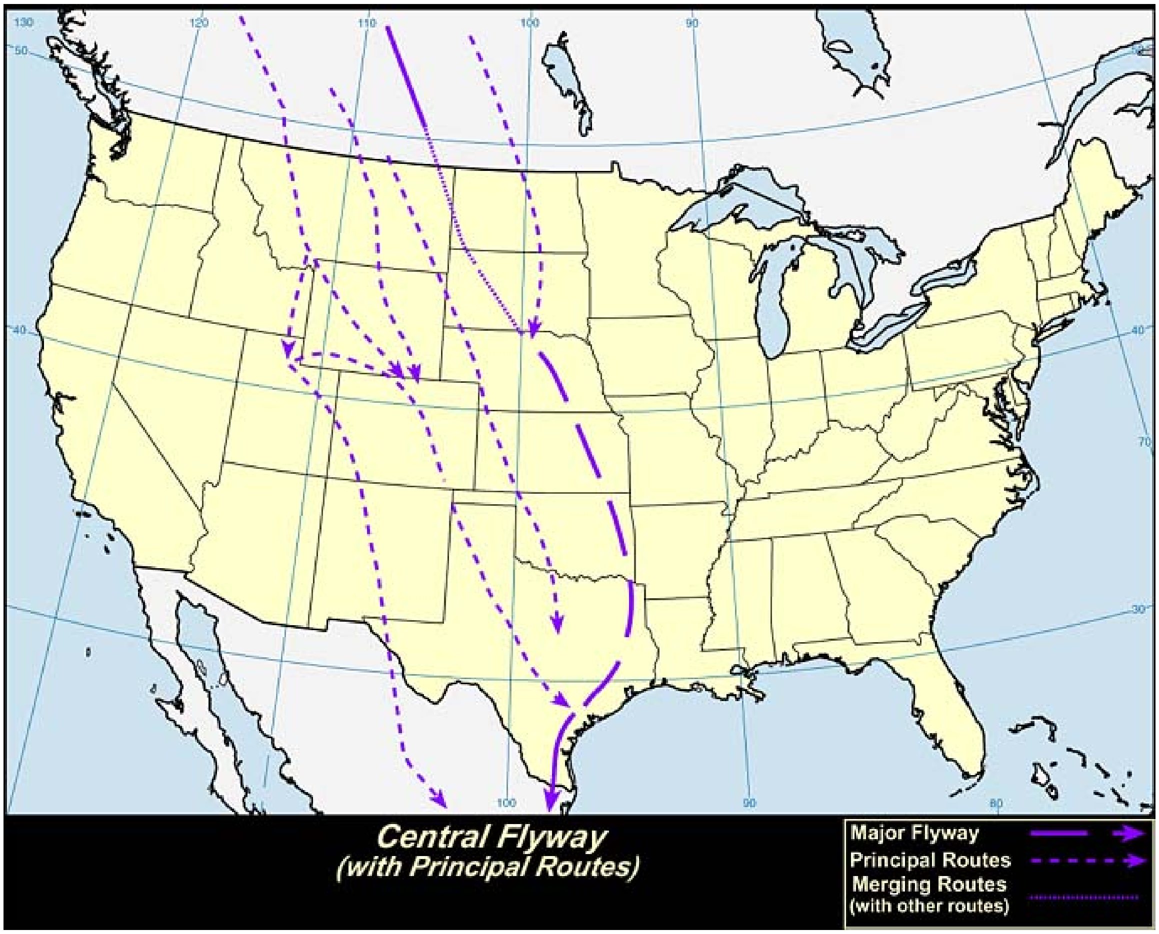

Figure 2. The primary routes taken by migratory birds through Texas and the lower Gulf Coast. Illustrator: J. Pahountis-Opacic

When landbirds start their southward migration, there is a convergence of the lines of flight taken by individual birds because of the conformation of the land mass and the east-west restriction of habitats suitable to certain species (Lincoln et al. 1998). For example, the Rose-breasted Grosbeak leaves the United States through the 600-mile stretch from eastern Texas to Apalachicola Bay, but thereafter it crosses the Gulf of Mexico and enters the northern part of its winter quarters in southern Mexico (Figure 3). A narrowing of migratory paths is the rule for the majority of North American birds. Both the shape of the continent and major habitat belts tend to constrict southward movement so that the width of the migration route in the latitude of the Gulf of Mexico is much less than in the breeding range. The American Redstart represents a case of a wide migration route, but even in the southern United States this path is still much narrower than the breeding range (Figure 4).

