APPENDIX B2 – ANALYSIS OF POTENTIAL AVIAN COLLISIONS WITH TRANSMISSION LINES AT FOUR LOCATIONS ON THE RIO GRANDE IN NEW MEXICO

SUNZIA SOUTHWEST
TRANSMISSION LINE PROJECT

ANALYSIS OF POTENTIAL
AVIAN COLLISIONS WITH TRANSMISSION LINES
AT FOUR LOCATIONS ON THE RIO GRANDE
IN NEW MEXICO

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1. INTRODUCTION

The SunZia Southwest Transmission Project consists of a pair of proposed new 500-kilovolt (kV) transmission lines that would connect a proposed new electrical substation, north of Carrizozo, New Mexico (SunZia East), with the existing Pinal Central Substation at Casa Grande, Arizona. To connect the two substations, the new lines will need to cross the Rio Grande in New Mexico. Three potential crossing alternatives are currently being reviewed by the Project proponent. These alternatives are located near San Antonio, between Arrey and Derry, and at Las Cruces, New Mexico. A fourth site that has been studied is on the Armendaris Ranch, south of the Bosque del Apache National Wildlife Refuge (NWR). This fourth site was considered as an alternative crossing site at one point, but dropped out of the planning process early on. It was maintained as a study site because of an existing 230 kV line crossing at that location. The potential for avian collisions with transmission lines that might result from placement of a new line across the Rio Grande was recognized early in the planning phase of the Project. This paper includes a review of the literature addressing avian mortality from anthropogenic sources, with a particular emphasis on avian transmission line interactions, provides information on site-specific bird use and potential impacts of the proposed crossing sites, and suggests possible mitigation options for the Project.

Estimates of the total breeding bird population for the continental United States reveal that there are approximately 10 billion land birds present during the spring breeding season, a figure that increases to about 20 billion birds in the fall after young have fledged (Aldrich et al. [1975] and Trapp [1992] both *in*: Manville 2005; USFWS 2002). This equates to an average of 3,325 birds per square mile in the spring.

About one-quarter of the 836 bird species covered under the federal Migratory Bird Treaty Act are known to be in jeopardy, many currently suffering precipitous population declines (USFWS 2002). Currently, 92 of these bird species are listed under the Endangered Species Act as either threatened or endangered, and 147 others are considered Birds of Conservation Concern by the United States Fish and Wildlife Service (USFWS 2010; 2008).

Banks (1979) estimated that human-caused bird deaths in the continental United States (in the early 1970s) amounted to about 196 million birds annually, or about 1.9 percent of total avian deaths from all causes. Banks estimated approximately 61 percent of avian deaths resulted from hunting, with the second largest cause of fatalities resulting from collisions with man-made structures (about 32 percent of the annual total). Considering the significant increase in structures of all kinds that could present collision hazards for birds, including buildings, transmission lines, towers of all kinds, and wind turbines that have been constructed in the United States in the 30+ years since the Banks paper, the annual number of human-caused bird fatalities is almost certainly higher today. As the human population continues to grow and man builds additional infrastructure, bird losses from these sources are likely to continue to increase due to the sheer increase in obstacles presented to birds (Erickson et al. 2005).

Simply stated, man-made structures that present collision hazards for birds can be any structure that is placed in an area used by birds. Potential impacts of structures are, to a great extent, a function of their height, visibility, and placement (siting). The greatest percentage of avian collisions with man-made structures is from collisions with windows (Klem 2008; USFWS 2002). Birds do not discriminate between reflected images or apparent flight paths observed through windows (Avery 1979). Windows present a significant hazard for birds due to their abundance in the environment. Other than windows, structures that are known to present significant avian collision hazards include overhead lines, including both telephone and electrical utility lines, communication towers, buildings, wind turbines, and chimneys (including factory stacks and power plant cooling towers) (Avery 1979; Morkill and Anderson 1991). Nonstructural, human-related causes of bird mortality include collisions with vehicles on highways; pesticide and lead poisoning; land disturbances associated with agriculture and development; transmission line electrocutions; oil and contaminant spills; entanglement, strangulation, and drowning in fishing gear; introduction of non-native plants and wildlife; predation by domestic animals; and collisions with aircraft (Avery 1979; Erickson et al. 2005; Manville 2005; USFWS 2002).

Approximately 10 billion birds die each year in the United States from all causes, including nonhuman sources such as natural mortality, predation, and disease. Less than 2 percent of this total is attributable to human impacts, and only 1 percent result from collisions with tall structures (Banks 1979).

Estimates of annual anthropogenic avian losses in the United States include:

- 0.5–1.6 billion total bird collisions from all man-made sources (Erickson et al. 2005; Klem 2008).
- 900 million bird collisions with buildings (primarily windows) (Klem 2008).
- 225 million bird collisions with transmission lines, communication towers, and wind turbines: electrical transmission and distribution lines may cause hundreds of thousands to 175 million birds annually, communication towers 4–50 million birds per year, and about 40,000 kills are estimated at wind turbines (Manville 2005).
- 130 million birds at high-tension transmission lines (Erickson et al. 2005).
- 100 million birds lost to domestic and feral cats (Erickson et al. 2005).
- 67–72 million birds lost to pesticide poisoning (Erickson et al. 2005; USFWS 2002).
- 60–80 million birds lost to collisions with vehicles (Erickson et al. 2005; USFWS 2002).
- 4–5 million bird collisions with communications towers (Erickson et al. 2005; USFWS 2002; 2000).
- 35 million birds taken by permitted hunting (Raftovich et al. 2010).
- 1.0–1.25 million birds at towers (Aldrich et al. 1966 and Banks 1979 *in*: Avery 1979). (This represents less than 0.02 percent of the total estimated annual avian mortality [Mayfield 1967 *in*: Avery 1979; Banks 1979]).
- 0.5–1.0 million birds in oil pits associated with oil and gas extraction (Trail 2006).

Some of these numbers may be artificially high because data are compiled from a variety of discrete studies that commonly address a narrowly identified problem area or season, and are extrapolated to a larger scale (Erickson et al. 2005). While actual losses are undoubtedly high for some of these sources at the discrete locations studied, caution needs to be used in applying such numbers to larger scales. What is needed are studies that address each unique avian hazard using representative examples over a wide range of locations, conditions, and times, such that local biases are not introduced into the results. Values obtained through properly controlled studies of individual hazards may then be applied to larger scales such as individual projects and national estimates with some level of confidence. Stochastic bird collision events commonly happen during periods of inclement weather when visibility is greatly reduced, exacerbating the avian collision potential. Bird collision studies that do not incorporate periods of inclement weather are likely to underestimate collision potential.

Population level effects of avian transmission line collisions for most bird species are low, but may be significant or critical for species suffering declines or already in jeopardy (Brown and Drewien 1995; Janss and Ferrer 1998). Determinations of the significance that avian collision impacts have on bird species' populations must consider effects on both local and overall species population levels (APLIC 1994). The significance of a specific anthropogenic bird collision hazard affecting bird populations is difficult to quantify due to naturally occurring factors that contribute to overall population impacts (Banks 1979; Manville 2005). Nonhuman-caused impacts to avian populations include, but are not limited to, natural mortality levels, predation, disease, and weather. The cumulative effect of human-caused and natural impacts on avian populations directly affects the potential significance of the human component of total impacts (Avery 1979). Estimates of effects on bird populations are aggravated by a lack of knowledge of species' population size. Accurate population numbers are not available for about a third of the bird species occurring in the United States (Manville 2005; USFWS 2002).

Consideration of the significance of site-specific avian collision loss must also consider age categories of birds lost. Impacts to adult breeding birds will likely have a more significant impact on a population than loss of juveniles, which appear to be more susceptible to collisions (Janss and Ferrer 2000). This is particularly true for larger, long-lived species, such as Sandhill Cranes (*Grus Canadensis*), which typically have low recruitment levels.

Some impacts that affect avian populations may not initially be of significant concern for a species, representing a small percentage of total annual mortality. However, the cumulative effects of multiple stressors on bird populations can whittle away at populations, such that a formerly insignificant source of loss may become significant at some point, and may ultimately lead to species extinction (Bevanger et al. 2009; Bevanger 1998; USFWS 2002). Such catalyst impacts are often different from those responsible for early declines of a species. Evaluating cumulative effects on birds is complicated by the lack of total population values available for many bird species (Erickson et al. 2005).

There have been many studies that quantify avian collisions with various man-made objects. These studies vary considerably in their breadth, with some studies using only small sample sizes. Some have not addressed searcher efficiency, scavenging, or provided estimates for numbers of collision-injured birds that escape the search area but eventually die (Erickson et al. 2005; Savereno et al. 1996).

Tall structures that intrude into aviation airspace are regulated by the Federal Aviation Administration (FAA). Various kinds of lights are required on structures depending on their location and height. Lighted towers have been proven to be detrimental and present special hazards for birds. Lights may attract birds to the vicinity of structures, placing them in peril of collision (APLIC 1994). Many bird species migrate at night and use the stars for navigation. Placement of lights high in the sky is likely disorienting for birds using celestial features for navigation (Able and Bingman 1987; Alerstam 1990). Because transmission line structures do not intrude into aviation space, they do not require FAA lighting, and this is not an issue for these structures.

Avian losses due to impacts are greater in fall than spring (Avery 1979). This is primarily due to the presence of clouds, fog, and precipitation associated with inclement weather, which reduces visibility, and causes the birds to fly at lower altitudes and increases the potential for collisions with structures (Alerstam 1978; Podolsky et al. 1998).

Due to a variety of factors, avian impacts associated with a given kind of structure or specific location may vary greatly between years. Because of this, estimates of losses should be averaged over several years (Avery 1979). Surveys of bird collisions need to take into account birds that are injured by collisions but manage to fly outside of the survey area before succumbing to their injuries (APLIC 1994; Bevanger et al. 2009; Krapu 1974). Such crippling losses have been estimated to represent up to 75 percent of collision losses (APLIC 1994; Meyer *in* Brown and Drewien 1995; Savereno et al. 1996). This is in addition to searcher efficiency and scavenging biases that must be considered. Transmission line avian collisions tend to be concentrated at certain line segments due to topography, proximity to avian resources, and transmission line design. Because of this, a realistic estimate of total bird loss along a transmission line cannot be determined by simply extrapolating a value obtained from a small, often problematic segment of the line that is studied (Janss and Ferrer 2000). Many avian collision studies look at loss of birds as a percentage of line overflights. This provides a rate of loss for a specific site, but total Project impacts or impacts to species' populations need to measure loss rate against the total species' population (Janss and Ferrer 2000).

An estimated half-million miles of bulk (115 kV and above) electrical transmission lines and millions of miles of electrical distribution (69 kV and below) lines existed in the United States in 2005 (Manville 2005), and the volume grows by about 5 percent annually (Jenkins et al. 2010). This currently (2010) equates to approximately 638,000 miles of bulk lines, and would double to about 1 million miles by 2020, if development were to continue at that rate. Considering the current economy, this rate of increase may not persist, but the end effect will nonetheless be significant.

Overhead lines are significant sources of avian collision mortality, particularly during dusk, dawn, and at night when the lines are effectively invisible (Anderson 1978; APLIC 1994; Bevanger 1998; Brown and Drewien 1995; Cochrane et al. 1989; Glue 1971; Janss 2000; Janss and Ferrer 1998; Malcolm 1982; McNeil et al. 1985; Podolsky et al. 1998). Avian mortality associated with overhead electrical lines has been documented since the 1800s (Coues 1876). Birds incur substantial annual mortality due to collision and electrocution associated with aerial electrical lines (APLIC 1994, Bevanger 1994). In the current situation, electrocution is not an issue due to the size and configuration of 500 kV transmission lines—it is not possible for even the largest birds in the world to successfully be in contact with a conductor and ground source. In some species avian mortality rates due to collisions with transmission lines have been found to be high enough to threaten population persistence. For example, transmission line collisions caused over one-third of the known mortality of Greater Sandhill Cranes in the Rocky Mountains (36 percent, Drewien 1973). In Trumpeter Swans (*Cygnus buccinators*) in Wyoming (44 percent, Lockman 1988), and in Whooping Cranes (*Grus Americana*) in the Rocky Mountains

(40 percent, Lewis 1993). Avian mortality risk is greatest where transmission lines intersect migratory pathways, feeding, nesting, or roosting sites (Scott et al. 1972; Malcolm 1982; McNeil et al. 1985; Brown et al. 1987; Faanes 1987; Morkill and Anderson 1991; Brown and Drewien 1995; and Murphy et al. 2009)

New transmission lines are needed to meet growing energy demands and to allow access to renewable energy sources, but the impacts of individual lines on wildlife are highly variable according to transmission line design, placement, and post-construction mitigation efforts (Beaulaurier 1981; APLIC 1994; Bevanger 1994; Yee 2008). Thus, there is tremendous value in designing new transmission lines to minimize detrimental impacts on biodiversity. Many proven options are available to developers to reduce impacts on wildlife, depending on the situation (Bevanger 1994; APLIC 1994; APLIC 2006). The most effective means of reducing avian collision-based mortality is to locate transmission lines away from areas of high flight volume (Yee 2008; Wright et al. 2009). Other measures to reduce avian mortality from transmission lines include undergrounding sections of transmission lines in areas of heavy bird traffic (Beaulaurier 1981; APLIC 2010), and increasing visibility of static wires (Morkill and Anderson 1991; Alonso et al. 1994; Brown and Drewien 1995; Savereno et al. 1996; Yee 2008; Murphy et al. 2009; Wright et al. 2009).

Bird collisions with overhead transmission static lines (earth wires) are much more frequent than with conductors. Reasons for this include primarily the smaller size and corresponding lower visibility of the static lines, but also their position at the top of structures, placing them in the flight path of birds attempting to avoid the more visible conductor wires beneath (APLIC 1994; Jenkins et al. 2010; Morkill and Anderson 1991; Savereno et al. 1996). Guyed structures are also a significant source of avian collisions, again primarily due to the small diameter and low visibility of guy wires (Gehring et al. 2009).

Incidence of collisions with overhead lines is greatest in areas of high bird activity such as migration corridors, nesting and feeding areas, and areas where birds are funneled by topography and weather (APLIC 1994; Krapu 1974; Malcolm 1982; Savereno et al. 1996; Williams et al. 2001). Birds commonly follow the most efficient flight paths to access resources, and in doing so, are naturally funneled through canyons, valley heads, and saddles, or follow ridges in mountainous areas. Bird flight paths need to be carefully considered for placement of structures and transmission lines in these areas (APLIC 1994; Jenkins et al. 2010).

Inclement weather commonly affects flight behavior of birds by forcing them to fly in areas where visibility is better, which often means a change of altitude or route, either of which could place them in proximity to transmission lines (Krapu 1974). Low clouds, fog, or intense precipitation may render transmission lines virtually invisible to birds (APLIC 1994). Strong winds can affect flight maneuverability of birds, impacting their ability to avoid hazards, and possibly forcing them off their normal routes and into areas where transmission lines present a collision hazard (Brown and Drewien 1995; Jenkins et al. 2010). While many birds will not fly in such conditions, some make short-range flights to feed, provide for young, or move if disturbed (Jenkins et al. 2010). Short flights where birds cannot gain sufficient altitude may place them in jeopardy of collision with transmission lines.

Susceptibility of a given bird species to collision with overhead lines is determined primarily by their morphology and behavior. Body weight, wing size (related to lift), flight speed, and visual acuity are all factors that determine bird species' susceptibility to collisions with structures. Bird behavior varies by species and season. Some species are active only by day or night. Crepuscular and nocturnally active species are obviously more susceptible to collision, due to reduced visibility of obstacles in the flight path (Krapu 1974). Older and resident birds are better at recognizing and avoiding hazards, compared to juveniles or migratory birds (APLIC 1994; Brown and Drewien 1995; Jenkins et al. 2010; Krapu 1974).

Impacts of structures on birds may be species specific to some degree, since structure design or placement is more likely to affect species that have particular flight behaviors. These may include flight height and use of topography (APLIC 1994). Such species specific impacts can disproportionately affect some bird species. For example, exposure to collision with overhead lines is directly related to height of lines in relation to flight altitudes normally occupied by each bird species. High-flying species are less likely to be impacted as they spend little time at altitudes occupied by transmission lines. Bird species that are essentially terrestrial and are relatively weak or poor fliers have a heightened exposure to collision, since a high percentage of their flight activity occurs within heights occupied by transmission lines and guy wires (Jenkins et al. 2010).

