Wind Power Development and Raptor Migration in the Central Appalachians

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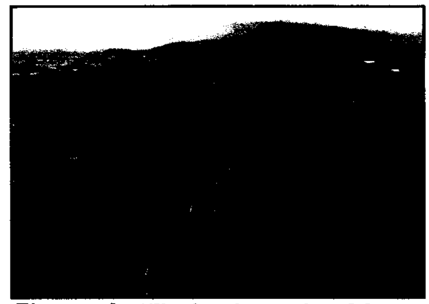

Figure 1. *Wind turbines along Moosic Mountain near Waymart, Pennsylvania.*

Introduction

The recent spike in gasoline prices after landfall of Hurricane Katrina was a sharp reminder of our dependence on low prices of fossil fuels and underscored the need to further develop other sources of energy. Wind power is a promising renewable energy source with relatively low environmental impact. Many environmental advocacy organizations and government agencies support wind power as the clean, green energy source of the future.

The U.S. Department of Energy (DOE) has a stated goal that 5% of U.S. electricity be generated by wind power by 2020; this will require construction of about 60,000 1.5-megawatt (MW) turbines (USGAO, 2005), the size typically used at new installations. Many states are also adopting "renewable portfolio standards" that require some specified percentage of electricity be provided by renewable energy sources (for example, in Pennsylvania the standard is 8% by 2020). Wind power currently accounts for only 1% of our electric power but is the fastest growing energy sector (USGAO, 2005), largely due to federal and state subsidies and tax shelters to boost renewable energy production. These incentives and a willingness of some customers to pay more for "green power," have resulted in a number of new wind plants in the central Appalachian region (defined for this paper as Pennsylvania (PA), western Maryland (MD), West Virginia (WV) and western Virginia (VA)). Many more sites are in the planning stages.

Figure 1 shows an aerial view of the 43-turbine Moosic Mountain wind power site in northeastern PA. Such ridgetop developments are raising concerns among hawkwatchers and scientists about the potential impact of large scale wind power development on migrating raptors in the region, despite assurances of minimal risk from the wind power industry. HMANA recently adopted a resolution regarding pre-construction monitoring and siting of wind turbines within migration flyways (see www.hmana.org).

This paper briefly reviews what is known about raptor collision risk from studies at existing wind power plants, as well as what is known about raptor migration in the central Appalachians that is relevant to the issue of siting and the operation of new wind power facilities. Factors that may make some raptor species more at risk than others are also discussed. Finally, implications and recommendations are presented. The paper is based on my own experience, discussions with wind power industry personnel, published reports about the impact of wind power facilities on raptors, review of raptor migration literature and review of migration count data published in HMANA's *Hawk Migration Studies* and HawkCount database (hawkcount.org).

Background

The feasibility of a particular wind power site depends primarily on two factors: average wind speed and access to transmission line infrastructure. Turbine power generation varies with wind velocity to the third power, so the viability of a facility is highly dependent on wind speed. Wind power resources are grouped into "classes" ranging from 1 to 7, based on mean wind speed. Areas that are potentially suitable for wind energy have winds of at least class 3 (about 6.5 to 7 m/sec at a 50-m measurement height). In the Appalachian region, wind class is strongly correlated with elevation (see *Wind Energy Resource Atlas of the United States*, http://rredc.nrel.gov/wind/pubs/atlas/ for more information). Ridgetops of the ridge-and-valley province of the central Appalachians generally fall into the class 3 and 4 categories. Areas with class 4 and 5 winds include the Pocono Plateau in PA, the Blue Ridge of VA, and the Allegheny Plateau of PA, western MD, eastern WV and western VA. Portions of the high Allegheny Plateau of WV are rated class 6. Because winds vary considerably by season, turbine output is highest in winter and lowest in summer.

