Mabey, S. and E. Paul. 2007. Critical Literature Review Impact of Wind Energy and Related Human Activities on Grassland and Shrub-Steppe Birds. Prepared for the National Wind Coordinating Collaborative by the Ornithological Council. The National Wind Coordinating Collabortive, Resolve, Inc., Washington, D.C. 183 pp.

Executive Summary: The Grassland and Shrub-Steppe Species Collaborative (GS3C), a subcommittee of the Wildlife Working Group of the National Wind Coordinating Collaborative (NWCC), commissioned this critical review of literature. This review pertains to the impacts of wind energy on grassland and shrub-steppe bird species. Its purpose was to examine the actual and potential impacts of wind energy facilities on grassland and shrub-steppe avian species. The impacts included mortality, avoidance, reductions in nesting success and adult survival, and behavioral changes. Commercial wind energy began in the United States in the early 1980s and did not grow appreciably until 1999. Thus, there is relatively little literature, and most comprises site-specific pre-construction wildlife evaluations with post-construction assessments of actual impacts. Studies of sublethal impacts (behavioral responses such as avoidance) are even rarer. The GS3C therefore requested that other anthropogenic activities that are components of or share some common features with wind farms be included, in an attempt to understand potential impacts in the absence of a substantial body of literature. These other activities are roads, urbanization, tall structures (including telecommunications towers and electric transmission lines and stanchions), and oil and gas extraction facilities.

We conducted a comprehensive literature search that included "gray" literature – a wide range of papers, articles, summaries and transcripts of talks, and other materials that did not appear in the peer-reviewed literature – and research from around the world (provided that the paper was available in English). All papers were screened through quality and relevance filters. We considered studies that pertained to grassland or shrub-steppe species or habitats to be relevant. The goal of the quality screening was to focus on well-designed research with adequate sample sizes and sound statistical or qualitative analyses. The selection process was based on the premise that papers of greatest interest would be those from which inferences could be drawn. This aspect of the review was particularly critical because many key questions about human activities have not been studied, or have been studied inadequately. Further, despite some commonalities, the human activities covered by the review were so diverse that only studies that investigated and assigned causation were deemed useful for understanding which components of these activities are of concern in wind energy development. For example, if a study showed that traffic on heavily traveled roads leads to settlement of particulate matter on plants, which destroys food sources or nesting materials or sites, the low level of traffic on roads leading to wind farms is not likely of concern, at least insofar as this particular effect is concerned. In contrast, a paper that shows an effect of weather – such as low cloud cover – on the rate of collisions with obstructions such as telecommunications towers – has implications for any obstruction. Weaknesses in the design or analysis of the papers included in this review are identified and discussed. Some papers have significant weaknesses, but are the best (or only) studies that examined a particular aspect of the activity or behavior of interest.

Wind energy: Mortality caused by wind energy development has been more frequently studied than have other impacts, and the studies are site specific. We found no landscape-level or regional studies of mortality, although combined fatality data from multiple independent studies in three regions of the country in which the study sites include some grassland or grassland-like habitat suggest that the lowest rate of mortality per megawatt of energy generated was 2.7 birds and the highest was 3.5 birds per megawatt. The lack of broader studies may be a function of the fact that studies of wind energy impacts tend to be initiated at the behest of regulatory agencies that respond to public concern or opposition, or by wind energy developers who seek to answer more general concerns about the impacts of wind energy. Studies have followed the development of the industry; thus, studies of Midwestern sites, which often include grassland sites, are fairly common. However, site variation made generalizing from the results difficult. Mortality appeared to be more strongly associated with migration than with local use of the area, although 30% of fatalities were resident or breeding birds. Passerines comprised 82% of the mortalities across nine sites. Few studies reported on the relative abundance of species at a site, and little inference could be drawn from the data. From the few papers that reported behavioral impacts, interesting and useful – but somewhat contradictory – observations emerged. Birds avoided areas with turbines, and although most flew below rotor height, those flying within the span of the rotors adjusted their flight patterns to avoid the spinning blades. Another study determined that configuration of the wind farm affected avoidance behavior, as did distance to other anthropogenic features. Birds stayed farther from strings than from clusters; the overall loss of foraging habitat caused by avoidance was three times greater than the loss of foraging area. Site characteristics such as wind speed and terrain affected the birds' ability to avoid turbines, particularly if they entered the turbine area from below the turbines. In this particular