Susceptibility of birds to collision may be aggravated by proximity of transmission lines to avian resource sites, where birds conduct regular, direct, short-range flights to feeding areas or roosts (APLIC 1994; Janss and Ferrer 2000; Jenkins et al. 2010; Krapu 1974; Morkill and Anderson 1991). The proximity of lines to resources often does not allow large birds such as cranes adequate time to gain altitude to clear structures and wires. Such resource areas may attract large aggregations of birds that often fly in flocks and at low altitudes, where collision potential is high. Birds traveling in flocks are more susceptible to collision because birds at the rear of the flock have their vision somewhat occluded by birds at the front, and they are more dependent on flock response to obstacle avoidance (APLIC 1994; Jenkins et al. 2010). Birds flushed by human disturbance may collide with nearby transmission lines (APLIC 1994). One study showed that transmission lines placed more than 1 mile from avian resource areas did not present a collision hazard for Sandhill Cranes or waterfowl (Brown et al. 1984, 1987 *in* APLIC 1994), so distance can be a useful mitigation option for some species.

Some bird species are more susceptible to collision with overhead lines than others due to differences in their morphology or behavior. Larger (heavier) birds, with smaller wings (less effective lift) and a resultant more rapid flight, commonly do not have the capability to make sudden course corrections when obstacles are encountered (Savereno et al. 1996). Because of this, species among the Anseriformes, Galliformes, Gruiformes, Pelecaniformes, and Ciconiiformes are particularly vulnerable to obstacles such as overhead transmission lines and supporting guy wires (Bevanger 1998).

Ongoing population declines of several bird species, including some cranes, bustards, and diurnal raptors have been attributed to transmission line collisions (Jenkins et al. 2010). Most birds killed in collisions with overhead wires are medium- to large-sized birds (Anderson 1991; APLIC 1994; Bevanger 1998; Janss 2000; Janss and Ferrer 1998; Jenkins et al. 2010; Krapu 1974; Manville 2005; Morkill and Malcolm 1982; Savereno et al. 1996). Many of the large bird species that are susceptible to collisions with transmission lines are long-lived and have a slow recruitment rate (Mitchusson 2003). Any impacts to these species will therefore potentially have a more significant impact on populations than species that are more prolific (Rooyen 2006). Three large bird species that occur in large numbers in the Rio Grande Valley during migration and wintering include the Sandhill Crane, Ross's Goose (*Chen rossii*), and the Snow Goose (*C. caerulescens*). Potential impacts to these species are of particular concern for this Project.

Sandhill Cranes have an average life expectancy of about 7 years, but in exceptional cases may live 20 (34 years maximum known) years. Sandhill Cranes begin breeding between 2 and 7 years of age (Mitchusson 2003; Tacha et al. 1992). During an average lifespan a reproductive adult will successfully rear only 2 or 3 birds that will reach reproductive age (Tacha et al. 1992). Similar reproductive capabilities are found in both Ross's and Snow geese. Ross's Goose begins reproduction earlier, at about 3 years of age and may live 12 to 14 (21 years maximum known) years, but still has a survivability of only 1.4 to 2.4 birds (Ryder and Alisauskas 1995). Snow geese begin breeding between 2 and 4 years of age and may live 15 to 17 (26 years maximum known) years (Mowbray et al. 2000; Terres 1980). There is little information on survivability in Snow geese (Mowbray et al. 2000), but it is likely similar to that for Ross's Goose. Cumulative effects to populations in species with low recruitment may take many years, often decades, to express themselves and contemporary impacts must be viewed with this in mind (Rooyen 2006).

Cranes, including both the Sandhill Crane and the Whooping Crane (*Grus americana*) are highly susceptible to collision with overhead lines (Brown and Drewien 1995; Morkill and Anderson 1991). A loss of 40 percent of a flock of Whooping Cranes resulted from collisions with overhead wires in the Rocky Mountain cross-fostered flock (Brown et al. *in* Morkill and Anderson 1991). Losses of these species are commonly the result of collisions during migration when birds are active in habitats transected by overhead lines (Morkill and Anderson 1991; Windingstad 1988).

A study of Sandhill Crane interactions with high-voltage transmission lines conducted in Nebraska between 1988 and 1990 detected a total of 45 collisions with the transmission lines during the spring migration in March and April over the 3-year study period. Overflights of cranes within the study segments averaged an estimated 180,000 birds per year. The resultant mortality represented 8.33 x 10^{-5} percent of the total, or 1 fatality for every 12,000 bird flyovers. The study compared marked and unmarked static line segments, and fatalities at both marked and unmarked segments are included in the 45 bird collision total. The study did determine that marking of static lines is effective in reducing collisions, with 69 percent of the recorded collisions associated with the unmarked study segments. Yellow aviation balls with a black vertical stripe were used on the static lines (Morkill and Anderson 1991).

The Rio Grande Valley of New Mexico forms a major migratory flyway for tens of thousands of Sandhill Cranes and millions of waterfowl annually. The centrally located Bosque del Apache NWR in Socorro County is a focal point for migratory stopover and winter foraging for thousands of cranes and tens of thousands of geese and ducks. For example, in the winter of 2007–2008, the high counts of individuals at the Bosque del Apache NWR were over 14,000 Sandhill Cranes, over 50,000 white geese (Ross's and Snow Goose), and over 50,000 ducks (www.friendsofthebosque.org). The riparian habitats in the middle Rio Grande flyway are also important stopover sites during both spring and fall migration for both neotropical and temperate migratory landbirds (Einch and Wang 2000)

The study being reported here was designed to evaluate potential impacts on bird populations of two proposed 500 kV electrical transmission lines across the Rio Grande. Transmission lines similar to the ones being proposed are known to cause avian mortality due to collision (Lee 1978; Meyer 1978; Anderson 1978; James and Haak 1979; Meyer and Lee 1979; Beaulaurier 1981; Morkill and Anderson 1991; Hartmann et al. 1992; APLIC 1994; Savereno et al. 1996; Janss and Ferrer 1998; Alonso and Alonso 1999a and b; Janss and Ferrer 2000; and De la Zerda and Rosselli 2002). Large-bodied birds, such as Sandhill Crane, which are abundant in the Middle Rio Grande Valley in winter, are especially vulnerable to collisions with transmission lines (Walkinshaw 1956; Drewien 1973; Brown and Drewien 1995; Yee 2008; and Wright et al. 2009) and are, correspondingly, of central concern to this assessment.

Identifying potential impacts to Sandhill Cranes was the focal point of this study, although all bird species were considered. The Sandhill Crane meets all of the conditions of a species that is vulnerable to detrimental impacts of overhead transmission lines. Additionally, they are an integral component of the North American charismatic megafauna and are cherished by birdwatchers, hunters, and the general public. At concentration points such as the Bosque del Apache (New Mexico) and the Platte River (Nebraska), Sandhill Cranes form spectacular concentrations that inspire visitors from throughout the world. The species is migratory and highly volant, but is characterized by large body size, limited maneuverability in flight, and suspected blind spots in the forward direction. The tendency of Sandhill Cranes to suffer high rates of mortality due to collisions with transmission lines has been well documented (Walkinshaw 1956; Drewien 1973; Brown and Drewien 1995; Yee 2008; Wright et al. 2009).

The three subspecies of Sandhill Crane that occur in New Mexico include the smaller-sized “Lesser” (*Grus canadensis canadensis*), the larger-sized “Greater” (*G. c. tabida*), and the intermediate-sized ‘Canadian’ (*G. c. rowanii*) (Mitchusson 2003). Recent genetic investigations suggest that there are two genetically distinct, evolutionarily divergent groups corresponding to the Lesser and Greater subspecies, with some individuals of the Canadian subspecies falling out in each group (Jones et al. 2005). This result is consistent with the possibility that the Canadian subspecies represents an intergrade between the Greater and Lesser subspecies that has formed by hybridization over thousands of years. The Canadian form is correspondingly intermediate in morphology and breeding latitude.

Sandhill Cranes are divided into distinct geographic populations based on their breeding distributions. The mid-continent population (MCP) is numerically the most abundant, estimated at 378,420 in 2006 (Sharp et al. 2007), and is comprised of Lesser, Canadian, and Greater Sandhill Cranes in the north, mid-latitudes, and southern part of the distribution, respectively. The MCP breeding range extends from Minnesota to Quebec, and through Arctic Canada, Alaska, and eastern Siberia. The MCP wintering range spans from Oklahoma to Arizona, including Texas and New Mexico, and south into Mexico (Sharp et al. 2007). Interestingly, the western portion of the MCP wintering range is occupied only by birds from the northern and northwestern portion of the breeding range, comprised primarily of Lesser Sandhill Cranes with a small proportion of Canadians. In New Mexico, the principal wintering concentration for these MCP Lessers (and Canadians) is along the Pecos Valley (Mitchusson 2003). In the Middle Rio

Grande Valley of New Mexico, moderate numbers of Lessers and Canadians mix with large numbers of Greater Sandhill Cranes from the Rocky Mountain population (RMP). In contrast to the Middle Rio Grande Valley, large numbers of wintering Lesser Sandhill Cranes mix with small numbers of Greaters at traditional crane wintering areas in southern New Mexico, including the area between Caballo Reservoir and the Hatch Valley in Sierra and Doña Ana counties, the adjacent Uvas Valley in Sierra and Doña Ana counties, and near the Deming and Columbus area in Luna County (Schmitt and Hale 1997; Mitchusson 2003).

The RMP is comprised exclusively of Greater Sandhill Cranes, and was estimated at 19,633 individuals in 2005 (Sharp et al. 2007). The primary breeding grounds of the RMP are river valleys and marshes throughout Montana, Wyoming, Idaho, Utah, and Colorado. The RMP migrates through the San Luis Valley in Colorado and winters primarily in the Middle Rio Grande Valley, New Mexico, with smaller numbers wintering in southwestern New Mexico, southeastern Arizona, and the Northern Highlands of Mexico (Sharp et al. 2007). Within the Middle Rio Grande Valley, the Bosque del Apache NWR is the single most important wintering location for Greater Sandhill Cranes, supporting over 50 percent of the entire population during winter (Drewien and Bizeau 1974, Mitchusson 2003).

Sandhill Cranes have historically incurred catastrophic population declines, likely due to overhunting (Bailey 1928; Mitchusson 2003). Population declines were most severe for the RMP. In 1944, Walkinshaw (1949) estimated only 188 to 250 breeding pairs of Greater Sandhill Cranes remained in the Rocky Mountain area. In 1966, the Greater subspecies was listed as "rare" (US Department of the Interior 1966). The Migratory Bird Treaty Act in 1918 ceased crane hunting in the United States and Canada. Sandhill Crane populations increased as a result of direct actions taken to protect the birds and their habitats (Lewis et al. 1977). Concerns about the imminent extinction of the RMP were alleviated by the early-mid 1970s (Drewien and Bizeau 1974). RMP cranes increased to an estimated 20,832 in 1985 (Benning et al. 1997). The population recovery was attributed to protection from unregulated hunting, establishment of refuges and management areas, and expansion of small grain agriculture (Mitchusson 2003). However; the RMP of Greater Sandhill Cranes is still considered vulnerable (Sharp et al. 2007).

Although virtually all volant bird species are susceptible to collisions with transmission lines, bird species with high wing loading and low wing aspect ratio have been shown to be at greatest risk for transmission line collisions (Bevanger 1998, Crowder and Rhodes 2002). Many bird species are able to modify their flight behavior to avoid collisions with transmission lines (Meyer 1978, James and Haak 1979; Meyer and Lee 1979; Savereno et al. 1996); however, the combination of heavy bodies and small wings in birds with high wing loading and low wing aspect ratio makes them less maneuverable, and thus more susceptible to collisions (Bevanger 1998). Particularly, cranes (Morkill and Anderson 1991; Brown and Drewien 1995; Janss and Ferrer 2000; Sundar and Choudhury 2005; Yee 2008; Wright et al. 2009), wading birds (Savereno et al. 1996), and waterfowl (Anderson 1978; Meyer and Lee 1979; Brown and Drewien 1995) have been found to suffer high rates of collision-based mortality in certain circumstances. Smaller, more maneuverable birds, including blackbirds, doves, shorebirds and songbirds are also known to suffer fatal transmission line collisions (Coues 1876; Emerson 1904; Faanes 1987; Brown and Drewien 1995; Savereno et al. 1996), but rates of mortality in small-bodied birds are poorly known and difficult to study. Accordingly, assessment of transmission line impacts should consider a broad taxonomic spectrum.

A recent study by Martin and Shaw (2010) showed that the visual system of the Blue Crane (*Anthropoides paradise*) is a major cause of their highly susceptibility to transmission line collisions. Cranes, including Sandhill Cranes, possess a narrow, vertically oriented area of binocular vision directly anterior from the head, with blind spots above and below. As a result, even subtle tilting of the pitch of the bird or head can render the bird blind in the direction of travel. The same mechanism is thought to cause blind spots for raptors, but few other bird groups have been examined in detail with respect to this newly discovered vulnerability. The limitations of the crane visual system may help explain why visual flight diverters on overhead transmission lines are only partly effective in reducing collision-based mortality (Brown and Drewien 1995; Yee 2008; Murphy et al. 2009). However; the RMP of Greater Sandhill Cranes is still considered vulnerable (Sharp et al. 2007).

The Sandhill Crane has the lowest known recruitment of any avian species hunted in North America (Drewien et al. 1995). Annual recruitment, measured by proportion of juveniles observed in winter, of Greater Sandhill Cranes from the RMP averaged 8.0 percent in winter over 21 years, and mean brood size was 1.23 (Drewien et al. 1995). Survival rates ranged from averages of 0.95 during 1972 to 1985 to 0.91 during 1990 to 92 (Drewien et al. 1995). Over the same time period, recruitment in Lessers from the MCP averaged 11.2 percent, and mean brood size was 1.14 (Drewien et al. 1995). Maximum known age of a wild Greater Sandhill Crane from the RMP is 34 years (Drewien et al. 2001), and 19 years for a wild Lesser Sandhill Crane from the MCP (Tacha et al. 1994). Although adult survival is high, low recruitment rates limit population growth of Sandhill Cranes, thus making them vulnerable to sudden population declines if mortality increases substantially.

Most (more than 70 percent) adult Sandhill Crane mortality is due to human causes. In a study of 180 banded and recovered RMP cranes between 1969 and 1999, legal and illegal shooting accounted for 58.3 percent with hunting (53.9 percent) the single most important mortality factor (Drewien et al. 2001). In this same study, transmission line collisions accounted for 5.6 percent of known mortality (Drewien et al. 2001). Avian botulism (*Clostridium botulinum*), avian cholera (*Pasteurella* spp.), mycotoxins (*Fusarium* spp.) on waste peanuts, avian tuberculosis (*Mycobacterium avium*), aspergillosis (*Aspergillus* spp.), lead poisoning, and even hailstorms and lightning are other nonhunting-related causes of crane mortality (Windingstad 1988; Tacha et al. 1992, 1994).

Sandhill Cranes are hunted throughout North America. Regulated hunting of MCP cranes began in 1975. From 1975 to 1985, total North American harvests of MCP cranes ranged from 10 to 20,000 individuals. From 1985 to 2007, harvests of MCP cranes ranged from 20,000 to just under 40,000 individuals. During 2006 to 2007, 35,341 Sandhill Cranes from the MCP were harvested, just below 10 percent of the total population (Sharp et al. 2007). Regulated hunting of RMP cranes began in 1981, and total harvests for the first 7 years ranged from 100 to 200 cranes (Sharp et al. 2007). From 1988 to 1997, harvests of RMP cranes ranged from 200 to 700 individuals; and from 1998 to 2006, harvests ranged from 500 to 900 individuals (Sharp et al. 2007). In 2006 to 2007, 907 RMP Sandhill Cranes were harvested, a record high, and almost 5 percent of the total population (Sharp et al. 2007). These harvest rates are considered high, and may outpace population growth rates. (Sharp et al. 2007).

In New Mexico, regulation of Sandhill Crane hunting is challenging because MCP cranes mix with RMP cranes. The Pacific and Central Flyway's Management Plan for the RMP of Greater Sandhill Cranes requires New Mexico's Department of Game and Fish to conduct harvest check stations in areas where RMP and MCP cranes mix to determine the subspecies composition and percentage of RMP cranes and to ensure the harvest is below the state's harvest allotment (Mitchusson 2003). From 1986 to 1994, in the Middle Rio Grande Valley, the mean total harvest of Sandhill Cranes was 459, with a subspecies composition of 27 percent Lesser, 7 percent Canadian, and 66 percent Greater (Schmitt and Hale 1997). From 1982 to 1994 in southwestern New Mexico, the mean total harvest of Sandhill Cranes was 100, with a subspecies composition of 66 percent Lessers, 13 percent Canadians, and 20 percent Greaters (Schmitt and Hale 1997). In 2009, Kruse et al. (2010) estimated that the total New Mexico harvest of RMP cranes was 603 individuals and the MCP harvest was 584 birds. The proportions of juveniles in these two harvests were 13 percent and 14 percent respectively (Schmitt and Hale 1997). The proportions of juveniles in hunter harvests are higher than average numbers of juveniles in each population because juveniles are more susceptible to being shot by hunters.