The potential conflict between wind power and raptors is now clear, as raptor migration is often concentrated along higher elevations (Mueller and Berger, 1967) such as ridgetops and the edges of plateau escarpments because of the presence of updrafts from deflected surface winds. This potential is recognized by the United States Fish and Wildlife Service (USFWS), which has issued interim guidance on the proper siting of wind power facilities to avoid or minimize impacts (USFWS, 2003). These guidelines stress careful evaluation of each monitoring site due to local differences in migration patterns, habitat, topography and weather. The recommendations include "avoid locating turbines in known local bird migration pathways or in areas where birds are highly concentrated, unless mortality risk is low," and to "configure turbine locations to avoid areas or features of the landscape known to attract raptors." However, these are guidelines not requirements. Neither the USFWS nor state wildlife agencies have prosecuted any cases for raptor strikes (USGAO, 2005). The legal authority to issue permits to wind power facilities is not held by the USFWS; rather it is governed by local land use ordinances (PA) or a combination of state and local regulations (WV, MD, VA). Due to concerns about the environmental impact of wind-energy projects (including avian impacts), a National Academy of Sciences panel has recently been established to examine these issues, focusing on the Mid-Atlantic highlands region.

Data From Existing Wind Power Facilities

Much of the concern regarding raptors and wind power stems from one particular site: Altamont Pass near Livermore, California (Figure 2). This facility of approximately 5000 turbines (the world's largest) was installed in the 1970s and is located in an area of rolling grassy hills where high densities of wintering raptors are attracted by the habitat and high prey base. Studies of impacts on raptors have been conducted for several decades at the site (many of these are available on-line). It is estimated that 881 to 1300 raptors are killed annually, including 75 to 116 Golden Eagles, 209 to 300 Red-tailed Hawks, and 73 to 333 American Kestrels (Smallwood and Thelander, 2004). Recently, an agreement was reached to temporarily shut down many of the Altamont turbines from November 2005 through February 2006, when the highest numbers of raptors are present.

The collision problem at Altamont has led to studies at the University of Maryland and Boise State University (funded by the National Renewable Energy Laboratory) on raptors' visual perception of rotating turbines. Several color schemes designed to help raptors better see and thus avoid the turbines have been proposed, but field testing of their effectiveness was inconclusive and further research is needed.

Although the Altamont case raises much concern about the impact of wind power generation on raptors, mortality of that magnitude is unlikely to occur in the Appalachians, where raptors would typically migrate past turbines, rather than winter and forage near them. Fatality rates at other wind power facilities in the U.S. have been much lower than at Altamont, generally less than one raptor per ten turbines per year (National Wind Coordinating Committee, 2004; USGAO, 2005). However, almost all of the sites studied so far have not been near raptor migration routes, and no mortality studies have been conducted for most facilities (USGAO, 2005). So the broad statement from the American Wind Energy Association's *Wind Energy and Wildlife: Frequently Asked Questions* (www.awea.org/pubs/factsheets.html) that "post-construction monitoring of bird kills at several wind sites in a wide variety of geographic locations ... has validated the industry's ability to assess risk to birds and build safe projects" cannot be accepted because existing mortality data cannot be extrapolated to larger-scale future developments in higher risk locations. Further, because of the lack of empirical data, it is not known if the larger newer generation turbines now being installed in the Appalachians pose less risk than the smaller turbines constructed at Altamont in the 1970s (NWCC, 2004).

An attempt was made to gather post-construction monitoring mortality data for this paper from operating sites in the central Appalachians, including those at Mill Run, (PA), Garrett (PA), Somerset (PA), Moosic Mountain (PA), Meadow Mountain (Myersdale, PA) and Mountaineer (Backbone Mountain, WV). The Mill Run, Garrett and Somerset sites are located on the Allegheny Plateau, while the other three are located on ridgetops.

At the 8-turbine Mill Run site located in farmland, 17 surveys were conducted from June 2000 through May 2001, and no raptor fatalities were reported (Kerlinger, 2001). This is not surprising, given the site's location far from any topographic leading lines. For the 44-turbine Mountaineer site located on a long ridge where raptor migration is known to occur (Titus and Mosher, 1982; Heintzelman, 2004), 1 Red-tailed Hawk and 2 Turkey Vulture carcasses were discovered during weekly searches between April and mid-November, 2003 (Kerns and Kerlinger, 2004). This suggests that risk is low; however, it is not known how many raptors were migrating and if any large flights occurred during the study period. Many more turbines are planned along Backbone Mountain in MD north of the Mountaineer site, so further migration monitoring and mortality studies along this ridge would be highly valuable for quantifying the actual risk.

Apparently no post-construction studies were conducted for the other four sites listed, though at least two of them (Moosic Mountain and Meadow Mountain, which is an extension of the Allegheny Front) are located along prominent leading lines. Thus, actual collision risks posed by newer generation wind power facilities to migrating raptors in the region have been very poorly studied and are largely unknown.