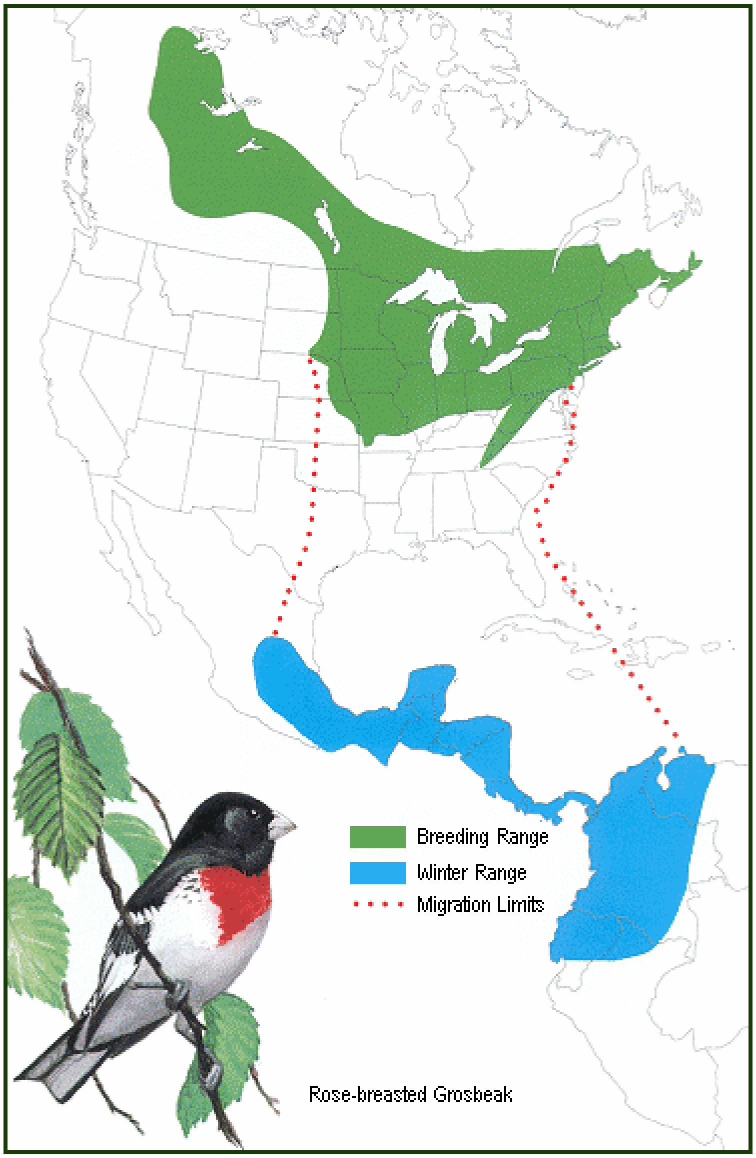

Figure 3. Distribution and migration of the Rose-breasted Grosbeak. Though the width of the breeding range is about 2,500 miles, the migratory lines converge until the boundaries are only about 1,000 miles apart when the birds leave the United States (Lincoln et al. 1998).