The following is a summary of the results of studies done on the Rio Grande between San Antonio and Las Cruces, New Mexico, between December 2009 and December 2010.

2. BIRD MOVEMENTS ALONG THE RIO GRANDE – SUNZIA PROJECT SURVEYS

2.1. Methods

EPG conducted studies between early December 2009 and the end of March 2010, and again between August 2010 and mid-December 2010. Thus this report addresses two separate study periods at the same locations on the Rio Grande.

These studies were carried out at, or in the vicinity of, prospective transmission-line crossing sites at Armendaris Ranch, Arrey to Derry, San Antonio, and Vado as described in Figures 1–10. The proposed Armendaris Ranch crossing alternative was dropped from consideration, but we continued to collect data, due to the presence of an existing 230 kV electrical transmission line at the site. Our primary objective at this site was to determine the extent to which the existing line appeared to create a collision hazard for birds traveling up and down the Rio Grande. We established one survey site at each of these localities, and an additional survey site at San Antonio in August 2010 that allowed us to monitor bird movements at an existing overhead transmission line.

The Armendaris site is located on Ted Turner's Armendaris Ranch, south of the Bosque del Apache NWR, but north of Elephant Butte Reservoir (Figures 1, 2, and 6). The survey site at Armendaris was at the junction of a levee-top road and an existing overhead transmission line. The habitat at Armendaris is dominated by riparian woodland (cottonwood and salt cedar) and freshwater marsh. Armendaris is the only site in this study with no agricultural habitat in the vicinity. Furthermore, the Rio Grande habitat corridor is narrowest at Armendaris.

The Arrey-Derry site (Figures 1, 3, and 7) lies just south of Caballo Lake Reservoir, in agriculture-dominated habitat. The survey site was surrounded by alfalfa and chile pepper fields and was just downstream of a large-scale dairy facility that was an attraction to scavengers such as Chihuahuan Ravens and Ring-billed Gulls. Just to the east of this area are large cliffs, covered with xerophytic vegetation (creosote bush, cactus, ocotillo, mesquite), that juts-out and into the riparian corridor and provide excellent habitat for raptors, wintering White-throated Swifts, breeding swallows, and many desert bird species.

The two San Antonio survey sites (Figures 1, 4, 8, 9) were located just north of the Bosque del Apache NWR, and within a known wintering area for large numbers of cranes and waterfowl. The northern San Antonio site (Figure 8; hereafter "San Antonio North") was located on top of the levee on the west side of the river in between two closely spaced prospective crossing points for the transmission line, just 1.3 miles north of the Route 380 Rio Grande crossing and the town of San Antonio. The southern site (Figure 9; hereafter "San Antonio South") was located immediately (0.4 mile) downstream of the Route 380 Rio Grande crossing, and directly adjacent to the town of San Antonio. While these sites were less than 2 miles apart, the critical differences with respect to birds were that San Antonio South was closer to both the Bosque del Apache NWR and the town of San Antonio, both of which provide rich food resources for certain bird species. To the east of both of the San Antonio survey points is riparian woodland (cottonwood, salt cedar, Russian olive), while to the west lies a canal, a narrow strip of trees, and extensive agricultural fields that are a known foraging area for Sandhill Cranes.

The Vado survey site, southeast of Las Cruces, New Mexico (Figures 1, 5, 10), is the only site that does not lie within the regular wintering distribution of Sandhill Cranes (Mitchusson 2003). This survey site was at the junction of the Rio Grande and an existing transmission line, within a riparian corridor of scrub and grassland that is flanked by an agricultural matrix on both sides.

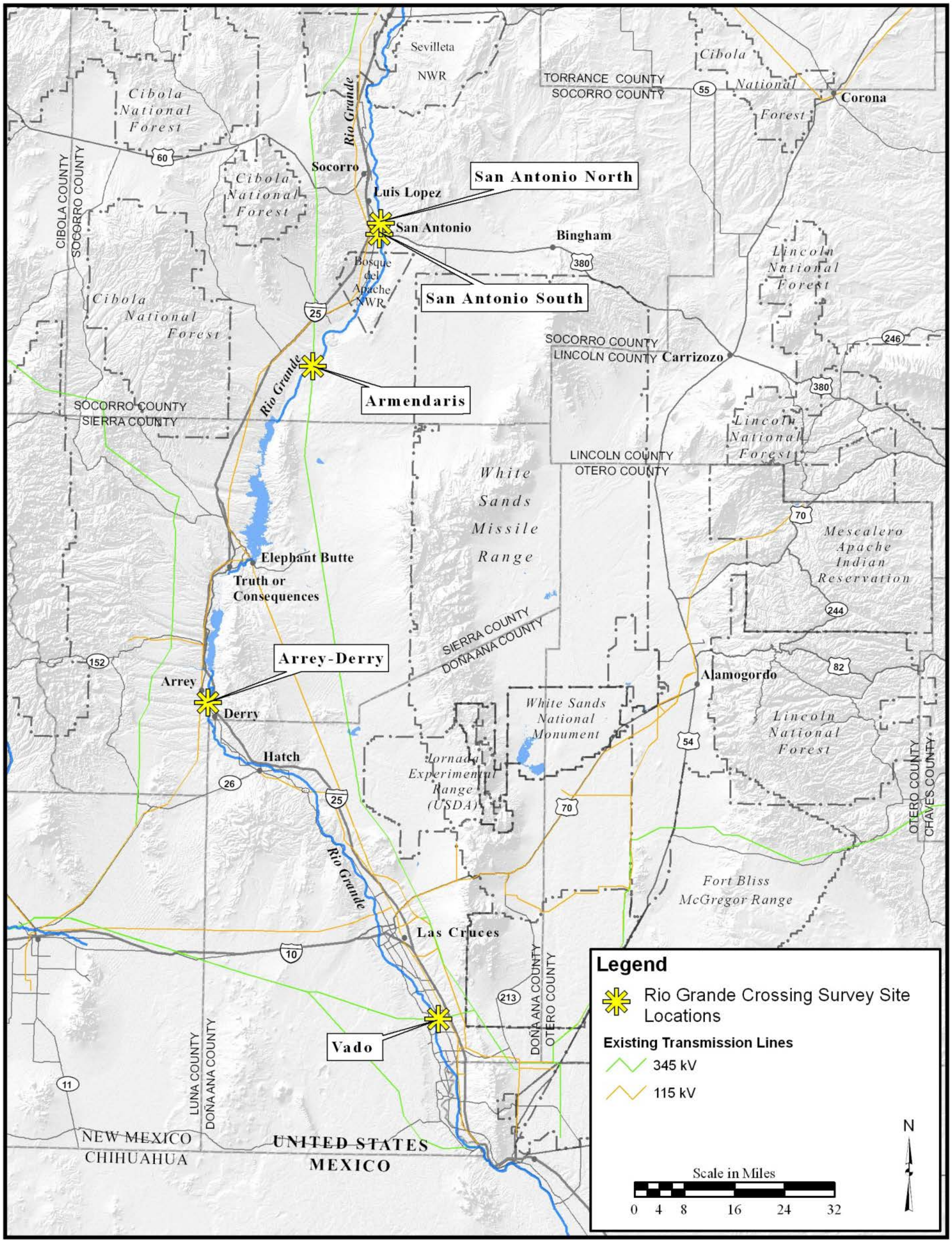

Figure 1. Rio Grande Crossing Survey Site Locations

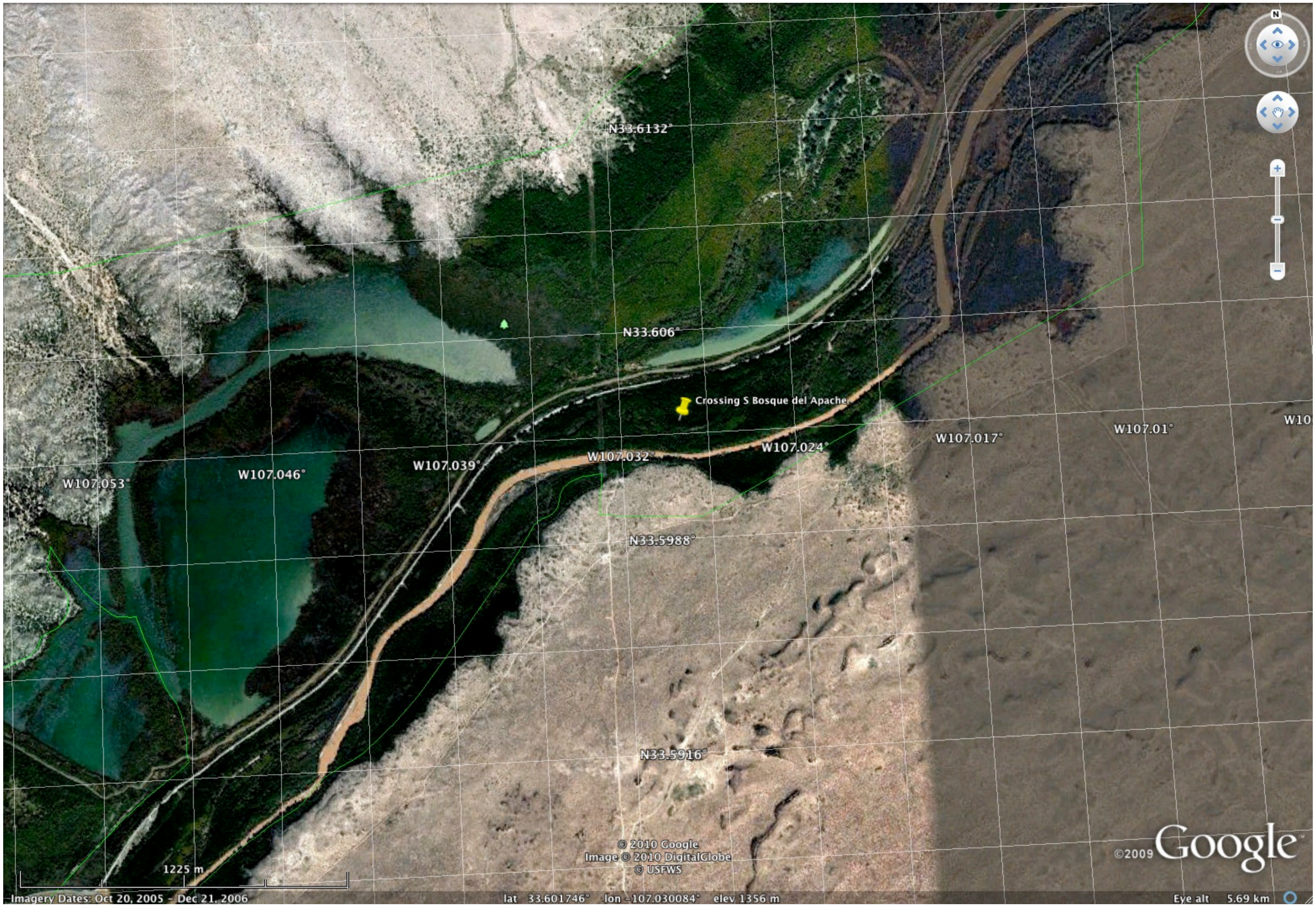

**Figure 2. Rio Grande Crossing Site Located on the Armendaris Ranch Property, South of the Bosque del Apache, near Fort Craig,
New Mexico (Google Earth) – The exact GPS coordinates for the survey point are 33.6039 N, 107.0325 W.**

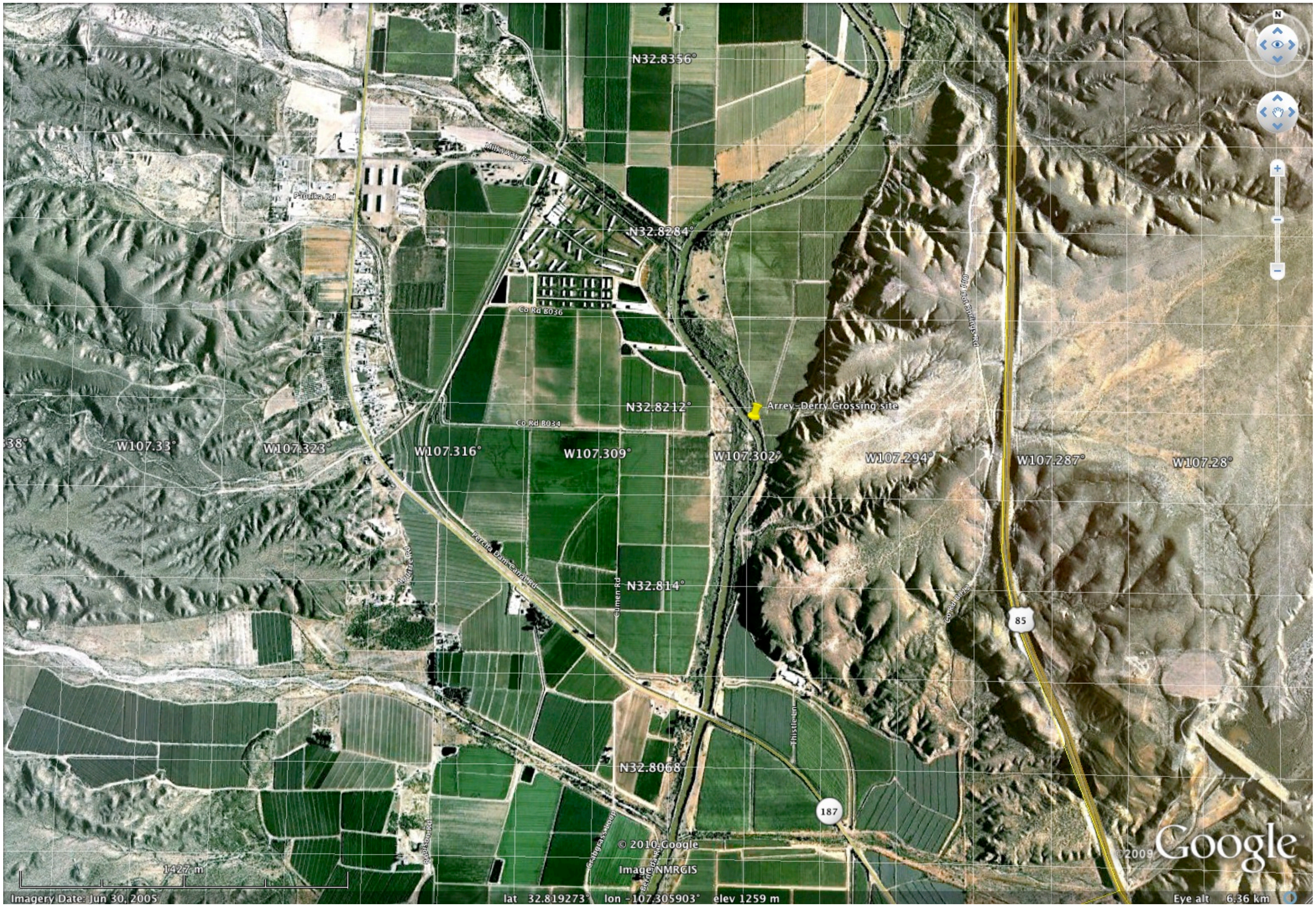

Figure 3. Rio Grande Crossing Site Located between Arrey and Derry, New Mexico (Google Earth) – The exact GPS coordinates for the survey point are 32.8207 N, 107.3021 W.