One site from outside the Appalachian region with pre- and post-construction monitoring data is the Foote Creek Rim site, a mesa top west of Laramie, Wyoming (the first commercial wind power site in Wyoming). Pre-construction monitoring at the site found that the mesa rim was frequently used by Golden Eagles. As a result, turbines were sited 50 m from the rim. Three years of post-construction monitoring documented no Golden Eagle fatalities and produced a raptor mortality rate of 0.03 raptors per turbine per year. This case illustrates the value of thorough pre- and post-construction monitoring for designing low risk wind power facilities. Setbacks from escarpment rims are one risk-reduction method that should apply well to some sites in the Appalachians, although this would be precluded on narrow ridgetops.

Learning From Hawkwatch Data

The wealth of data collected at a few long-term raptor monitoring sites, as well as at many other hawkwatches in the central Appalachians (Heintzelman, 2004; Zalles and Bildstein, 2000), provides a basis for describing the general dynamics of raptor migration relevant to the siting of wind power facilities in the region. Such data can be used as an indicator of potential collision risk, particularly when flightpath data are collected (Smith, 2005); however, one cannot infer actual risk, because migrating raptors are likely to alter their flight patterns near turbines. Although hawkwatch counts are biased toward low-flying birds (Newton, 1979; Kerlinger, 1989), this bias does not reduce the value of the data for assessing risk potential, because raptors are easily visible at the altitude of typical 1.5-megawatt wind turbines (120 meters above ground).

Fall Migration

The Kittatinny Ridge (Blue Mountain) has the highest annual numbers of migrant raptors in the region, typified by the consistently high counts at Hawk Mountain and Waggoners Gap (north of Carlisle, PA). Although raptors clearly follow the Kittatinny Ridge, the numbers and species of raptors are not entirely consistent from one site to another, indicating that many raptors leave and join the ridge rather than adhering to it for long distances. Raptor migration pathways to the southwest after leaving the Kittatinny Ridge are unknown. Presumably, the flight becomes more scattered on the many folded ridges just west of Waggoners Gap; however, several prominent ridges continue farther southwestward into eastern WV, and other than a few exploratory counts conducted 50 years ago (DeGarmo, 1953), little is known of flights in this area.

Raptor migration also occurs along the ridges north and west of the Kittatinny Ridge. Species composition is similar to that along the Kittatinny, but seasonal totals are significantly lower (Van Fleet, 2001). However, one species, the Golden Eagle, apparently migrates in greater numbers along the more western ridges than on the Kittatinny (Van Fleet, 2001; Goodrich, 1999); the timing of the Golden Eagle migration along these western ridges is later, and flights of more than 20 Golden Eagles per day extend into December on Bald Eagle Mountain, PA (pers. obs). Farther south, hawkwatch data from the Blue Ridge of VA and at several ridge-and-valley sites in southern WV indicate similar numbers of migrants as at the PA ridges in September, but generally much fewer mid and late season migrants (DeGarmo, 1953). However, late season coverage at most sites south of PA has been very spotty.

Little is known of the migration over the Allegheny Plateau region, although the Allegheny Front, which marks the eastern edge of the plateau, is a major leading line through the region (DeGarmo, 1953; Titus and Mosher, 1982). Counts along this geographic feature in WV, MD and PA indicate it is a significant migration route. Some of the most remarkable flights in the region in recent years occurred at Allegheny Front, Bedford County, PA, on light southeasterly winds (the same conditions found by DeGarmo (1953) and Titus and Mosher (1982) to result in large flights). On November 23, 2003, 51 Golden Eagles passed the hawkwatch, the same number as recorded three days earlier at Franklin Mountain, NY. On October 26, 2004, more than 2,000 raptors were counted, including 82 Red-shouldered Hawks, 1,156 Red-tailed Hawks and 24 Golden Eagles. In a near repeat of the November 2003 flight, 48 Golden Eagles were tallied on November 14, 2005, again three days after a new eastern U.S. record flight of 71 passed Franklin Mountain. This suggests a regional-scale connection across PA between these two sites.