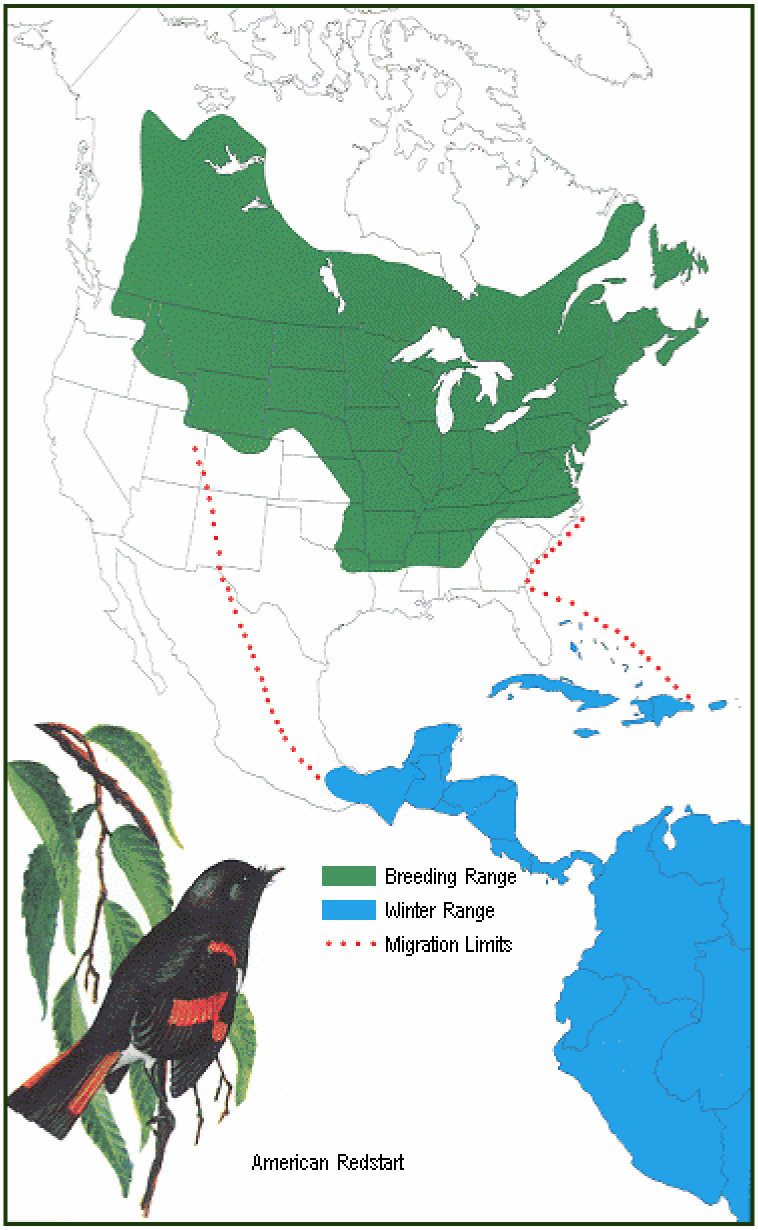

Figure 4. Distribution and migration of the Redstart. An example of a wide migration route, birds of this species cross all parts of the Gulf of Mexico, or may travel from Florida to Cuba and through the Bahamas. Their route has an east-and-west width of more than 2,000 miles (Lincoln et al. 1998).

The largest number of migrating birds cross the Gulf of Mexico from the northern Texas coast, eastward to the Florida panhandle (Figure 5, route 4). As evident from Figure 5, crossing the Gulf represents the shortest route to extreme southeast Mexico. In contrast, birds migrating along the LGC tend to follow the coastline because of its primary north-south orientation, rendering crossing the Gulf relatively less important (Figure 5, route 5) (Lincoln et al. 1998).

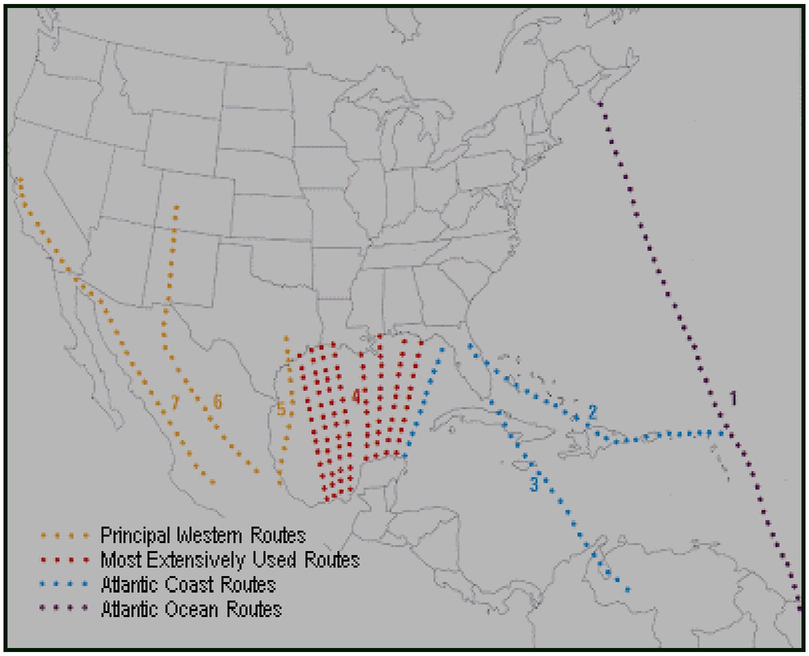

Figure 5. Primary migratory routes of birds (Lincoln et al. 1998)