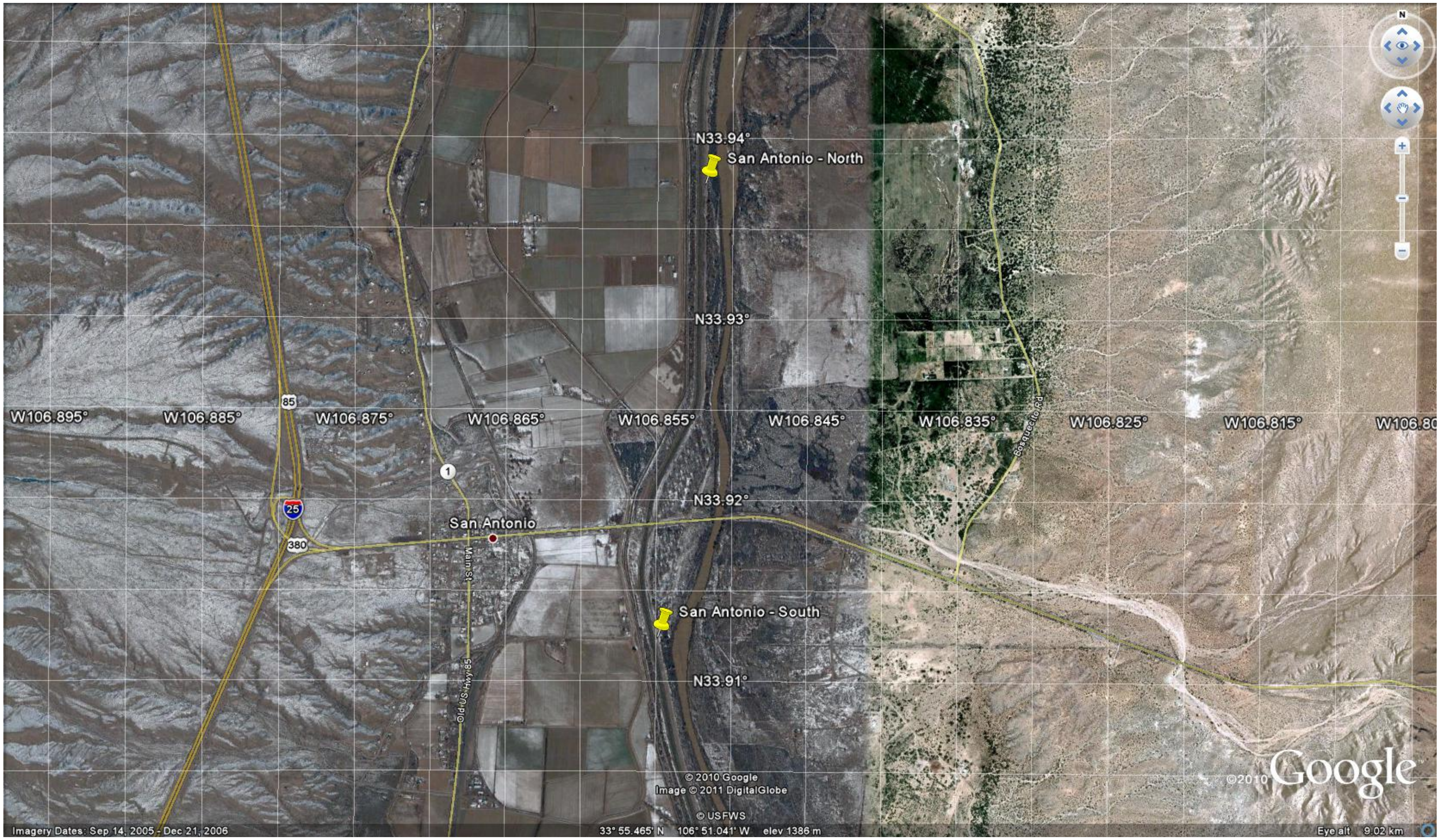

Figure 4. Rio Grande Crossing Sites Located in San Antonio, New Mexico, Closest to the Bosque del Apache NWR (Google Earth) – The exact GPS coordinates for the survey points are 33.9378° N, 106.8518° W, and 33.9125° N, 106.8549° W.

Figure 5. Rio Grande Crossing Site Located near Vado, New Mexico, South of Las Cruces (Google Earth) – The exact GPS coordinates for the survey point are 32.0982 N, 106.6571 W.

Figure 6. Armendaris Survey Site – Looking west, toward the existing transmission lines and extensive marsh habitat.

Figure 7. Arrey-Derry Survey Site – (A) Looking west, and (B) looking east, toward the prominent cliffs that form the boundary of the riparian habitat corridor.

Figure 8. San Antonio North Survey Site – (A) Looking north from the survey site, and (B) looking west from the survey site towards the Magdalena Mountains.

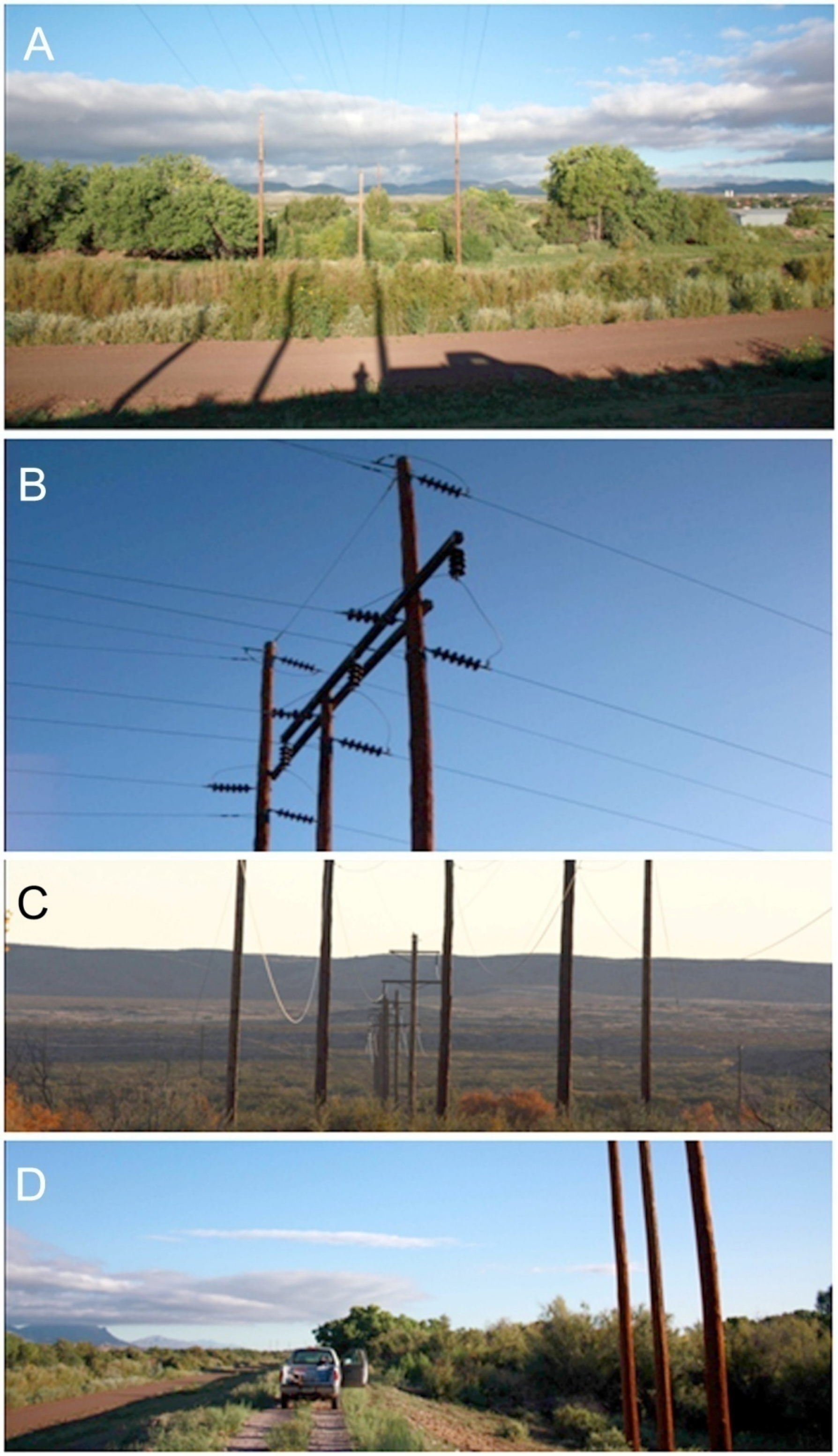

Figure 9. San Antonio South Survey Site – (A) Looking west under the overhead transmission lines toward the nearby town of San Antonio; (B) close-up view of the transmission-line configuration, 12–17 meters above the levee-top survey point; (C) looking east; and (D) looking north.

Figure 10. Vado Survey Site (SE Las Cruces) – (A) Looking east at the survey site, located on the bank of the river on the north side of the existing transmission-line corridor; (B) viewing existing transmission lines under foggy, early-morning conditions in late December 2009.

Bird Surveys: During the seasons of winter to spring (2009–2010), and late summer to early winter (2010), EPG conducted one dawn and one dusk survey per week at each of the four prospective crossing sites (five sites were studied from late summer 2010, with the addition of San Antonio South). We began our surveying efforts in December 2009 and the end of March 2010, and continued them between late August 2010 and mid-December 2010. On average, over this entire period, we conducted one dawn and one dusk survey per week for each of the five survey sites. Each survey was carried out by two or three observers working for four continuous hours. At least one observer on each survey was an expert on bird identification and census techniques. Dawn surveys started 1 hour before sunrise and continued to 3 hours after sunrise. Dusk surveys started 3 hours before sunset and continued to 1 hour after sunset. At each of the four sites and at San Antonio South, observers were positioned for maximum visibility along the hypothetical east-west plane of the transmission lines. All birds that were observed flying across the hypothetical plane of the transmission line during the survey were identified and recorded. Observers recorded hourly weather conditions, including visibility, cloud cover, precipitation, temperature, and wind speed and direction. The presence or absence of hunters was also noted due to potential effects of hunting pressure on flight behavior. Over the two sampling periods, we conducted 59 surveys (totaling 224 hours) at Armendaris, 65 surveys (totaling 253 hours) at Arrey-Derry, 71 surveys (totaling 282 hours) at Vado, 64 surveys (totaling 253.5 hours) at San Antonio North, and 35 surveys (totaling 137 hours) at San Antonio South. The total number of surveys conducted was 294, totaling 1,149.5 hours.

Each bird observation, consisting of a single individual bird or flock of conspecific individuals, was accompanied by the following details: (1) species, (2) number of individuals, (3) general direction of flight, (4) azimuth or compass angle at nearest point of passage to the observer, (5) vertical angle relative to the observer at point of nearest passage, and (6) distance from observer at point of nearest passage. These variables allow for the calculation of precise spatial position of each bird, including flight direction and height. Taxonomic identification was made to the most specific level to which the observers could be 99 percent certain (e.g., family, genus, species, or subspecies). Numbers of individuals in each flock were counted or estimated by eye, and estimated counts were checked using high-resolution digital photos (Canon Digital Rebel XSi) and image analysis software (ImageJ, National Institutes of Health). General direction of flight was used to polarize the flight vector that was calculated from the azimuth, vertical angle, and distance data. Azimuth at closest point to the observer was recorded using a digital or manual compass with appropriate correction for declination (www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination). Compass direction of the flight vector was calculated as azimuth angle plus (or minus) 90 degrees. Vertical angle was estimated with a handheld digital inclinometer or a digital level attached, with Velcro, to the barrel of a spotting scope. Vertical angle was used in conjunction with distance estimates to calculate above-ground height using the Pythagorean theorem. Distance from observer was estimated using one of three methods: (1) a digital handheld rangefinder (Newcon Optik, Toronto, Canada) was used for precision laser-measurements; (2) a Canon Digital Rebel XSi with a Canon EF 300 mm f/4L IS USM telephoto lens was used to photograph the birds as they passed at the nearest point to the observer (Figure 10); three observers estimated distance while using a suite of known-distance objects and landmarks as points of reference.

Photographs were analyzed in ImageJ to estimate distances from the survey point to flocks (Figure 10). We generated a distance formula by taking photographs of an object of known size at known distances using a Canon Digital Rebel XSi and fixed focal length Canon telephoto lens (300 mm). Using ImageJ, we calculated the number of pixels corresponding to the length of the object for each distance. We then calculated pixels per centimeter for each distance and we generated a function that provides an approximate conversion from pixel length to distance using nonlinear regression of known distances and pixel lengths for objects of known size. The distance equation we used was

$$D = 229.49e^{(-0.048x/L)}$$

where, D = distance in meters, x=number of pixels corresponding to length, and L= Length of bird in centimeters. Note that this equation is specific to the lens and camera used by in this study. To find the L parameter for each bird species, we measured the average length from the tip of the bill to the tip of the tail from museum specimens at the Museum of Southwestern Biology (MSB Division of Birds, University of New Mexico). For example, the average length for Greater Sandhill Cranes was 119 centimeters, and for Lesser Snow Goose was 71 centimeters.

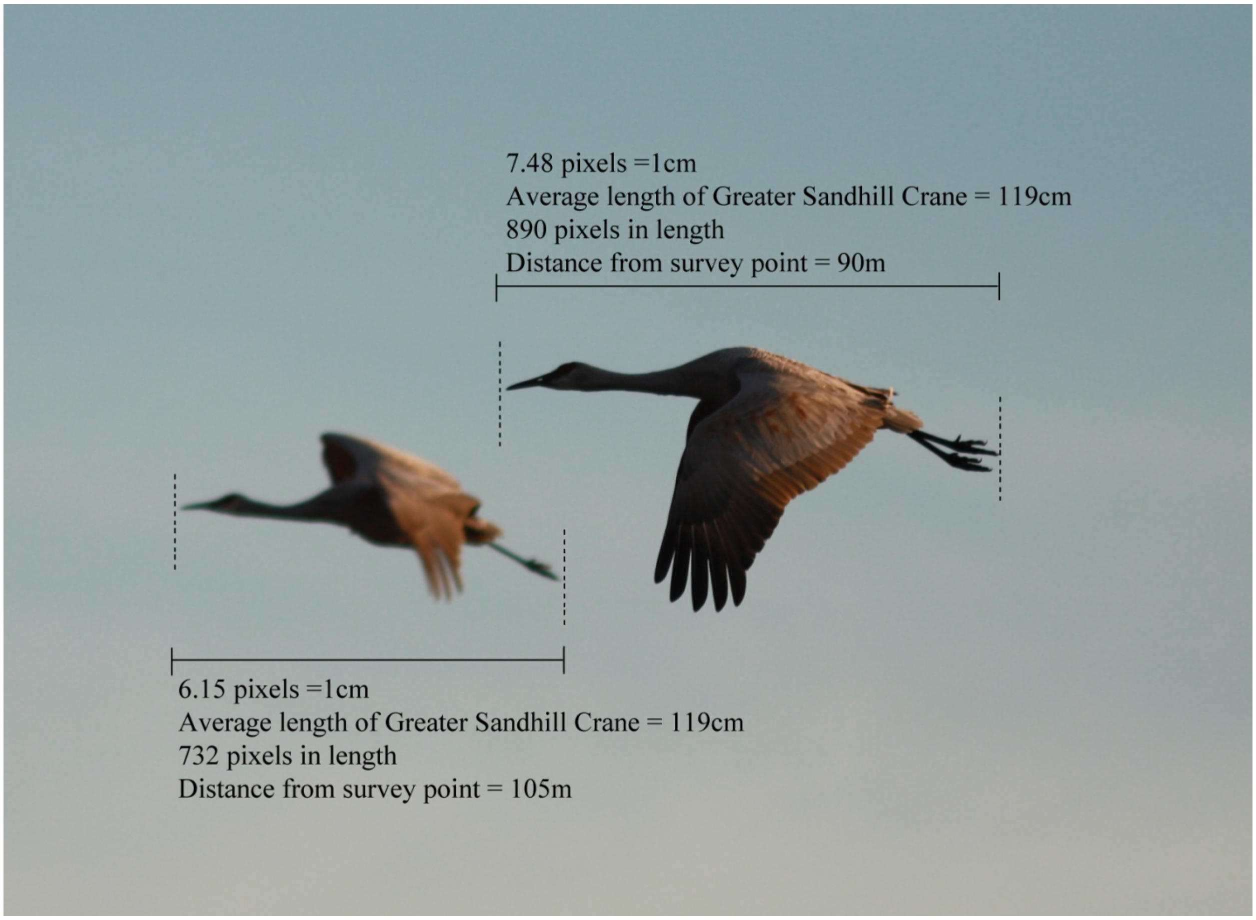

Figure 11. A typical image used for distance estimation based on pixel length and average size of Greater Sandhill Cranes. Photographed at the San Antonio North site, January 9, 2010.