These impressive counts at Allegheny Front illustrate that while the Kittatinny Ridge consistently has the highest annual numbers and often the highest daily counts, other sites also concentrate large numbers of raptors under particular weather/wind conditions. These conditions are distinctly different at different sites, due to the combination of wind direction and terrain orientation required to produce updrafts. For example, it is well known that the passing of a cold front followed by northwest winds brings good raptor flights along the Kittatinny Ridge in eastern PA (Broun, M., 1949; Allen et al., 1996). However, northwest winds do not bring good raptor flights along the Allegheny Front and at Jacks Mountain in central PA where southeast winds bring the best flights. As a result, site-specific pre-construction monitoring data is necessary for each proposed site, both to understand that site's general migration patterns and to document the specific conditions associated with large flights. This cannot be determined based on part-time or single season observations, because weather conditions and flights are highly variable.

Spring Migration

Spring totals at hawkwatches in the Appalachians are significantly smaller than in fall, and flights are much less consistent, indicating that raptors are less inclined to divert their migration along topographic leading lines. Therefore, spring is also likely to be a time of lower collision risk than the fall. However, even then large flights can occur under rather specific conditions—typically warm southerly winds with clouds, particularly after an extended wet period.

An exception to this general conclusion is the Golden Eagle. This species has a more spatially concentrated migration in spring (through the western portion of the ridge-and-valley province) than in fall (Brandes, 1998), and 150+ are recorded each spring at Tussey Mountain in central PA. Large spring flights also occur consistently along the Allegheny Front. Part-time monitoring at other sites (e.g., Sideling Hill, PA, and Town Hill, MD) also suggests a concentrated spring migration. This indicates a dependence on terrain updrafts that is not seen in other raptor species in spring.

Raptor Species Most at Risk

A variety of factors can be expected to contribute to the risk posed by wind turbines to migrating raptors. These factors relate to species-specific migration patterns, migration timing and flight style. A discussion of these factors follows, with the objective of qualitatively determining relative risk among raptor species.

First, species that migrate primarily over ridges and high plateaus are more vulnerable, because they spend more time in the terrain where wind turbines are (and will be) located. In general, raptors migrate over both high terrain and lowlands. However, some species are seen in much larger numbers along the Atlantic coast than at ridgetop sites, including Osprey, Northern Harrier and all three falcon species. Others are seen in similar numbers in the mountains, Piedmont and coastal plain, such as Sharp-shinned Hawk, Cooper's Hawk, Broad-winged Hawk and Red-shouldered Hawk. Based on available count data, only the Northern Goshawk, Red-tailed Hawk and Golden Eagle appear to have a marked tendency to migrate primarily in regions of high terrain. Note that all three of these species are late migrants, which relates to the second factor.

Second, species that migrate primarily during time periods of reduced thermal lift are more reliant on wind and terrain-induced updrafts and so are more oriented toward topographic features. This includes Northern Goshawk, Red-tailed Hawk, Red-shouldered Hawk and Golden Eagle. Rough-legged Hawk is also included although its movements southward into the region are irregular and involve very low numbers. As previously stated, the Golden Eagle is unique among the raptor species in the region as the size of its early spring migration (late February through March) along the ridgetops is similar to that of its fall migration.

Third, species that often glide in ridge updrafts during migration are more likely to follow topographic features at low altitude and so are more at risk. Species that rely fairly exclusively on thermals (Broad-winged Hawks) or those that often utilize powered flight during migration (kestrels, Merlins and Peregrine Falcons) are less dependent on updrafts and are less vulnerable to strikes during migration.

Fourth, species that migrate in large flocks are more vulnerable because a single collision event could affect many birds. Turkey Vultures and Broad-winged Hawks are the two species likely to migrate in large flocks in this region. Studies at Altamont Pass suggest that Turkey Vultures are not susceptible to collision. However, at Tarifa, Spain (near Gibraltar), many Griffon Vultures have been killed by turbines.

Fifth, species that often hunt along ridgetops during migration are at higher risk than those that do not. Foraging near turbines is believed to be a critical factor in the high collision rates at Altamont Pass. Generally, species that use aerial hunting methods such as thermal and slope soaring, kiting, hovering and stooping are most at risk. Species that typically forage within the forest canopy or just above ground are at lower risk. A recent study (Hoover and Morrison, 2005) indicates that kiting in strong updrafts is the highest risk behavior for Red-tailed Hawks at Altamont. This behavior is commonly observed in Red-tailed Hawks during migration in the Appalachians and sometimes by Golden Eagles.