Sidney A. Gauthreaux, Jr. (Department of Biological Sciences, Clemson University, Clemson, South Carolina) has pioneered the use of weather surveillance radar to monitor bird migrations. Doppler weather surveillance radar (WSR-88D) on the Gulf coast provides information on the direction and speed of bird movements—all displayed in bright colorful images. When properly calibrated, the WSR-88D can be used to measure the density of migrating birds aloft and use the speed of movement relative to the winds aloft to roughly determine the types of birds involved. Based on simultaneous visual observations, it was found that small songbirds flew considerably slower than shorebirds and waterfowl. This information revealed that flight contains not only flocks of songbirds, but also flocks of herons, waterfowl, shorebirds, gallinules and allies, and occasionally raptors. By simultaneously monitoring all the WSR-88D radars along the northern Gulf coast, the researchers were also able to determine the spatial extent of trans-Gulf flights. While migrants could be detected arriving from Brownsville, Texas, to Mobile, Alabama, the Houston and Lake Charles radar stations recorded more arrivals than any other station on the northern Gulf coast.

The Gauthreaux research program has shown that migrant birds take off 30 to 45 minutes after dark—an exodus event—and climb into the early evening sky. As they climb to altitudes sampled by the radar beam, they become "visible" as echoes in the radar image. For a brief period of time the locations of echoes from concentrations of migrants indicate the geographical locations of the stopover areas. The strength of the cluster of echoes indicates the density of birds and may indirectly indicate the quality of the habitat at the associated stopover area. Once images showing exodus events are summed over a season and imported as a data layer into a geographic information system, remote sensing imagery can be used to determine the topography and type of habitat in stopover areas. These maps show the density and direction of peak migratory movements over the radar stations, and in time will allow one to determine if migratory flights are decreasing, stable, or increasing for different regions of the country. With this initiative in place they can monitor the status of migration systems along the Gulf coast (and throughout the United States).

The most direct route for many Neotropical and Nearctic migrants wintering in the Caribbean and Central and South America to breeding grounds in eastern and central North America is across the Gulf of Mexico. Birds must cross this ecological barrier in a single flight, often choosing to fly when weather conditions are most favorable for this long journey. Birds leave Yucatan, Central America, and Caribbean islands 30 to 45 minutes after sunset, and they fly through the night. The distance from these departure sites to the U.S. Gulf coast is 400 to 600 miles; under favorable weather conditions and depending on the species (and thus flight speed) birds arrive from just before dawn to the late morning or early afternoon. If birds encounter unfavorable weather conditions, such as those associated with a frontal passage, their arrival can be delayed by many hours. Migrating birds do not fly well through heavy precipitation and will often be forced to land if a storm is strong enough. If the birds can detect the storm by sight, smell, sound, humidity, or pressure, they may fly around or away from it (summarized from S. Gauthreaux).

A substantial number of raptors migrate through the LGC during fall. For example, the Hazel Bazemore Hawk Watch is conducted annually near Corpus Christi (Nueces County). The count of raptors for the 2004 season totaled 1,030,762 birds as follows by species:

1,016	Black vulture
17,750	Turkey vulture
205	Osprey
34	Swallow-tailed kite
2	White-tailed kite
4,440	Mississippi kite
3	Bald eagle
101	Northern harrier
895	Sharp-shinned hawk
480	Cooper's hawk
24	Red-shouldered hawk
989,875	Broad-winged hawk
14,753	Swainson's hawk
178	Red-tailed hawk
2	Ferruginous hawk
19	White-tailed hawk

1	Short-tailed hawk
2	Zone-tailed hawk
23	Harris's hawk
1	Golden eagle
365	American kestrel
32	Merlin
143	Peregrine falcon
2	Prairie falcon
4	Crested caracara
252	Unknown accipiters
48	Unknown buteos
15	Unknown falcons
88	Unknown raptors
9	Unknown vultures

Note that nearly 1 million broad-winged hawks were observed, along with more than 17,000 turkey vultures; 14,000 Swainson's hawks; and 4,000 Mississippi kites. The movement of raptors from areas to the north and then south into and along the Gulf Coast occurs along a broad front. Thus, there are millions of raptors moving through the Gulf Coast during fall (August through November).