Vocal Method of Sandhill Crane Subspecies Identification: Greater and Lesser Sandhill Cranes both winter in the Rio Grande Valley of New Mexico, but come from geographically disparate breeding areas, are genetically distinct, have strikingly different population sizes, and contrasting levels of conservation concern. Despite the differences, these subspecies are exceedingly difficult to distinguish by sight and are consequently often considered as a single entity. There are no known vocal differences between subspecies; however, a paper by Gaunt et al. (1987) showed that body size in cranes and other birds is correlated with the dispersion of formants as visible on a sonogram. Formants are amplitude peaks in the frequency spectrum. The body size relationship makes sense because the formant spacing should be correlated with the inverse of the length of the sound-producing tube (i.e., the vocal tract, which in cranes is primarily the trachea) (Fitch 1999). Thus, larger cranes should have longer tracheae and more closely spaced formants. Conversely, smaller cranes should have shorter tracheae and more dispersed formants. We dissected and measured tracheae from 39 Greater Sandhill Cranes from the RMP, and 25 Lesser and 8 Canadian Sandhill Cranes from the MCP that we acquired at hunter check stations with the cooperation of the New Mexico Department of Game and Fish and from Wildlife Rescue Incorporated. We found that external measures of body size that define the differences between subspecies also explain 91 percent of the variation in trachea length (M.R. Jones and C.C. Witt, unpublished data). Therefore, formant spacing should be sufficient to identify Sandhill Cranes to subspecies. To test this, we compiled a set of recordings from Sandhill Cranes of known subspecies and established the respective distributions of formant-spacing. We found that the formant spacing distributions for Greater and Lesser Sandhill Cranes were almost completely non-overlapping. It follows that a set of vocalizations of cranes unidentified to subspecies recorded in the field could be used to estimate the subspecies composition at the recording locality. We applied this technique by compiling sets of independent recordings of crane vocalizations from the local areas around San Antonio and Arrey-Derry during December 2010.

Data Analysis: We calculated total number of birds per hour for all bird species encountered during each individual survey. Because bird collisions with transmission lines are more likely to occur during periods of low light or low visibility, we also divided each survey into high-light (post-sunrise, and pre-sunset) and low-light hours (approximately 1 minute before sunrise and 1 minute after sunset), and calculated volume per hour of all birds observed during high- and low-light hours. There were too few precipitation and high wind events during our survey period to specifically address the effects on precipitation and high wind on bird flight patterns.

Individual survey sessions (contiguous 4-hour periods) were considered replicates for each site in our statistical analyses. We used ANOVA (PROC GLM, SAS Version 9.2, 2007) to test for differences among sites and between light levels in number of birds per hour and average flock height. Tukey’s Studentized Range Test was used to test for pair-wise differences between sites. Type III Sums of Squares were used. There were no significant site by light level interactions for number of birds per hour or average flock height, thus we did not include the site by light level interaction term in our analyses (results not shown). Since site differences were shown to be the same in both high and low light, we lumped light levels together in all subsequent analyses.

We calculated total number of Sandhill Cranes per hour during each individual survey, and considered surveys as replicates for statistical analyses. We used ANOVA (PROC GLM, SAS Version 9.2, 2007) to test for differences among sites in number of Sandhill Cranes per hour and average individual crane height. Tukey's Studentized Range Test was used to test for pairwise differences between sites.

To analyze differences in height distributions among sites, we created the following height categories: (1) less than 0 meters, (2) every 10 meters up to 300 meters, (3) more than 300 meters. We summarized total numbers of birds detected in each height category for the following well-represented subgroups of birds: blackbirds (includes European Starlings plus Icteridae species other than orioles or meadowlarks); cormorants (Phalacrocoracidae); corvids (includes all Corvidae species); doves (Columbidae); ducks (Anatidae other than Anserinae); gulls (Laridae); herons (Ardeidae); ibis (*Plegadis chihi* was the only member of the Threskiornithidae recorded); raptors (Accipitridae, Pandionidae, Cathartidae, and Falconidae species); Sandhill Cranes (all subspecies); shorebirds (Charadriiformes); songbirds (includes all Passeriformes species other than those included in blackbirds or corvids categories, above); white geese; and woodpeckers (Picidae). For Sandhill Cranes, we only compared the height distributions of Arrey-Derry and the two San Antonio sites using the Kolmogorov-Smirnov test (PROC NPAR1WAY, with EDF option, SAS Version 9.2, 2007), because the height distributions at Armendaris and Vado had too many missing cells due to the rarity of cranes at those sites. To minimize the total number of statistical comparisons made, we did not use Kolmogorov-Smirnov tests to compare height distributions of any of the other subgroups of birds.

During our first surveying period, we generated a list of all bird species observed at each of the four sites. We calculated total number of bird species observed at each site and number of species unique to each site. Finally, we calculated the hourly rate of birds observed crossing the transmission-line plane, and the average individual bird height for each species at each of our four study sites to facilitate a full, species-by-species comparison.

3. RESULTS

Non-Crane Species: During the August to December 2010 survey period, substantial differences in both taxonomic group composition and flight-height distribution of bird traffic were observed among the five sites (Table 1).

Blackbirds were most abundant at the Vado site, and their flights were mostly observed below 50 meters in height, including large volumes in the risk zone. Cormorants were far more abundant at Armendaris than any other site, and their flights were mostly observed below 50 meters in height. Corvids (including crows and ravens) were more abundant at San Antonio South than any other site, likely due to the proximity of this site to winter roost sites for American Crow. Corvid flights were mostly observed below 100 meters in height, including high volumes in the risk zone. Doves were most abundant at San Antonio South, but were also very abundant at San Antonio North and Arrey-Derry, and their flights occurred mostly below 50 meters in height including high volumes in the risk zone, though the majority was lower. Ducks were more abundant at Vado than any other site, although considerable numbers of ducks were also observed at Arrey-Derry and both San Antonio sites. Most duck flight volume was observed below 100 meters in height, although the flight distribution was skewed upwards at Arrey-Derry. At Armendaris and both San Antonio sites, the risk zone corresponded to the area at or just above the peak flight volume. The peak volume of ducks at Vado occurred in the risk zone.

Table 1. Number of Birds per Hour (August to December 2010) of Selected Taxonomic Groupings in the Risk Zone* at Each Study Site

	Armendaris	Arrey-Derry	San Antonio North	San Antonio South	Vado
Blackbirds	1.480	3.457	0.1508	3.745	**22.79**
Cormorants	**0.3779**	0.00787	0.0238	0.00730	0
Corvids	4.260	2.677	10.38	**41.94**	2.831
Doves	0.0551	0.6456	0.3969	**0.7372**	0.2206
Ducks	0.7795	2.866	1.921	2.241	**11.87**
Gulls	0	**0.0472**	0.0317	0	0
Herons	0	0.0787	0	0	**2.133**
Ibis	0.00787	0.1889	0.1429	0.3358	**8.794**
Raptors	0.2519	0.2914	0.1270	0.1314	**0.3383**
Sandhill Cranes	0.1496	**25.03**	5.477	8.088	0.0441
Shorebirds	0	0	0	**0.0292**	0.00735
Songbirds	**12.58**	4.811	0.8254	1.861	0
White geese	0	0	0.8333	**1.964**	0.00735
Woodpeckers	**0.0551**	0.0315	0.0476	0	0
Total	19.99697	40.13217	20.3574	61.0799	49.0357

*We considered the "risk zone" to be between 30 and 50 meters.
The highest rate of passage for each taxonomic category is in **bold**.

Gulls were substantial in numbers only at Arrey-Derry, and their heights of flight were concentrated between 50–150 meters, with only a few gulls observed flying within the risk zone at any site. Both herons and White-faced Ibis were most abundant at the Vado site, where the majority of herons were Cattle Egrets. Flight-volume of herons and ibis occurred mostly below 50 meters in height, including proportionately high volumes in the risk zone. Raptors were more abundant at Vado than any other site, and their flights were mostly observed below 100 meters in height, although the overall height-distributions were highly variable, with many higher flying raptors observed at Armendaris and Arrey-Derry. Shorebirds were not particularly abundant at any site, but were observed in modest numbers at Vado followed by Arrey-Derry, and were primarily observed flying below 50 meters. Songbirds were most abundant at Armendaris, but were also very abundant at Arrey-Derry and both San Antonio sites. Songbird heights of flight mostly occurred below 50 meters, with the risk zone comprising the upper one-third of the flight-volume distribution. However, few songbirds were recorded flying above 100 meters, reflecting the difficulty of detecting small birds at long distances. White geese were only prevalent at the San Antonio sites, and their flights occurred primarily at higher altitudes, White geese tended to fly lower at San Antonio South (the transmission lines site), flying as low as the risk zone on occasion At San Antonio North, flight heights were primarily concentrated above 100 meters. Woodpeckers were not particularly abundant at any site, but were observed in modest numbers at both San Antonio sites, followed by Armendaris, and were primarily observed flying below 50 meters, mostly below the risk zone, though small numbers of migrating Northern Flickers would potentially be susceptible to collision. Canada geese, hummingbirds, kingfishers, nighthawks, and pelicans were not particularly abundant at any site; however, Canada Geese, hummingbirds, and kingfishers were most abundant at Arrey-Derry, nighthawks were most abundant at San Antonio North, and pelicans were most abundant at San Antonio South. Overall, Armendaris was the least active site, with fewer than 100 birds per hour observed. All the other sites had much higher rates of bird passage, with over 200 birds per hour observed .

During the December 2009 to March 2010 survey period, the number of birds per hour also varied by site and the differences were statistically significant by site, (df = 3, 244, F=5.65, p=0.0009) and light level (df = 1, 244, F = 4.34, p = 0.00383). Armendaris had fewer birds per hour than Vado or San Antonio, but the rate of passage at Arrey-Derry was not significantly different from any of the other sites. Fewer birds per hour were recorded flying in low-light hours versus high-light hours, but patterns of inter-site variation were consistent across light levels. Average flock height significantly differed by site (df = 3, 239, F = 6.37, p = 0.0004), but did not differ by light level (df = 1, 239, F = 2.76, p = 0.0980). Average flock height was higher at Arrey-Derry than at Armendaris or Vado, but average flock height at San Antonio did not significantly differ from any of the other sites.

Table 2 provides a similar summary of risk zone passages for the second survey period, December 2009 to March 2010.

Table 2. Number of Birds per Hour (December 2009 to March 2010) of All Bird Species Combined, and Selected Taxonomic Groupings in the Risk Zone* at Each Study Site

	Armendaris	Arrey-Derry	Vado	San Antonio
All Bird Species Combined	6.05	42.73	**62.07**	32.33
Sandhill Cranes	0.39	**14.35**	0.26	4.25
White geese	0	0.12	0	**12.42**
Blackbirds	0.35	7.79	**29.44**	7.98
Cormorants	**0.66**	0.01	0.06	0.02
Corvids	0.33	2.79	**8.08**	2.84
Doves	0.01	0.45	**1.50**	0.02
Ducks	2.10	4.36	**17.82**	0.94
Herons	**0.13**	0	0.04	0

Table 2. Number of Birds per Hour (December 2009 to March 2010) of All Bird Species Combined, and Selected Taxonomic Groupings in the Risk Zone* at Each Study Site				
	Armendaris	**Arrey-Derry**	**Vado**	**San Antonio**
Raptors	0.10	**0.18**	0.14	0.06
Songbirds	1.05	**8.03**	1.51	2.64
Total	**11.17**	**80.81**	**120.92**	**63.5**

*We considered the "risk zone" to be between 30 and 50 meters.
The highest rate of passage for each taxonomic category is in **bold**.

Number of Sandhill Cranes per hour differed significantly by site (df = 3, 124, F = 13.82, $p < 0.0001$). San Antonio and Arrey-Derry had significantly more cranes per hour than either Armendaris or Vado. Figure 12 displays numbers of birds per hour (Sandhill Cranes, ducks, raptors, and white geese) passing each survey site during both study periods. Average height of flight of individual cranes also differed significantly by site (df = 3, 66, F = 6.48, p = 0.0007). Individual crane flight heights were significantly higher at Armendaris than at either Arrey-Derry or San Antonio. Height profiles for Sandhill Cranes at each site during each study period for each site are summarized in Figure 13. Height profiles for ducks, raptors, and white geese at each site during each study period for each site are summarized in Figures 14 through 16.

Height distributions of total numbers of birds per hour were substantially different among sites. Bird traffic was concentrated at lower heights (mostly less than 100 meters) at Vado and Armendaris. The vertical dispersion of flight volume was very pronounced at San Antonio, and to a lesser extent, Arrey-Derry, with many flocks occurring at more than 100 meters. Height distributions of total number of birds per hour were significantly different according to Kolmogorov-Smirnov tests between Armendaris and San Antonio (KSa = 3.0835, p = 0.0001); between Arrey-Derry and Vado (KSa = 2.6813, p = 0.0001); between Arrey-Derry and San Antonio (KSa = 5.8118, p = 0.0001); and between Vado and San Antonio (KSa = 8.9367, p = 0.0001). Height distributions of total number of birds per hour were not significantly different between Armendaris and Arrey-Derry, and Armendaris and Vado. Total numbers of birds per hour in the risk zone (30 to 50 meters high) of the proposed transmission lines also differed substantially among sites, Armendaris had the fewest and Vado had the most.

Sandhill Crane height distributions at San Antonio and Arrey-Derry were significantly different according to the Kolmogorov-Smirnov test (KSa = 3.0429, p = 0.0001). The maximum difference in their cumulative frequency distributions at San Antonio and Arrey-Derry occurred at 30 meters, suggesting that San Antonio has a substantially higher proportion of Sandhill Cranes flying below 30 meters than at Arrey-Derry. Sandhill Crane height distributions at Vado and Armendaris were fragmented, as very few crane flocks were observed at either site, and those that were observed spanned both low (less than 100 meters) and high (more than 300 meters) heights. Arrey-Derry had the greatest number of Sandhill Cranes per hour in the risk zone, followed by San Antonio. Armendaris and Vado had very few cranes in this zone, and very few cranes all together (Table 2).

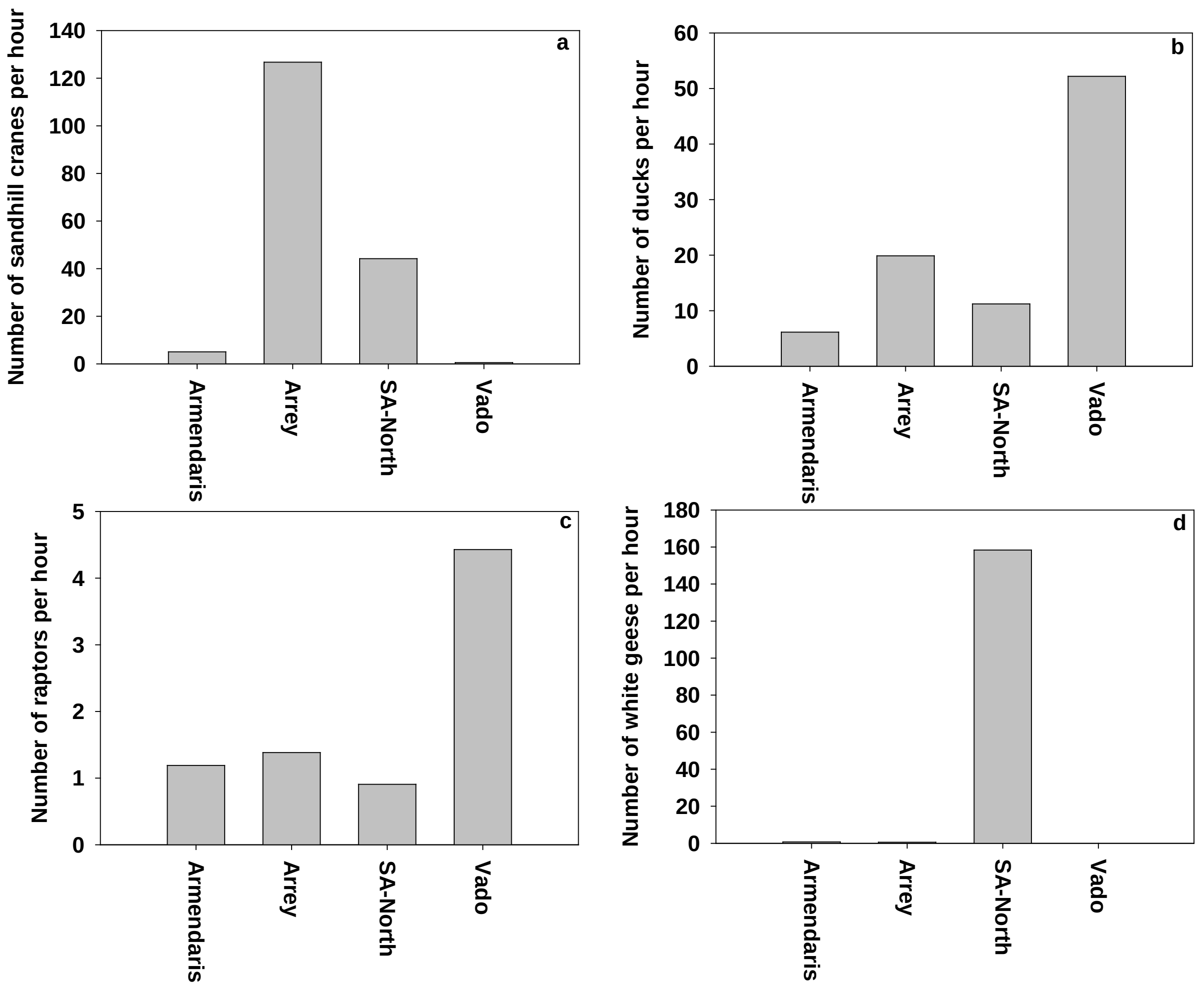

Figure 12. Numbers of Birds Observed per Hour at Four Rio Grande Crossings in New Mexico – (a) Sandhill Cranes, (b) ducks, (c) raptors, and white geese (d).
Surveys were conducted from December 2009 through December 2010.