study, there was no evidence that birds actively avoided the turbines. Population-level impacts were difficult to assess, because there were so few papers, and they were not representative of all landscape and habitat types. The results of papers reviewed here were inconsistent. Two showed a reduction in breeding populations (passerines and raptors), whereas two others found no effect. However, the designs were such that the ability to detect a true difference was weak. One study showed a marked difference in species abundance at control plots, as well as increased species richness, but little difference in community composition. Of particular interest is that avian density did not increase when turbines were turned off. In a second study, no raptors nested in a wind plant area, compared to 5.94 nests per 100 km2 in the surrounding area, which comprised similar habitat. However, the wind plant area would have otherwise been expected to support only two nests, so the finding might not have been significant. The results of a third study were mixed in that density of nonbreeding birds differed significantly from year to year and between the wind farms and the control sites, whereas the density of breeding birds was not significantly different between the sites. At an Oklahoma wind facility, nine of 22 breeding bird species (but only three grassland bird species) showed significant differences in density as distance from the turbines increased. Nine grassland bird species showed no difference in density as a function of distance. However, sample size was low and statistical power (ability to detect a difference) was probably inadequate.

Roads: Roads are key components of all the human activities included in this review. The papers discussed in this section assessed the edge effect of roads through grasslands, the quality of roadside habitat, and disturbance resulting from traffic. We found few studies of road-related mortality that focused specifically on grassland or shrub-steppe bird species. Behavioral impacts associated with edge effects were mixed, and none of the studies isolated the mechanism or mechanisms, other than noise and predation, responsible for observed effects. Loggerhead Shrikes, which are predatory, preferred nesting territories with road fence lines, probably as vantage points to spot prey, but nesting success was significantly lower than that at sites away from the fence lines. No statistical relationship between roads and nest success was found for Mallard, Gadwall, or Blue-winged Teal. Along two-lane roads bordered by agricultural land on one side and grassland on the other, Bobolink density increased as distance from edge increased, though forest edge had a greater impact than road or agricultural edge. Another study of Bobolinks found a very strong roadside edge effect up to 50 m from the road edge, although daily survival rates did not vary with distance from edge. In a recent study of the response of Lesser Prairie-Chickens to various human activities, unimproved roads had no effect on distance to nests, but only buildings had a greater impact than improved roads; nest distance averaged 859 yards from the road. For Red-winged Blackbirds, density and productivity were significantly lower – even to the extent that they constituted population sinks – along roadsides. In that study, predation was the only causal factor that explained this result. Abundance for five of eight grassland bird species was significantly lower along roads with drainage ditches and fences and planted with a non-native species than along trails (a trail is defined as a road with a single pair of wheel ruts). However, in agricultural areas where roadside vegetation was the only remaining natural grassland habitat, 10 grassland species used the habitat. Even if nesting density along roads was high, a predation rate of 52%, combined with mowing and cowbird parasitism, resulted in productivity that was no higher than that of the nearby agricultural fields. A study of managed and unmanaged roadside verges along roads with varying traffic intensity found no consistent correlations between nest density (or nest success) and road type or traffic volume. In fact, nest densities were highest along the busiest road. However, an experimental study that used artificial nests showed that road type and habitat adjacent to roadside habitat had no effect on predation rate, whereas roadside habitat and nest position (nests on backslopes) in that habitat were significant factors. Fences resulted in much higher predation rates. Noise has been studied as one cause of the observed avoidance of roads, but the effect seems to vary with species. Studies of urban roads with significant traffic volume (5,000 to 850,000 vehicles per day) have been a major focus in the Netherlands. At lower traffic volumes, noise accounted for a reduction of more than 10% in density of seven species within 100 m of roads; higher traffic volumes resulted in a reduction of 40% in density of all 12 species studied within 100 m of roads. Yet another study that examined the effect of traffic volume found that low traffic volumes (3,000 to 8,000 vehicles per day) had no effect on the abundance of grassland bird distributions, although density within that range varied with patch size. At moderate volumes (8,000 to 15,000 vehicles per day), roads reduced breeding bird density within 400 m but had otherwise no effect on the distribution of grassland birds. At heavier traffic levels (15,000 to 30,000 vehicles per day), roads affected presence and breeding density to a distance of 700 m. At the heaviest traffic volumes (30,000 or more vehicles per day), road effects extended to 1,200 m. In Denmark, the avoidance of roads by Pink-footed Geese reduced available foraging habitat by 21% near large roads and 10% near small roads. Observations of a variety of human disturbances in the landscape led to the conclusion that wind turbines and other disturbances should be clustered or overlapped to minimize overall impact on habitat availability. In contrast, Barnacle Geese were unaffected by roads. No significant difference was found in grazing intensity regardless of the distance from the road. Avian mortality from automobile collisions may be a function of the suitability of adjacent habitat for prey species. Barn Owls and Long-eared Owls suffered the greatest mortality near grain fields that were ideal habitat for voles and on roads that were at the same elevation as the surrounding habitat.