Endangered and threatened species found in Texas include the peregrine falcon, bald eagle, black-capped vireo, eastern brown pelican, golden-cheeked warbler, interior least tern, piping plover, whooping crane, Mexican long-nosed bat, Rafineaque's big-eared bat, southern yellow bat, and spotted bat. Note that the whooping crane winters in an area centered at Aransas National Wildlife Refuge, which is located centrally along the LGC.

E. Proposal to Develop Risk Assessments

1. Development of a strategic plan for wind development

The United Kingdom has completed a Strategic Environmental Assessment (SEA) for wind-energy development, a process that is similar to the Environmental Impact Assessment process in the United States. Also, other European counties have strategic plans in motion. For example, the potential for substantial offshore development of wind resources led the United Kingdom to develop a comprehensive strategy for siting wind farms. The United Kingdom's Department of Trade and Industry (2002) developed a strategy that sets out the government's analysis, options, and proposals for offshore development. The conclusion of the consultation was to launch a strategy for offshore wind farms that will:

- Establish a site allocation process that promotes efficient development;
- Use strategic environmental assessment to guide the pattern and scale of development;
- Ensure proper evaluation of impacts through strategic planning and consenting processes;

- Provide for monitoring, mitigation, and control of individual and cumulative impacts;
- Deliver consistent and transparent regulatory decisions in an efficient manner.

The program developed by the United Kingdom is proactive and considers potential development across a broad area. Such planning, if implemented along the Gulf Coast, would allow for a comprehensive analysis of wind-energy development and thus result in identification of specific locations that could support wind development in an economically viable and environmentally acceptable manner. This process also allows for development of a true cumulative impact assessment of likely environmental impacts, and leads to comprehensive mitigation as warranted.

2. Research and monitoring

To minimize the potential risks from wind turbines, it is important to first assess what those risks are. Prior to the development of the first large commercial wind farms in North America, protocols and methodologies for assessing risks to birds within wind resource areas had not been developed. Assessments of other potential environmental impacts, such as impacts on habitat and animal movements and visual and noise impacts, were minimally considered.

During the early years of wind farm developments, specifically in California, it became apparent that bird collisions, especially raptors, with wind turbines were occurring. Approaches to assessing potential environmental impacts needed to be developed.

3. Initial site selection and permitting

The National Wind Coordinating Committee (NWCC), a collaborative of representatives from the environmental community, wind energy industry, state legislatures, state utility commissions, consumer advocacy offices, green power marketers, and federal and state governments, was established in 1994 to support the development of wind power. The NWCC Web site is www.nationalwind.org/. The Siting Subcommittee of the NWCC was formed to address wind generation siting and permitting issues. This subcommittee prepared a collaborative document, entitled *Permitting of Wind Energy Facilities: a Handbook* (www.nationalwind.org/publications/permit/permitting2002.pdf) to provide guidance in evaluating wind projects for all stakeholders. Some aspects of wind facility permitting closely resemble permitting considerations for any other large energy facility or other development project. Others are unique to wind generation facilities. Unlike most energy facilities, wind generation facilities tend to be located in rural or remote areas and are land-intrusive rather than land-intensive. Thus, they may extend over a very large area and have a broad area of influence, but physically occupy only a small area for the turbine towers and associated structures and infrastructure (e.g., roads, transmission lines). The rest of the land may be used for other activities.

This NWCC handbook outlines the many factors that must be considered when permitting a wind generation facility, including (but not limited to) land use, noise, birds and other biological resources, visual resources, soil erosion and water quality, cultural resources, and socioeconomic considerations. Permitting processes that result in timely decisions, focus on the critical issues early, involve the public, and avoid unnecessary court challenges will enable wind generation to compete with other energy technologies and provide a diverse supply of energy.

As summarized by the National Wind Coordinating Committee (www.nationalwind.org/events/offshore/2003/summary.pdf), wind power developers in North America are beginning to look offshore for greater wind resources and lower costs. As this is a new application for wind power in the United States, the NWCC noted that background information is needed about environmental, technical, economic, and political issues associated with offshore developments. Some of this information can be gathered from Europe as researchers there have been working on offshore wind energy development for the past decade. However, each situation varies and thus local factors need to be taken into account.