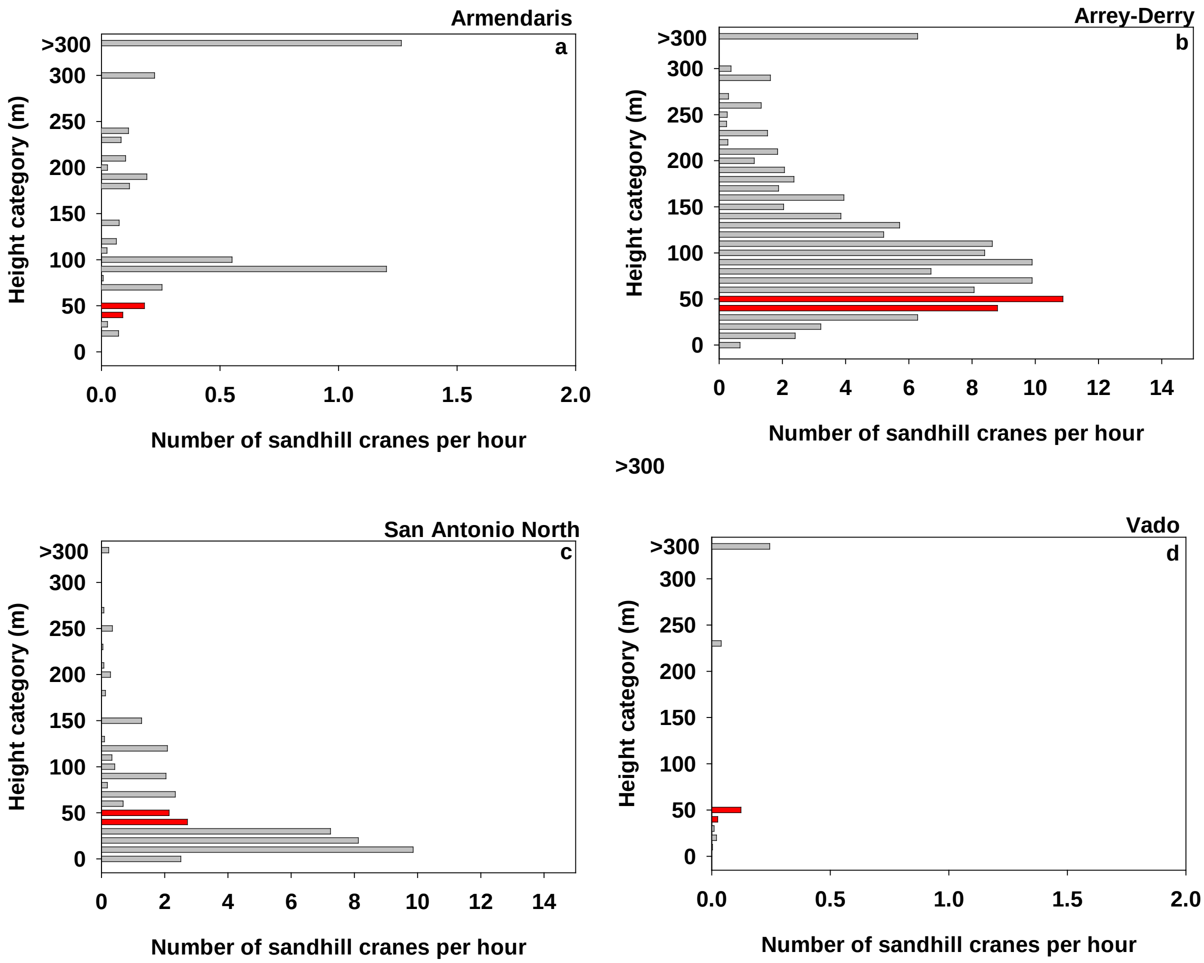

Figure 13. Height Profiles (Meters) of Sandhill Cranes at Four Rio Grande Crossings in New Mexico.

Surveys were conducted from December 2009 through December 2010. Note that x-axes in height profile plots are not all the same scale.

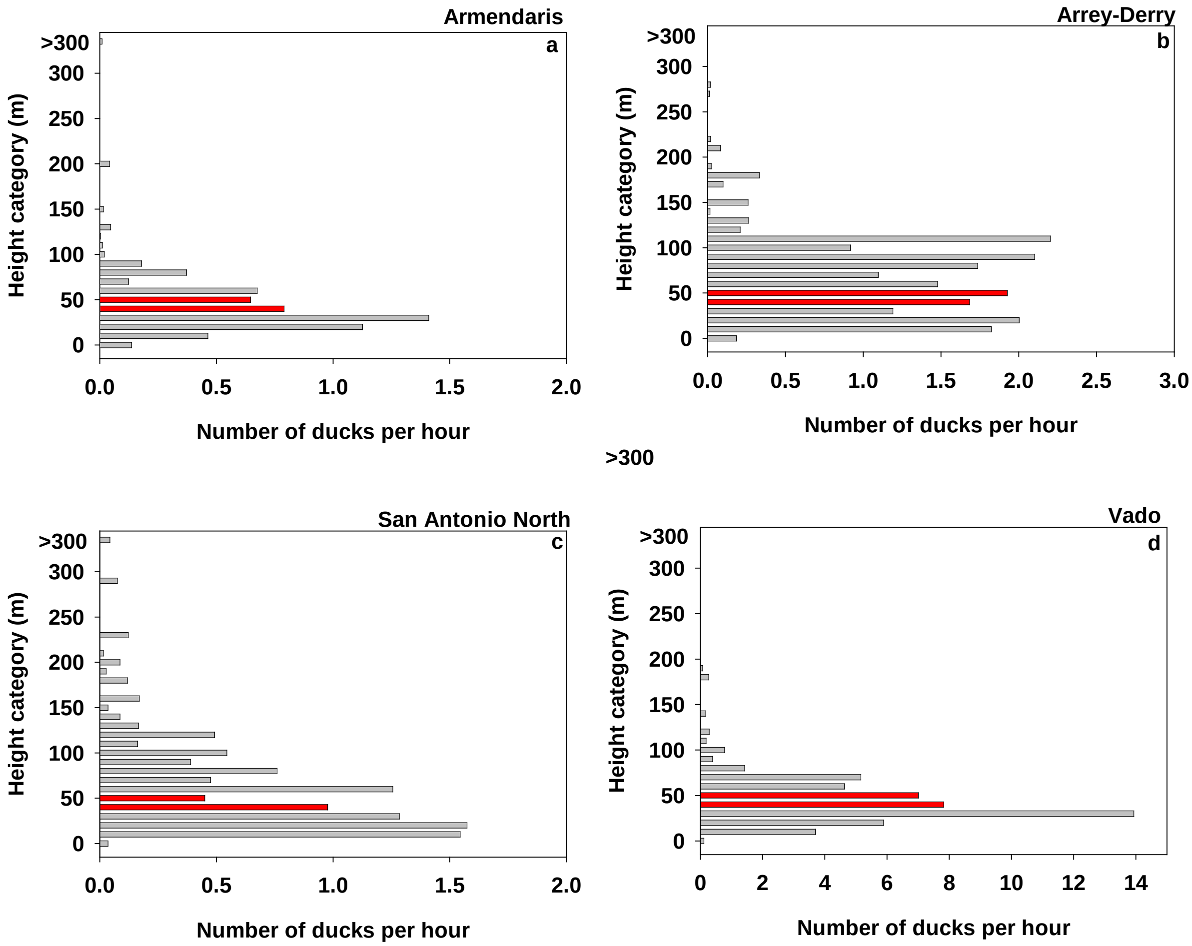

Figure 14. Height Profiles (Meters) of Ducks at Four Rio Grande Crossings in New Mexico.

Surveys were conducted from December 2009 through December 2010.
Note that x-axes in height profile plots are not all the same scale.

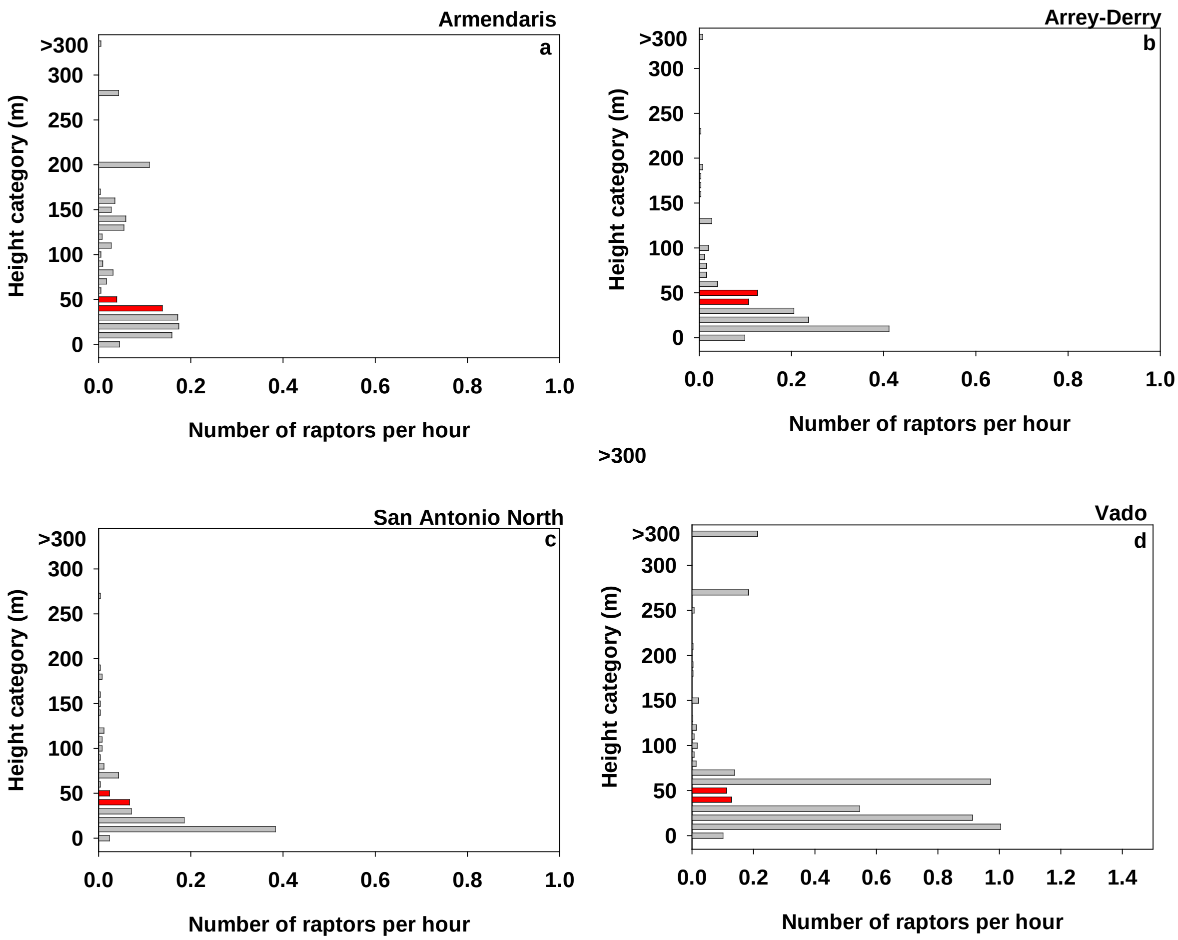

Figure 15. Height Profiles (Meters) of Raptors at Four Rio Grande Crossings in New Mexico.

Surveys were conducted from December 2009 through December 2010.
Note that x-axes in height profile plots are not all the same scale.

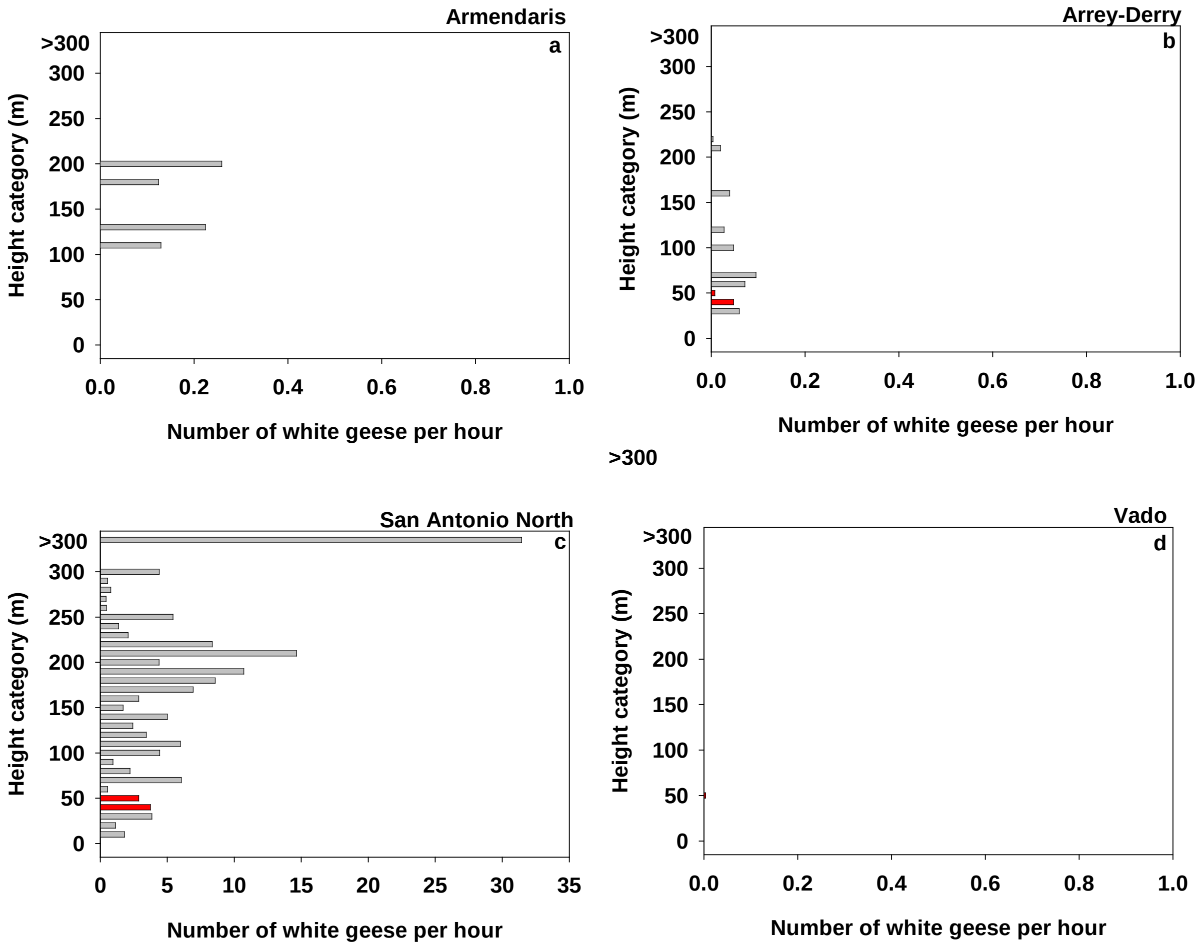

Figure 16. Height Profiles (Meters) of White Geese at Four Rio Grande Crossings in New Mexico.

Surveys were conducted from December 2009 through December 2010.
Note that x-axes in height profile plots are not all the same scale.

Height distributions of other subgroups of birds demonstrated substantial differences in bird traffic among the four sites. White geese were only prevalent at San Antonio, and at this site, flights occurred throughout the measured range of heights including the risk zone, although greater numbers of geese were detected at heights more than 100 meters. Blackbirds were much more abundant at Vado than any other site.