Sixth and finally, species with small populations have higher relative risk, because of the higher likelihood of population-scale effects. Although total population estimates are generally not available for raptors migrating through the Appalachians, some species, such as Broad-winged Hawks, Sharp-shinned Hawks and Red-tailed Hawks are much more numerous than others. Raptors listed on state threatened and endangered lists for the four states considered here are Bald Eagle, Golden Eagle, Osprey, Northern Goshawk and Peregrine Falcon. The relative significance of five goshawks striking turbines is thus greater than that of five Sharp-shinned hawks striking turbines.

An overall summary of the six identified risk factors is shown in Table 1. Assuming (for lack of additional data) that the risk factors have equal weighting, Golden Eagle, Red-tailed Hawk and Northern Goshawk are the species at highest risk from wind power development in the region. The Golden Eagle appears to be at the highest risk, as a large fraction of its small eastern North American population migrates along the ridges of the central Appalachian region in both fall and spring, and some regularly winter in areas being considered for development (e.g., Highland County, VA). It is also rare (in the eastern U.S.), long-lived and has slow reproduction rates. In contrast, Northern Goshawks appear irregularly along the Kittatinny Ridge and in very small numbers elsewhere in the region during fall migration and are very rarely seen during spring migration. Red-tailed Hawks will likely suffer the most collisions but are common throughout the region.

It should not be inferred from Table 1 that species such as Sharp-shinned Hawks, Cooper's Hawks, Broad-winged Hawks and American Kestrels are unlikely to collide with ridgetop turbines. However, the relative overall risk of these species appears to be lower than others. Further data is needed to assign weights to the risk factors and thereby develop a more refined risk analysis.

Implications

Based on this discussion, the potential for raptor mortality at new wind power plants in the central Appalachians, a region well known for raptor migration along its many ridges and escarpments, is clear. Despite the USFWS guidance, wind power sites are being proposed in the region on known raptor migration pathways. Continuing the current uncoordinated, inconsistent and largely unregulated approach to pre- and post-construction monitoring and siting is not conducive to determining how site location, design and turbine operation affect collision risk. Until more rigorous monitoring is required of developers, the impact on raptors will remain largely unknown, and both sides of the issue will continue to put forth politically, financially and emotionally motivated arguments to promote their respective agendas. Consequently, there will be very little gain in scientific understanding of the issue.

Raptors die during migration from a variety of causes, including starvation, shooting, extreme weather events and exhaustion during water crossings, although little quantitative data exists on migration mortality (Newton, 1979; Kerlinger, 1989). The challenge is to develop the wind resource without adding a new cause of significant mortality during migration, and the issue of what defines "significant" will undoubtedly be the subject of much debate.

Perhaps it is more reasonable to define "significant" with respect to raptor migration pathways. Clearly, some pathways in the region (such as the Kittatinny Ridge, designated as a Globally Important Bird Area by the American Bird Conservancy) have such ecological value that no wind power projects should be sited along them. Other significant pathways have been identified as Important Bird Areas (e.g., Tussey Mountain, Stone Mountain and Bald Eagle Mountain in PA). Pathways with fewer numbers of migrants can likely be safely developed if turbine siting conforms to certain standards (e.g., setbacks from locations with updrafts) and operational constraints (e.g., shut-downs during the peak migration season of high-risk species or temporary shutdowns during high-risk weather conditions) based on preconstruction monitoring. Undoubtedly, raptor migration at many potential wind power sites in the region is minimal and thus collision risk is insignificant.

The following points are relevant to determining which sites fall into which of these categories:

- Plateau sites inherently have much lower risk than sites on narrow ridgetops or those near the edges of escarpments where updrafts are present.
- Multi-year full-time migration monitoring conducted before turbine construction is necessary for all sites located along topographic leading lines to determine site-specific migration patterns and the weather conditions that result in large flights.
- Multiyear post-construction monitoring data should be collected at all sites located along topographic leading lines until collision risk is better quantified.
- Golden Eagle appears to be the species most at risk, so particular attention should be paid to spatial and temporal migration patterns of this species in the design of monitoring protocols and mitigation strategies.