4. Sampling protocols

Sampling protocols and methods of quantifying bird fatalities in the field must be rigorous and scientifically valid. Failure to establish rigorous protocols and methods results in data sets that are subject to criticism and are not ideal for determining how to reduce wildlife fatalities in wind developments.

The NWCC Wildlife Workgroup (formally the Avian Subcommittee) formed to address avian interactions with wind developments. It also identifies research needs and serves as an advisory group. To address differences in methodologies, lack of adequate control or baseline data in existing studies, and the resulting lack of interstudy comparability, the NWCC adopted a consensus guidebook titled *Studying Wind Energy/Bird Interactions: A Guidance Document* (www.nationalwind.org/publications/wildlife/avian99/Avian_booklet.pdf). The document provides a comprehensive guide to standardized methods and metrics to determine impacts to birds at existing and future wind farm sites. A stated purpose of the guide is to promote efficient, cost-effective study designs that will produce comparable data and reduce the overall need for some future studies.

The *Guidance Document* identifies three levels of surveys of increasing intensity that should be applied to a proposed or developing wind development. Although focused on birds, these general guidelines can be applied to most aspects of the environment. "Site evaluation" or "reconnaissance" surveys are relatively nonrigorous and use primarily published literature and nonpublished reports, expert opinions, and other sources of information to make a first determination as to whether a proposed site will likely have environmental problems. Such reconnaissance surveys are cursory in nature but should help eliminate problematic sites from further consideration. If the reconnaissance survey indicates that the site should be suitable for development, then a "level 1" protocol is indicated, in which more intensive and quantitative onsite surveys occur, usually for a minimum of 1 year prior to a decision to proceed with development. Such level 1 surveys include onsite sampling of wildlife movements and other activities (e.g., foraging and nesting), quantification of the presence and abundance of sensitive species, and development of projections on potential bird and bat fatality levels based on risk assessment. If a decision is made to proceed with development after level 1 surveys have been evaluated, then the data set also serves as the "before" data to be compared with changes in environmental conditions following ("after") development. In rare cases, the results of a level 1 study indicate that more intensive study is necessary, such as when the presence of a legally protected, threatened, or endangered species is located.

The methodology used to conduct fatality searches will vary, dependent on the terrain and rigor required to adequately assess a site. Often the level of rigor is dictated by the budget available for the task. Ideally, the appropriate budget will be allocated to conduct the level of work required for the specific site under consideration. Search methods have been developed and have proved very successful under research studies funded by the Department of Energy's National Renewable Energy Laboratory. These search methods have been developed for both flat and steep terrain.

Additionally, other efforts are ongoing to increase the guidance available for placing and operating wind developments. For example, the U.S. Fish and Wildlife Service (USFWS) released a document entitled *Interim Guidelines to Avoid and Minimize Wildlife Impacts for Wind Turbines* (10 July 2003). The stated intent of the USFWS was to have experts on wildlife-wind turbine interactions evaluate these guidelines over a 2-year period and provide comment to the USFWS; a revised document would then be prepared (but is not available at this writing). The Wildlife Workgroup will also be developing a companion document to the guidance document that will focus on nocturnal species (birds and bats). And, several states have or are in the process of developing their own standards or guidelines/requirements for wind developments (e.g., Maryland, Michigan, Washington, Virginia, and California).

Many European countries limited the size of initial off-shore developments so careful environmental analysis could be conducted before implementing full-scale projects. For example, the United Kingdom initially limited offshore wind farms to 30 turbines to reduce environmental and visual impacts, and to ease the cost of decommissioning and dismantling when problems arise. Now, commercial developments (over 1000 MW) are in operation.

5. Risk reduction

a. Wind farm operation

Recognition of the potential avian fatality risk has influenced the selection criteria used in developing some new WRAs. Along with providing a framework for the development of more robust experimental field design, use of standardized protocols (as reviewed above) has greatly enhanced researchers' ability to compare and analyze data among studies from various WRAs.

Decreasing operation time of problem turbines or WRAs has been suggested as a risk reduction measure. Critical shutdown times could be seasonal (e.g., during migration periods) or based on inclement weather or nighttime periods when visibility is reduced. For example, permitting requirements for a new wind development in Maryland included the option for restricting turbine operations if bird fatalities were found to occur during peak migration periods. Economic consequences of any kind of adjustments to operation time should be considered prior to site construction so that the developer can make a feasibility assessment. Most of the newer wind turbines in the Altamont Pass repowering areas will increase operation time by as much as 55%. The effect that such an increase in operating time will have on bird fatalities is unknown and deserves study. As noted above, some European governments limit the size of wind developments to ease the financial ramifications of closing a development.