Sandhill Cranes: Sandhill Cranes were most abundant at Arrey-Derry, but were also very abundant at both San Antonio sites. Sandhill Cranes were very infrequent at both the Armendaris and Vado sites. Heights of flight of Sandhill Cranes spanned the entire range from 0 to more than 300 meters at Arrey-Derry, with most flights occurring between 50 and 200 meters. Sandhill Crane flight height was considerably lower at both San Antonio sites, primarily occurring below 100 meters. The greatest numbers of Sandhill Cranes flying in the risk zone were observed at Arrey-Derry, but considerable numbers of cranes in the risk zone were also observed at both San Antonio sites (Table 2).

Number of Sandhill Cranes per hour differed significantly by site ($df = 4, 158$, $F = 11.26$, $p < 0.0001$). Arrey-Derry had significantly more cranes per hour than any other site. The two San Antonio sites also had more cranes than Armendaris and Vado, but this difference was not detectable with Tukey’s Studentized Range Test, likely because there were several surveys with low numbers of cranes earlier in the survey season, before Sandhill Cranes arrived at San Antonio in earnest, creating high variability in the data. Average height of flight of individual cranes also differed significantly by site ($df = 4, 69$, $F = 4.54$, $p = 0.0026$). Individual crane flight heights were significantly lower at the San Antonio North site than at either the Armendaris or Vado sites. Individual crane heights at San Antonio South and Arrey-Derry were intermediate in height, and not significantly different from any other site, likely due to a broader distribution in heights of flight at those sites. Sandhill Cranes arrived in large numbers at Arrey-Derry earlier than they did at the San Antonio sites. At Arrey-Derry, large numbers of cranes were detected by mid-October, whereas at the San Antonio sites, the largest numbers of cranes were not detected until early-December. Sandhill Cranes vacated the Rio Grande Valley between mid-February and early March 2010. Subspecies composition also differed between Arrey-Derry and the San Antonio sites.

Crane Vocalizations and Subspecies Distributions: In accordance with our predictions based on theory of sound production, Greater Sandhill Cranes have lower formant-spacing in sonograms, likely due to their longer tracheae and vocal tracts, and the distribution of formant spacing between known Lesser and known Greaters barely overlapped. The distribution of formant spacing among cranes of unknown subspecies that were recorded in the immediate vicinity of San Antonio and Arrey-Derry survey sites reveal striking differences in subspecies composition between the two sites. San Antonio Sandhill Cranes are comprised predominantly of Greaters, whereas Arrey-Derry Sandhill Cranes are predominantly Lessers.

Species Diversity: During August through December 2010, the total number of bird species detected flying across the plane of the proposed transmission line corridor was highest at San Antonio South (125 species), followed by San Antonio North and Arrey-Derry (110 species each), Armendaris (98 species), and only 47 species were detected at Vado (Table 3). Each site had several species that were uniquely observed at that site. Ten unique species were observed at Armendaris; they were Bufflehead, Cackling Goose, Eastern Phoebe, Harlan’s Hawk, Marsh

Wren, Mexican Duck x Mallard hybrid, Pied-billed Grebe, Red-headed Woodpecker, Rusty Blackbird, and Wild Turkey. Twelve unique species were observed at Arrey-Derry; they were Canyon Towhee, Cassin's Vireo, Eastern Kingbird, Gambel's Quail, Lincoln's Sparrow, Loggerhead Shrike, Lucy's Warbler, Northern Mockingbird, Purple Finch, Pyrrhuloxia, Spotted Sandpiper, and White-throated Sparrow. Eight unique species were detected at San Antonio North; they were Gray Catbird, Lazuli Bunting, Northern Waterthrush, Ruddy Duck, Townsend's Warbler, Virginia's Warbler, Warbling Vireo, and Willet. Eleven unique species were observed at San Antonio South; they were Baird's Sandpiper, Bell's Vireo, Broad-tailed Hummingbird, Curve-billed Thrasher, Least Sandpiper, Red-breasted Nuthatch, Rufous Hummingbird, Solitary Sandpiper, Sprague's Pipit, White-tailed Kite, and Yellow-billed Cuckoo. Four unique species were observed at Vado; they were Aplomado Falcon, Lesser Yellowlegs, Long-billed Curlew, and Northern Goshawk (Table 3).

During the December 2009 through March 2010 survey period, the total number of bird species detected flying across the plane of the proposed transmission line corridor was highest at Arrey-Derry (89 species), followed by San Antonio (80 species), and we detected 68 species each at Armendaris and Vado (Table 3). Each site had several species that were uniquely observed at that site. Eleven unique species were detected at Armendaris; they were Brown Creeper, Curve-billed Thrasher, Dusky Flycatcher, Hermit Thrush, Juniper Titmouse, Marsh Wren, Pied-billed Grebe, Pine Siskin, Virginia Rail, White-winged Scoter, and Wild Turkey. Twelve unique species were detected at Arrey-Derry; they were Blue-winged Teal, Bonaparte's Gull, Canvasback, Chipping Sparrow, Common Goldeneye, Gambel's Quail, Harlan's Hawk, Loggerhead Shrike, Mexican Duck, Osprey, Pyrrhuloxia, and Rusty Blackbird. Eleven unique species were detected at Vado; they were Aplomado Falcon, Black-crowned Night Heron, Burrowing Owl, Cattle Egret, Lesser Yellowlegs, Orange-crowned Warbler, Greater Roadrunner, Rock Pigeon, Swainson's Hawk, Vesper Sparrow, and Wilson's Snipe. Thirteen unique species were detected at San Antonio; they were Cackling Goose, Cedar Waxwing, Eastern Bluebird, Forester's Tern, Franklin's Gull, Mountain Chickadee, Nuttall's Woodpecker, Red-breasted Merganser, Short-eared Owl, Spotted Towhee, Townsend's Solitaire, Western Screech Owl, and White-breasted Nuthatch (Table 3).

At the Vado site, we observed one currently recognized endangered species in the United States, the Aplomado Falcon. A reintroduction program is currently underway for this species, and we were able to verify that the individual Aplomado Falcon we observed at Vado was bred and released from the Armendaris Ranch re-introduction program .

Table 4 is a summary of birds observed at each study site during the December 2009 through March 2010 survey period.

Direct Observations of Bird-Transmission Line Interactions: Interactions of birds and transmission lines were witnessed at all three sites containing transmission lines: Armendaris, San Antonio South, and Vado. We observed birds from across the taxonomic spectrum modifying their flight behavior to avoid collision with the lines. The following bird species were observed taking evasive actions to avoid collision with the lines on at least one occasion: American Crow, American Kestrel, Barn Swallow, Cattle Egret, Common Raven, Gadwall, Ladder-backed Woodpecker, Mexican Duck, Mourning Dove, Peregrine Falcon, Red-headed Woodpecker, Red-winged Blackbird, Sandhill Crane, Snowy Egret, and Wood Duck. At the

Vado site, one apparently nonfatal collision was observed. A White-winged Dove was observed colliding with the transmission lines, and continued flying at least until it was out of sight of the observers. No other collisions were observed during the August to December 2010 survey period, despite a combined 400 hours of surveying at the three sites with existing overhead lines. During the December 2009 to March 2010 survey period, two fatal collisions were witnessed at the Armendaris site—one was a Cinnamon Teal and the second was a Mallard. In both cases, the birds hit the lower transmission lines during ascent from nearby marsh habitat. At the Vado site, observers witnessed two apparently nonfatal collisions by Mallards that struck the existing transmission lines but continued flying until they were out of site of the observers. As in the August to December 2010 study, the December 2009 to March 2010 study also included all types of birds altering flight patterns to avoid transmission lines were observed.

Table 3. List of 174 Species and 40 Additional Categories of Birds and Bats Observed (August to December 2010) at Survey Sites on the Rio Grande in New Mexico

Three of the five sites are potential locations from crossing of the river by the SunZia 500 kV electrical transmission lines. The Armendaris and San Antonio South sites are not being considered as potential crossing sites. The total number of individuals flying past per hour (num/hr) and average height (m) are shown for each taxon for each site.

Species	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
All birds combined	92.46	48.22	285.13	85.32	203.22	45.14	364.64	45.70	234.54	46.55
Accipiter sp.					0.01	12.21	0.01	20.93	0.03	7.45
American Avocet					0.01	10.46	0.01	19.21	0.13	5.66
American Crow	15.38	107.11	4.76	38.63	80.92	22.41	216.97	38.71		
American Goldfinch	0.05	19.99			0.37	16.05	0.04	95.62		
American Kestrel	0.05	39.02	0.18	18.80	0.22	12.93	0.49	10.97	0.53	20.50
American Pipit	0.14	91.67	2.35	21.34	0.33	25.00	0.58	14.49		
American Robin	0.02	9.73	0.01	9.82	0.59	20.28	0.12	15.05		
American White Pelican	0.24	56.23			0.12	427.36	0.09	45.94		
American Wigeon	0.15	36.08	8.45	89.03	0.35	22.83	0.01	54.73	1.74	38.47
Aplomado Falcon									0.01	23.30
Aythya sp.	0.06	34.07			0.15	7.00	0.07	25.60		
Baird's Sandpiper							0.01	0.00		
Bald Eagle	0.02	35.15	0.01	23.13	0.01	5.05				
Bank Swallow	0.20	16.51	0.02	4.00	0.22	23.72	0.15	10.46	0.66	17.34
Barn Owl							0.01	0.00	0.01	2.05
Barn Swallow	39.13	31.14	3.06	14.69	3.67	18.00	5.75	15.11		

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Bat sp.	0.02	6.36	0.13	3.50			0.05	2.82		
Bell's Vireo							0.01	-3.76		
Belted Kingfisher	0.04	37.30	0.21	0.67			0.04	1.53	0.07	6.17
Bewick's Wren			0.03	-0.72	0.02	-4.24	0.01	-0.69		
Black Phoebe	0.01	2.00	0.12	4.21	0.06	1.66	0.09	5.60		
Black-chinned Hummingbird			0.06	2.32	0.11	2.64	0.04	4.52		
Black-crowned Night-Heron	0.02	4.40	0.01	7.56					0.27	16.45
Black-headed Grosbeak					0.02	0.00	0.04	-2.58		
Blue Grosbeak			0.23	7.15	0.19	6.44	0.15	8.48		
bluebird sp.	0.02	24.97								
Blue-winged Teal	0.09	20.84	0.20	-1.20	0.16	94.54			0.25	11.16
Brewer's Blackbird	0.01	20.57	0.20	19.32	0.65	14.46	2.31	15.71	1.47	17.58
Brewer's Sparrow			0.06	-0.13	0.02	2.73	0.01	10.74		
Broad-tailed Hummingbird							0.01	5.21		
Brown-headed Cowbird	0.01	10.63	0.01	0.00			0.01	-1.74		
Bufflehead	0.02	42.80								

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Bullock's Oriole					0.01	12.94	0.01	4.90		
Bushtit	0.90	-1.52			0.02	0.05	0.33	-2.62		
Buteo sp.							0.01	18.98		
Cackling Goose	0.01	300.00								
Canada Goose (all subspp.)	0.10	350.00	0.52	19.98	0.33	38.52	0.20	27.77		
Canvasback			0.01	100.00	0.17	117.69	0.03	14.83		
Canyon Towhee			0.02	0.62						
Cassin's Kingbird	0.01	18.72			0.02	15.01	0.01	16.26		
Cassin's Vireo			0.01	-0.44						
Cattle Egret			0.05	23.78			0.07	5.69	18.10	16.56
Cedar Waxwing	0.02	16.96					0.01	40.00		
Chestnut-collared Longspur			0.02	5.59	0.03	71.81				
Chihuahuan Raven	0.09	49.45	2.37	46.33	1.46	15.14	0.45	49.61	20.13	123.59
Chipping Sparrow	0.24	11.92	2.39	2.52	1.18	10.88	0.54	3.70		
Chordeiles sp.	0.06	12.79			0.38	16.34	0.01	16.91	0.01	10.14
Cinnamon Teal	0.13	12.90			0.38	15.12	0.26	58.49		
Clay-colored Sparrow					0.07	5.12	0.01	1.86		

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Species	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Cliff Swallow	0.16	30.72	0.13	58.60	0.39	6.71	0.46	52.32		
Common Merganser	0.02	52.01					0.31	146.66		
Common Nighthawk	0.03	46.54	0.15	16.92	0.06	27.89	0.11	25.06		
Common Raven	0.30	22.16	7.04	22.57	0.55	12.29	1.55	9.81	0.56	220.49
Common Yellowthroat	0.06	-1.43	0.01	-5.01			0.01	-2.92		
Cooper's Hawk	0.01	0.00	0.06	12.61	0.03	75.07	0.07	8.09	0.11	11.67
Cormorant sp.	0.09	33.63	0.01	40.00						
Corvus sp.	0.25	34.05	3.06	28.89	9.76	63.75	0.05	12.41	0.75	20.08
Curve-billed Thrasher							0.01	0.70		
Dark-eyed Junco	0.19	-0.16	0.04	3.03	0.61	0.95	0.39	1.67		
Dickcissel					0.01	0.00	0.01	0.00		
Double-crested Cormorant	1.20	29.44	0.02	51.94	0.03	48.52	0.01	58.36	0.08	10.31
dove sp.	0.05	12.42	0.40	21.24	0.84	5.11	0.34	9.73		
Downy Woodpecker	0.01	11.12			0.01	3.28	0.02	9.33		
duck sp.	1.30	26.46	5.87	51.46	2.93	60.85	3.22	53.63	26.62	46.00
Eastern Kingbird			0.01	4.39						
Eastern Phoebe	0.01	14.14								

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	Armendaris		**Arrey-Derry**		**San Antonio North**		**San Antonio South**		**Vado**	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
egret sp.									0.07	72.79
Empidonax sp.					0.01	4.25	0.01	0.86		
Eurasian Collared-Dove	0.21	52.83			0.03	3.95	0.07	5.49		
European Starling			0.08	29.24	0.19	9.30	1.04	32.33		
falcon sp.			0.03	38.82	0.02	66.22	0.01	26.24	0.01	19.03
Ferruginous Hawk			0.03	44.22			0.06	12.66		
finch sp.	0.06	16.86	0.12	22.88			0.01	30.60		
flycatcher sp.							0.01	6.81		
Gadwall	0.16	51.64	0.76	74.87	0.32	65.04	0.72	30.63		
Gambel's Quail			0.70	-0.71						
Golden Eagle			0.05	170.36			0.01	27.83		
goldfinch sp.	0.08	25.00	0.24	30.66	0.03	26.06				
Gray Catbird					0.02	2.09				
Great Blue Heron	0.14	21.08	0.25	13.03	0.06	39.50	0.03	4.50	0.29	12.49
Great Egret	0.02	20.68	0.05	13.26	0.04	25.79	0.01	134.52	0.24	10.23
Great Horned Owl	0.02	3.66	0.02	4.17	0.06	4.51	0.06	10.18	0.01	1.41
Greater Roadrunner			0.01	0.58			0.01	0.00		

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	Armendaris		**Arrey-Derry**		**San Antonio North**		**San Antonio South**		**Vado**	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
Greater Yellowlegs	0.02	2.36							0.01	50.00
Great-tailed Grackle	0.13	26.67	0.31	58.32					0.11	21.18
Green-winged Teal	0.20	26.91	1.40	22.07	0.60	87.80	0.53	32.38	0.04	21.69
grosbeak sp.							0.01	5.49		
gull sp.			1.31	54.27	0.24	156.43	0.02	79.06		
Hairy Woodpecker	0.01	8.86					0.01	4.21		
Harlan's Hawk	0.01	40.10								
hawk sp.	0.01	87.89			0.01	29.42	0.02	10.34		
Hooded Merganser			0.02	0.72						
Horned Lark			0.87	69.54			0.62	25.20		
House Finch	0.17	16.80	0.77	25.91	0.39	41.08	0.69	20.36		
House Sparrow			0.07	2.67	0.03	8.99				
House Wren			0.01	-0.16	0.02	0.39	0.02	4.53		
hummingbird sp.	0.01	2.00	0.02	1.18			0.02	5.16		
Icteridae sp.	0.31	16.54	16.50	17.67	0.18	15.58	1.20	23.26	108.42	37.92
Killdeer	0.02	35.24	0.53	-1.09	0.14	7.13	0.08	23.79	0.51	26.67