Urbanization: Urbanization entails a broad loss and degradation of habitat. Few studies of the impacts of urbanization on grassland and shrub-steppe species were found; the eight reviewed here document changes in bird species composition, richness, and abundance in relation to density of urban features. As wind farms are generally sited in open areas, the findings pertinent to urbanization may have limited relevance. The impact of the growth of Tulsa, Oklahoma, from 1967 to 1991 was studied by contrasting two sites – a "low-density" rural area and a "high-density" rural area. Some species declined in both landscapes, others in only one landscape, and others did not change in either landscape. Protected grassland in an urbanizing area (Boulder, Colorado) maintained populations of 22 of 29 grassland bird species for nearly a century; however, four of these species declined significantly in Boulder County; the other seven disappeared entirely from the Boulder area. One of two raptor species in the same area declined significantly, but not until the latter half of the 40-year period of human growth, which suggests a possible threshold effect. The other species increased significantly and were found more commonly in the more densely developed areas. That same Boulder Open Space served as the setting for a study about the impacts of urbanization on grassland songbirds. Declines in songbird populations were determined to be significantly affected by the quality of the habitat; severe declines occurred when urban cover types in the 40-ha landscape area constituted more than 5% of the land cover. A similar result was seen in Sweden, where species richness declined in proportion to the extent of urban elements in the landscape. Urbanization seemed to influence the life history traits of two populations of Lesser Prairie-Chickens. Higher female survival and lower reproductive effort (few renesting attempts 10 within a single season) were observed in a population residing in an area with large open parcels and few fences, roads, or power lines. The other population suffered reduced female survival and higher reproductive effort, which resulted in population instability. A reduction in vertebrate abundance in suburban areas (versus protected areas) was thought to cause partial brood loss in a suburban Florida Scrub Jay population because the last hatched chicks starved. However, the results of this study suggest that starvation might result not from inadequate vertebrate abundance, but from the relative paucity of nest helpers, a prominent feature of Florida Scrub Jay behavior that involves younger, nonreproductive birds helping older birds to raise broods.

Tall structures: Budget and time constraints prevented us from reviewing the more than 1,000 papers in this category. However, earlier reviews of much of this literature led us to believe that most would not meet the quality criteria we had established. Much of it was purely observational and inadequately reported important variables. As the description of habitat was often lacking and many papers primarily reported species identification and counts of dead birds, identifying papers on grassland and shrub-steppe species would be extremely difficult. Therefore, a more general discussion is provided here to identify variables that might provide insight into causal mechanisms. Mortality estimates for tall structures generally span orders of magnitude for any particular kind of structure. These estimates are based on biased observations, as per-structure estimates are often based on mass mortality events or nonrandom monitoring of structures that are suspected of causing mortality. If little or no mortality is observed, monitoring stops and the observations are not reported. There have been no randomized, landscape-level monitoring efforts. These per-structure estimates are then multiplied by the number of individual structures of a particular type, even though those estimates are probably not typical of the mortality rates for structures in that category. In addition, many studies result from regulatory inquiry into site specific applications and employ the Before-After/Control-Impact (BACI) methodology, which, in the case of wind energy studies to date, comprised assessments of species composition and abundance before and after construction at construction and reference sites, but have not assessed mortality or changes in mortality rates. Positive associations have been found between the incidence of avian collisions with telecommunications towers and structure height, lighting, and weather conditions (primarily fog, cold fronts, and storms). Numerous observers have reported nonlinear flight (e.g., circling behavior) around towers with lights, but the specific attributes of light – color, lighting type (steady versus flash, incandescent versus strobe) – have not been studied experimentally until very recently, and these data have not yet been published. Earlier reports about the impacts of light color and type are conflicting. Extinguishing the lights in buildings has been documented to reduce mortality, but as lights associated with tall structures tend to be aviation warning lights, this is not an option.