Design and maintenance characteristics of road and structures may indirectly contribute to higher bird fatality rates by increasing prey densities. It has been suggested that vertical and lateral edges and other features associated with roads, turbine pads, and maintenance areas may create suitable burrow sites for raptor prey in the vicinity of wind turbines, with a corresponding increase in raptor foraging activity. Newer facilities that are built with larger, more-efficient turbines require fewer roads and have a greater amount of space between them. In addition, many of the newer facilities have underground distribution lines, greatly reducing the likelihood of wire collisions and electrocutions. Offshore developments in Europe manage the movement of maintenance crews to minimize disturbance to birds and other animals.

b. Turbine characteristics and location

Lights seem to play a key role in attracting birds, and the lighting of tall structures appears to contribute to avian fatalities. Illuminating other taller aerial structures to make them more visible to aircraft has increased bird fatalities. Migratory species generally migrate at night and appear to be most susceptible to collisions with lit towers on foggy, misty, rainy, low-cloud-ceiling nights. Passerines migrating at night during poor visibility conditions appear to be particularly susceptible. Solid or blinking red lights seem to attract birds on foggy, misty nights more than white strobes, which may flash every 1–3 seconds. Preliminary research suggests that the longer the duration of the “off” phase, the less likely a light is to attract birds. The advent of turbines with longer blades that are mounted on tall towers could require the use of warning lights for aircraft in certain locations.

Studies indicate that tower placement is a site-specific phenomenon, but several key conclusions have been found: (1) irregularly spaced turbines might increase fatalities because birds try to negotiate the apparent gaps between turbines; (2) turbines placed close to the edge of ridges show higher fatality rates because raptors often hover in such locations; and (3) turbines placed near a gully have higher fatalities because birds often use these locations as flight paths.

Although no research has been conducted on auditory deterrents to birds approaching wind turbines, audible devices to scare or warn birds have been used at airports, television towers, utility poles, and oil spills. Most studies of auditory warning devices have found that birds become habituated to these devices. Birds do not hear as well as humans (Dooling 2002), and minor modifications to the acoustic signature of a turbine blade could make blades more audible to birds, while at the same time making no measurable contribution to overall noise level. Under certain conditions (e.g., high wind), birds might lose their ability to see a turbine blade before they are close enough to hear the blade. At present there is no research underway that tests the effects of auditory deterrents, and because of the low likelihood of developing a successful application, none is planned for the foreseeable future.

Motion smear, which makes the blade tips of wind turbines appear transparent at high speeds, could be reduced under laboratory conditions. Results suggest that a single, solid-black blade paired with two white blades (inverse blade pattern) could be effective at reducing visual smearing of blades. However, motion smear and a very narrow blade profile encountered when approaching from the side could be very risky for birds. One potential solution is a rectangular attachment to the outer tip at right angles to the long axis of the blade. The visibility and practicality of these attachments have not yet been evaluated (Hodos 2003).

c. Habitat management

The density of raptors at the Altamont Pass WRA is, at least in part, a result of high prey availability. San Gorgonio and Tehachapi WRAs, California, have lower prey densities, lower raptor densities, and lower per-turbine fatality rates. Prey densities appear to be highest at disturbed sites such as roads and turbine pads, the latter of which would exacerbate collision risk. Reducing prey populations within the vicinity of wind turbines might reduce high-risk foraging activities for raptors. Suggested methods include county-sponsored abatement programs, reduced grazing intensities, and revegetation with higher-stature plants that pocket gophers and ground squirrels tend to avoid. These measures, however, could impact other populations, including special-status species such as the San Joaquin kit fox, burrowing owl, and badger.

It has been suggested that in areas where high densities of gopher burrowing systems are found, controlling populations in the immediate vicinity of wind turbines could be effective. They cautioned, however, that small mammal abatement efforts by ranchers in surrounding areas could exacerbate the effect of burrow clusters in the vicinity of turbines by increasing the focus of raptor foraging. This effect occurs when there is rapid recolonization and higher-than-average densities of gophers on edges of abatement areas. Research would have to evaluate reduced grazing or revegetation with higher structure plants to determine its effects on fire management, watershed protection, and other land-management practices.