Finally, one must consider that the cumulative impacts of dozens of wind power plants containing thousand of turbines could adversely affect raptors, even if direct mortality from turbine strikes is insignificant. If raptors abandon historic migration pathways to avoid long strings of ridgetop turbines, they are likely to take new routes that are more energetically expensive, through less suitable habitat, and perhaps make them more prone to mortality from other human causes. Therefore, a regional perspective that considers the connectivity of migration pathways is necessary to fully understand the impact of large-scale wind power development in the region. Smith (2005) suggests this could be explored through regional scale migration modeling.

Recommendations

In conclusion, I offer three recommendations. First, NWCC (1999) has produced the report *Studying Wind Energy/Bird Interactions: a Guidance Document*, that contains a wealth of information on study design, sampling methods and statistical methods for data interpretation. However, the report does not cover recommended field methods. Based on the studies I have reviewed, widely varying methods have been used during pre-construction monitoring in the region. In several cases, inadequate data collection has resulted in inaccurate conclusions about raptor migration. This indicates that a recommended practice document on field methods in raptor migration monitoring is needed for proposed wind power sites.

Second, a map of known and suspected significant raptor migration flyways through the region should be compiled based on all existing data. This would serve to highlight areas that should not be developed until further research on collision risk is completed, as outlined below.

Most importantly, I strongly recommend a coordinated peer-reviewed research effort to quantify actual collision risk and the response of migrating raptors to turbines. This would involve a set of rigorous pre-and post construction monitoring studies at turbine sites in a variety of topographic settings, over perhaps a five to ten-year period. Behavioral observations and radar can be used to study raptor response to turbines, and satellite telemetry and modeling can be used to study the connectivity of migration pathways on a regional scale. Ideally, this effort would involve a collaboration of federal agencies, states promoting wind power, wind power industry consultants and other experts in raptor migration. Such an effort will answer the basic question of whether turbines placed along migration pathways pose significant risk to migrating raptors. If the answer is yes, the collected data would form the basis for developing effective siting and operational requirements, and further research and testing would be warranted to develop safer turbine designs. If the answer is no, the wind power industry can expect much less skepticism from raptor enthusiasts.

Table 1. Summary of collision risk factors for migrating raptors in the central Appalachians.

Factor	TV	BV	OS	BE	NH	SS	CH	NG	RS	BW	RT	RL	GE	AK	ML	PG
Spatial pattern								X			X		X			
Temporal pattern								X	X		X	X	X			
Flight style	X	X	X	X	X	X	X	X	X		X	X	X			
Flocking	X									X						
Foraging	X	X		X							X	X	X	X	X	X
Population			X	X				X					X			X

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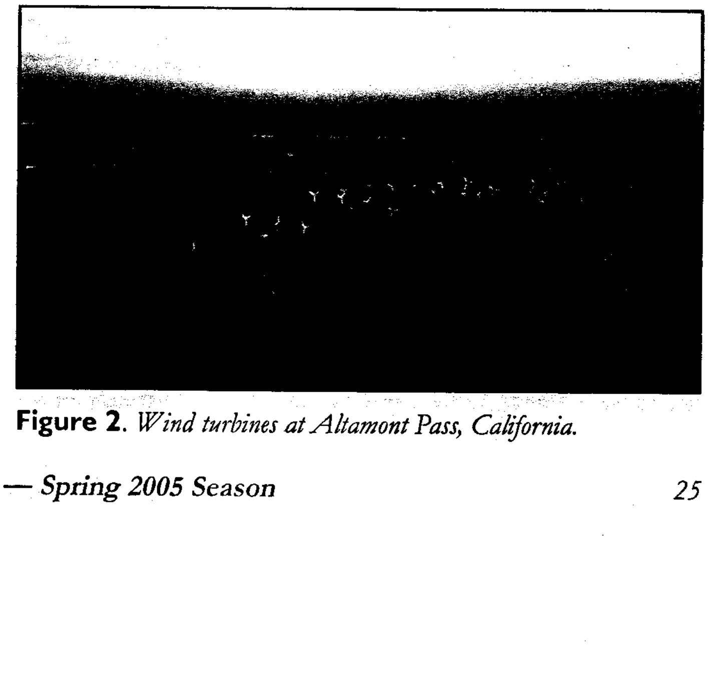

Figure 2. *Wind turbines at Altamont Pass, California.*