Oil and gas extraction: Elements of this activity overlap other categories discussed in this review, including roads and power lines. The analysis here focused on avoidance and other behavioral responses to oil and gas wells, though referenced studies focused on various elements of these features, including noise, physical motion, associated structures such as pipelines, roads (as a type of habitat fragmentation and with regard to traffic), and habitat change that promotes the establishment of new pathogens into the environment. Avian population changes resulted primarily from avoidance rather than mortality; the loss of usable habitat resulted in population reductions. Most studies we examined involved shrub-steppe species; some discuss the impacts on grassland passerines. Assessments of avoidance are more common than are studies that identify specific components associated with that avoidance. Retaining ponds that hold water pumped from coal beds that are in the process of extracting methane are ideal breeding grounds for the mosquito species that transmit West Nile Virus. The potential impact on sage-grouse and other species found in these areas is being evaluated. The water in these ponds may also be contaminated with petroleum and heavy metals, but the impact on birds has not been studied. Some species do not avoid oil and gas wells. Prairie Falcons seemed unaffected, regardless of the density of wells, although they nested at some distance and reacted to blasting noise by flushing from nests or sitting upright. Strong declines in sage-grouse populations in Alberta and Colorado have been amply documented, but the association with oil and gas development is weak because that development began at least two decades before population counts began. Sage-grouse will locate in or near oil fields if suitable habitat is available and if they can avoid paved roads and oil structures. However, power lines associated with oil and gas fields may lead to increased raptor predation and, in turn, lower population growth rates. Leks at a greater distance from compressor stations had more birds than did leks nearer to the stations, but whether this was due to the noise emanating from the compressor, roads, traffic, or habitat loss is not clear. Increased mortality of males at leks and a reduction in female population growth have also been attributed to wells. The impact of proximity to wells was significant – the negative impact was observed to a distance of 4.7 km for producing wells and 6.2 km for drilling rigs. Two major studies of the impacts of oil and gas wells on sage-grouse were published in the past two years. The first comprehensive study examined relationships between breeding success and adult life history traits with numerous habitat conditions, including vegetation structure and composition, wetness (a measure of soil or surface moisture content derived from remotely sensed data), distance to wells, and other human activities such as roads. Chick and adult male mortality increased closer to wells and with increased well density. Male attendance at lek sites decreased closer to wells and with increased traffic volume, and in areas with high densities of wells. Females chose nest sites nearer to wells than would be expected by random distribution, but avoided areas with higher well density. Broods were also closer to wells than would be expected in a random distribution, but chick mortality increased closer to wells and with increased well density. In contrast, female sage-grouse that visited leks disturbed by wells established nest sites farther from those leks than did females that visited undisturbed lek sites. Results with Lesser Prairie-Chickens were mixed: all nests at two sites were at a greater distance from wells than would be predicted by random distribution. At one site, the difference in distances for all nests was statistically significant. However, at the other site, the difference in distances was not statistically significant for any of the nests. A model of the relationship between distance to wells from sage-grouse nests, as well as 12 vegetation variables, predicted nest success 74.6% of the time. Another model combined two separate models for probability of use and habitat-associated risk for Greater Sage-Grouse. It was based on five vegetation characteristics and one parameter that combined all human activities in the area, which is called "edge," though it does not actually measure distance to habitat edge. The model identified source habitat and attractive sink habitat (which has suitable vegetation characteristics but is also high risk) with 65% success in predicting nest location and 71% success in predicting brood location. Traffic volume along roads associated with oil and gas wells affected sagebrush obligates such as Brewer's Sparrow, Sage Thrasher, and Sage Sparrow. Declines of 60% were observed within 100 m of roads with higher traffic volumes (697 vehicles per day) compared to roads with lower volume (fewer than 344 vehicles per day). However, there was no observed difference in abundance within 100 m of pipelines and from 100 m to 200 m of pipelines.

Emergent questions and research needs: Though the body of literature is large, there are few well-designed studies with adequate sample sizes for all activities included in this review. However, the studies discussed here suggest hypotheses for further testing. Careful designs are needed to assess causation with regard to mortality and behavioral responses. Three design flaws were common to most of the studies reviewed here: (1) small sample size; (2) inappropriate sampling scale (temporal, spatial, or both); and (3) poorly described or controlled reference sites. Most studies lacked replicates. Some failed to adequately describe the habitat type and other habitat characteristics; few quantified those variables. Baseline studies of pre-impact conditions are almost universally lacking, although BACI studies are recommended for wind energy facilities by the NWCC Wildlife Workgroup, and are sometimes undertaken. Also needed are multi-site, landscape-level studies that use stratified random samples to distinguish between the various attributes of activities that are thought to have negative impacts on avian behavior and survival. These large-scale studies will also result in much better mortality estimates, which will be useful for determining the needed level of mitigation and other conservation responses.