Habitat modification to reduce prey densities has been discussed as a possible avian risk-reduction technique. There have been some efforts to reduce ground squirrel populations in portions of the Altamont Pass WRA, but no results of the effects on reducing raptor mortalities have been published to date. The effects of a widespread control program would have to take into account the effects on other wildlife, such as protected species that prey on ground squirrels or depend on their burrows for nesting and cover habitat. Widespread use of rodenticides or other measures to remove prey may prove to be controversial and costly. Feasibility of more benign habitat modification measures—such as manipulation of annual grassland grazing practices or conversion to perennial grassland—may be worth studying. However, any reduction in habitat quality would likely cause an ultimate, although indirect, negative impact on birds. For example, although reducing prey in wind developments might lower bird fatalities, it could also result in bird starvation or fatalities in other locations. It was shown in The Netherlands that turbines adjacent to the Wadden Sea showed a higher rate of bird kills compared to turbines in upland areas. These higher kills appeared to be related to the large number of birds in and around the sea compared to the upland locations. Unfortunately, virtually no information is available on fatalities at offshore wind farms in Europe.

d. Turbine treatments

Effective visual treatments could provide a cost-effective method to reduce risk from turbines determined to cause fatalities. Laboratory and field tests of treatments that make turbine blades more conspicuous to raptors and other birds are needed.

6. Research needs

The priority research objective is to quantify seasonal occurrence, abundance, and location of bats and birds along the LGC. Specifically, research should focus on the following issues.

- The location, magnitude, and timing of movements of raptors during fall migration
  - Because of the substantial numbers of raptors migrating through the LGC, and the known rates of raptor fatalities in wind facilities, there is potential for substantial raptor fatalities at new wind installations. Although "hawk watch" locations and data sets are available, they are few in number and should be substantially expanded to gain a better understanding of the extent of raptor migration. But with nearly 1 million broad-winged hawks passing by a single observation station, the potential for substantial seasonal fatalities exists.
- The location, magnitude, and timing of movements of bats and birds during spring and fall migration
  - It appears that a substantial number of passerines and other nonraptorial birds move along the LGC during migration, likely staying close to the coastline and along the nearshore area. Such behavior could increase the risk for these species relative to direct flights out over the Gulf.
- Identification of locations where rare and endangered species (bats and birds) occur during breeding and nonbreeding periods

  - A number of the raptorial species that migrate through the LGC are rare or threatened/endangered in Texas and other regions of the United States, including the peregrine falcon, Swainson's hawk, osprey, and bald eagle.
- Identification of any special environmental features that could concentrate bats and birds (e.g., roosting caves for bats, riparian areas for birds)
  - Surveys should be conducted to identify any potential bat roosts, foraging areas (e.g., open water), locations of concentrated bird activity (e.g., springs, riparian areas), and other environmental features that could concentrate bats and birds near proposed wind facilities.

It is not possible to identify specific locations or species for study in the absence of knowledge of likely sites for wind-energy developments. Thus, wind-energy developers are encouraged to work closely with bat and bird ecologists in conducting initial screening of potential development sites. Such screenings are frequently termed "reconnaissance" surveys, and are designed to eliminate areas of high bat or bird use from being developed as wind-energy facilities. Reconnaissance surveys need to be of sufficient intensity and duration to adequately quantify bat and bird use of a potential development site during all seasons of the year. Brief visits to potential development sites are inadequate. In all cases, what are frequently termed "Phase I" surveys should be initiated at all sites likely to be developed. Phase I surveys build on reconnaissance surveys and incorporate more intensive study of the distribution and abundance of bats and birds. Phase I surveys incorporate rigorous counts of all bird species using methods appropriate to major bird types (e.g., songbirds, raptors, and waterfowl). Methods for quantifying bat use of potential wind developments are undergoing a rapid growth, and include radar, acoustic recordings, thermal imagery, and other techniques. The "metrics" document (Anderson et al. 1999) produced by the NWCC is being revised to incorporate many of the techniques available for bats and birds.

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The purpose of this paper is to discuss the possible impacts of wind development to birds along the lower Gulf Coast, including both proposed near-shore and offshore developments. The report summarizes wind resources in Texas, discusses timing and magnitude of bird migratrion as it relates to wind development, reviews research that has been conducted throughout the world on near- and offshore developments, and provides recommendations for research that will help guide wind development that minimizes negative impacts to birds and other wildlife resources.

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