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Species	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Ladder-backed Woodpecker	0.06	16.01	0.01	0.79			0.02	19.18		
Lark Bunting	0.02	0.00			0.29	1.65	0.18	14.45		
Lark Sparrow			0.41	-0.61	0.31	4.57	0.38	8.87		
Lazuli Bunting					0.08	18.45				
Least Sandpiper							0.02	10.45		
Lesser Goldfinch	0.19	11.73	0.39	7.38	0.51	15.57	1.87	11.93		
Lesser Nighthawk	0.02	27.19	0.01	9.73	0.02	24.91				
Lesser Yellowlegs									0.21	9.40
Lincoln's Sparrow			0.17	-1.08						
Loggerhead Shrike			0.01	0.17						
Long-billed Curlew									0.01	18.86
Lucy's Warbler			0.01	-1.26						
MacGillivray's Warbler					0.01	0.00	0.01	2.39		
Mallard	1.47	41.46	3.23	63.00	2.95	67.35	6.85	54.61	8.43	46.15
Marsh Wren	0.04	-2.87								
meadowlark sp.			0.02	30.90						

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	Armendaris		**Arrey-Derry**		**San Antonio North**		**San Antonio South**		**Vado**	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
merganser sp.			0.02	62.47						
Merlin			0.02	16.60	0.01	25.36	0.01	3.00		
Mexican Duck	0.18	15.47	0.01	1.41						
Mexican Duck x Mallard hybrid	0.02	31.97								
Mourning Dove	1.33	12.27	1.94	18.52	4.99	8.36	4.89	12.05	0.55	27.86
Neotropic Cormorant	0.46	22.73			0.02	13.12	0.01	35.65		
Northern Flicker	0.57	14.76	0.31	11.28	2.11	8.32	1.18	9.48	0.06	5.95
Northern Goshawk									0.01	3.98
Northern Harrier	0.10	11.88	0.39	11.04	0.21	21.20	0.12	9.32	0.39	7.43
Northern Mockingbird			0.01	4.15						
Northern Pintail	0.28	76.69	0.02	33.32	1.12	104.73	0.59	72.67	0.09	28.50
N. Rough-winged Swallow	0.07	20.87	0.80	26.40	0.20	13.04	0.05	7.56		
Northern Shoveler	0.37	30.11	0.02	6.44	2.29	61.67	1.66	182.35	0.09	44.90
Northern Waterthrush					0.01	5.23				
Olive-sided Flycatcher					0.01	6.98	0.01	9.02		
Orange-crowned Warbler					0.02	3.50	0.04	0.89		

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Osprey			0.02	40.30	0.01	5.31	0.03	12.70	0.02	21.94
owl sp.			0.01	-1.95					0.04	19.54
passerine sp.	0.39	20.05	5.78	36.34	0.80	12.95	0.92	15.04		
Peregrine Falcon			0.03	28.19			0.02	16.08	0.10	13.43
Phainopepla					0.02	10.85	0.02	5.65		
Pied-billed Grebe	0.01	11.98								
Pine Siskin	0.25	20.39	0.02	-4.39	0.29	11.04	0.62	27.98		
Prairie Falcon			0.02	98.04	0.01	3.14	0.02	16.84	0.04	21.44
Purple Finch			0.02	10.88						
Pyrrholoxia			0.02	2.50						
raptor sp.									0.01	0.00
raven sp.			2.09	7.74						
Red-breasted Nuthatch							0.02	0.60		
Red-headed Woodpecker	0.01	18.56								
Red-naped Sapsucker	0.02	2.03			0.02	10.82				
Red-shafted Flicker	0.01	7.81					0.01	11.21		
Red-tailed Hawk	0.11	30.79	0.10	50.09	0.13	18.62	0.20	19.15	0.55	32.75

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	num/hr	height	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Red-winged Blackbird	13.64	21.10	8.90	32.39	4.13	18.20	31.04	17.79		
Ring-billed Gull	0.26	116.74	1.17	127.80	0.10	41.60	0.09	34.58		
Ring-necked Duck	0.06	21.80					0.16	39.09	0.10	7.25
Rock Dove	0.01	15.93	1.38	30.09			0.82	18.95		
Ross's Goose					0.10	141.90	0.09	106.99		
Ruby-crowned Kinglet	0.01	5.00	0.06	0.57	0.05	0.24	0.06	9.84		
Ruddy Duck					0.03	8.21				
Rufous Hummingbird							0.01	-0.15		
Rusty Blackbird	0.01	-0.87								
Sandhill Crane	4.49	139.63	183.39	113.79	42.09	47.97	36.77	63.30	0.38	263.29
sandpiper sp.			0.01	0.00			0.01	14.05	0.15	-0.27
sapsucker sp.							0.01	2.11		
Savannah Sparrow			0.13	2.57	0.01	0.00				
Say's Phoebe			0.24	9.06	0.10	8.23	0.10	9.88	0.01	-0.11
Sharp-shinned Hawk	0.02	92.51	0.15	18.86	0.06	10.81	0.01	5.34	0.47	27.04
Snow Goose	0.45	123.80	0.18	157.86	20.77	160.13	25.67	139.95	0.01	41.89
Snowy Egret			0.04	31.78			0.03	15.96	1.51	21.97

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
Solitary Sandpiper							0.01	15.69		
Song Sparrow	0.05	-1.53	0.02	-0.85	0.02	-3.39				
sparrow sp.	0.02	10.35	0.55	5.42	0.28	9.97	0.43	35.84		
Spizella sp.			0.12	8.75	0.14	4.79	0.03	15.00		
Spotted Sandpiper			0.14	-4.98						
Spotted Towhee	0.01	-1.89	0.02	0.42	0.06	-0.77	0.01	-2.04		
Sprague's Pipit							0.02	113.83		
Summer Tanager	0.02	7.52	0.01	0.37	0.02	6.33	0.04	3.51		
Swainson's Hawk			0.02	65.92	0.03	23.14	0.05	64.20	0.05	351.96
swallow sp.	1.20	19.64	1.00	14.88	2.41	10.84	1.19	27.59		
swift sp.			0.01	30.14						
Townsend's Warbler					0.02	8.78				
Tree Swallow	0.06	2.97	0.01	1.09	0.18	21.42	0.23	27.98		
Turkey Vulture	1.21	113.06	0.53	39.81	0.47	46.27	0.49	47.51	3.71	129.07
Unidentified	0.01	11.52	0.39	53.62	0.01	0.10	0.02	39.74		
Verdin			0.01	-0.18	0.01	-1.63	0.02	1.30		
Vermilion Flycatcher	0.02	12.58	0.02	1.88			0.01	5.78		

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	Armendaris		**Arrey-Derry**		**San Antonio North**		**San Antonio South**		**Vado**	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
Vesper Sparrow			0.11	1.98	0.08	12.49				
Violet-green Swallow	0.13	14.86	0.01	4.41			0.03	3.93		
Virginia's Warbler					0.04	6.47				
warbler sp.	0.01	3.14	0.04	7.82	0.07	4.75	0.06	10.81		
Warbling Vireo					0.01	0.52				
Western Bluebird			0.01	12.63	0.18	35.59	0.10	38.65		
Western Kingbird	0.05	28.57	0.04	22.87	0.07	10.03	0.06	6.27		
Western Meadowlark					0.03	12.96	0.03	22.66		
Western Screech-Owl			0.01	0.00	0.01	0.00	0.03	1.15	0.01	20.67
Western Scrub-Jay	0.01	15.01	0.01	0.00	0.01	0.84	0.01	0.00		
Western Tanager	0.01	5.00			0.22	7.86	0.02	1.89		
Western Wood-Pewee	0.02	3.22			0.03	2.30	0.04	4.13		
white goose sp.							0.49	235.64		
White-breasted Nuthatch					0.02	7.88	0.01	7.69		
White-crowned Sparrow	0.16	2.76	1.44	1.77	1.14	7.14	0.39	3.78		
White-faced Ibis	0.01	36.94	1.09	20.74	1.92	20.86	1.31	45.27	27.97	33.73
White-tailed Kite							0.01	8.79		

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	Armendaris		Arrey-Derry		San Antonio North		San Antonio South		Vado	
Species	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**	**num/hr**	**height**
White-throated Sparrow			0.01	0.00						
White-winged Dove	0.23	19.18	0.99	25.41	0.31	22.97	1.98	15.21	0.04	27.55
Wild Turkey	0.06	-4.76								
Willet					0.01	10.44				
Wilson's Snipe	0.02	0.00	0.01	-0.94						
Wilson's Warbler	0.06	-0.27	0.11	-1.09	0.54	7.70	0.55	4.50		
Wood Duck	0.09	11.15	0.01	6.85	0.09	6.95	0.23	10.29		
woodpecker sp.	0.01	19.77	0.01	-1.73			0.01	9.16		
wren sp.							0.01	-0.33		
Yellow Warbler	0.01	7.52	0.03	-2.11			0.01	3.75		
Yellow-billed Cuckoo							0.01	-1.29		
Yellow-breasted Chat	0.02	-3.24	0.01	0.00			0.01	-2.44		
Yellow-headed Blackbird	1.41	20.21			0.03	57.58	0.20	18.37	8.31	57.49
Yellow-rumped Warbler	0.24	5.21	0.43	10.00	1.04	9.54	1.04	8.01		

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Species	Armendaris		Arrey-Derry		Vado		San Antonio	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height
American Coot	0.0622	-1.54	0		0.0069	-1.90	0.0706	13.32
American Crow	0.6010	39.48	0.8606	36.02	0.0137	30	8.3451	67.96
American Goldfinch	0.0829	6.10	0		0		0.0941	13.33
American Kestrel	0.0518	18.96	0.1036	16.03	0.1924	19.02	0.0706	5.61
American Pipit	0.2591	48.77	25.93	27.56	0.0687	8.00	0.3529	20.85
American Robin	0.4249	30.65	0.1275	11.21	0.1718	9.28	17.94	46.84
American White Pelican	0.4041	52.96	0.1434	320.5	0		0.0078	45.71
American Wigeon	0.5285	26.02	4.876	80.44	2.186	32.22	0.3216	9.22
Aplomado Falcon	0		0		0.0344	16.39	0	
Bald Eagle	0.0725	33.65	0.0080	382.77	0		0.0314	47.99
Barn Owl	0		0.0080	11.36	0.0344	3.86	0	
Barn Swallow	0		0.1195	12.38	0.0412	3.14	0.0314	-1.05
Belted Kingfisher	0.0414	4.86	0.0876	7.40	0.0137	4.92	0.0078	0
Bewick’s Wren	0.0104	-2.5	0.0080	-1.85	0		0.0392	-1.56
Black Phoebe	0.0207	1.89	0.1195	0.08	0.0069	3.73	0.0235	22.08
Black-crowned Night Heron	0		0		0.1649	16.07	0	
Blue-winged Teal	0		0.0319	63.85	0		0	
Bonaparte’s Gull	0		0.0159	13.96	0		0	
Brewer’s Blackbird	0		10.45	22.92	13.28	26.57	3.945	7.02
Brown Creeper	0.0207	3.11	0		0		0	
Brown-headed Cowbird	0.0104	5	0.0797	98.00	0		0	
Bufflehead	0.0311	30	0.1355	20.23	0.0275	60.37	0.0078	11.77
Burrowing Owl	0		0		0.0344	0.23	0	

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	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Bushtit	0.2280	-1.58	0		0		0.3216	-0.57
Cackling Goose	0		0		0		0.0392	10.56
Canada Goose	0.1969	127.22	0.0478	31.76	0		4.949	29.52
Canvasback	0		0.0717	53.46	0		0	
Cattle Egret	0		0		0.0893	7.48	0	
Cedar Waxwing	0		0		0		0.9882	16.95
Chestnut-collared Longspur	0		6.956	17.44	0		3.569	5.78
Chihuahuan Raven	0.4663	18.62	5.625	196.74	12.19	39.56	0.3059	327.39
Chipping Sparrow	0		0.0319	0.86	0		0	
Cinnamon Teal	0.1762	3.64	0.1195	28.65	0		0	
Cliff Swallow	0		0.0797	15.40	0.0619	22.37	0	
Common Goldeneye	0		0.0080	50.0	0		0	
Common Merganser	0.3316	54.88	0.7490	72.10	0		0.1255	20.93
Common Raven	0.3109	47.32	5.793	24.69	0		0.3529	33.13
Cooper’s Hawk	0.0415	13.53	0.0876	13.23	0.3299	15.81	0.0471	10.24
Curve-billed Thrasher	0.0104	18	0		0		0	
Dark-eyed Junco	1.482	3.53	0.0558	2.86	0.0412	0.43	0.4627	-0.44
Double-crested Cormorant	0.7565	33.92	0.0239	21.04	0.5430	7.35	0.1882	25.00
Downy Woodpecker	0.0311	15.56	0		0		0.0078	6.88
Dusky Flycatcher	0.0104	10	0		0		0	
Eastern Bluebird	0		0		0		0.0157	21.56
Eurasian Collared Dove	0.0311	19.56	0.0637	12.62	0.0275	5.59	0.0471	9.76
European Starling	0.0104	22.82	0.5976	23.08	0.2955	34.62	3.647	26.03

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Species	Armendaris		Arrey-Derry		Vado		San Antonio	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Ferruginous Hawk	0		0.0159	53.46	0		0.0157	3.04
Forester's Tern	0		0		0		0.0078	60.48
Franklin's Gull	0		0		0		0.0392	14.13
Gadwall	0.8083	31.52	4.948	46.05	0.4192	18.87	0.1647	25.43
Gambel's Quail	0		0.1195	0	0		0	
Great Blue Heron	0.6839	17.66	0.0797	108.15	0.1649	13.38	0.1098	8.44
Great Egret	0		0		0.0893	25.06	0.0078	10.08
Great Horned Owl	0.0207	15	0.0478	1.68	0.0137	14.02	0.0549	4.50
Greater Yellowlegs	0		0.0319	0.38	0.1787	7.86	0	
Great-tailed Grackle	0		0.2390	54.12	1.127	23.12	0	
Green-winged Teal	0.3316	34.22	1.147	5.06	0.2955	14.92	0.0549	7.24
Harlan's Hawk	0		0.0080	36.24	0		0	
Hermit Thrush	0.0104	3	0		0		0	
Herring Gull	0.0311	56.32	1.052	28.55	0		0.0784	35.66
Hooded Merganser	0.0104	22.19	0		0		0.0784	6.48
Horned Lark	0		0.2151	13.35	17.31	17.44	0.0314	40.0
House Finch	0.1451	19.01	0.7968	18.04	0.1237	32.33	0.0471	11.81
Juniper Titmouse	0.0104	7.65	0		0		0	
Killdeer	0.0104	50.0	0.1753	11.17	2.213	13.53	0	
Ladder-backed Woodpecker	0.0518	8.68	0		0		0.0157	10.02
Least Sandpiper	0		0.4861	19.65	0.0069	15.0	0	
Lesser Goldfinch	0		0.0319	26.87	0		0.0078	40.0
Lesser Yellowlegs	0		0		0.0412	15.08	0	
Loggerhead Shrike	0		0.0080	7.38	0		0	

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Species	Armendaris		Arrey-Derry		Vado		San Antonio	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Long-billed Curlew	0		0.0080	50.0	0.6529	22.39	0	
Mallard	3.036	38.18	2.191	66.48	30.41	38.30	3.827	40.73
Marsh Wren	0.0518	-3.32	0		0		0	
Merlin	0		0.0080	17.86	0.0137	23.19		
Mexican Duck	0		0.0239	35.45	0		0	
Mountain Bluebird	0		0.1355	13.45	0		1.027	12.75
Mountain Chickadee	0		0		0		0.0235	0.22
Mourning Dove	0.0622	6.27	0.9721	14.37	9.73	16.04	0.4863	10.48
Neotropic Cormorant	0.9016	21.54	0		0		0.1098	9.11
Northern Flicker	0.3316	11.82	0.0478	15.84	0.3574	9.51	0.0549	7.85
Northern Harrier	0.2902	11.37	0.4382	9.66	0.3918	9.16	0.1490	12.69
Northern Pintail	0.3316	90.76	1.036	69.71	0.5292	31.44	0.2118	48.63
Northern Rough-winged Swallow	0.3627	22.77	5.570	10.28	0		0.1490	5.96
Northern Shoveler	0.2902	33.76	0.1912	21.33	0.9759	31.27	1.686	81.47
Nuttall’s Woodpecker	0		0		0		0.0078	2.53
Orange-crowned Warbler	0		0		0.0206	4	0	
Osprey	0		0.0080	74.95	0		0	
Peregrine Falcon	0		0.0478	48.77	0.0069	37.83	0	
Phainopepla	0		0.1992	10.14	0		0.0078	40.0
Pied-billed Grebe	0.0104	9.0	0		0		0	
Pine Siskin	0.2798	46.49	0		0		0	
Prairie Falcon	0.0104	15.20	0.0319	46.22	0.1168	43.51	0	
Pyrrhuloxia	0		0.0637	1.90	0		0	

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Species	Armendaris		Arrey-Derry		Vado		San Antonio	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Red-breasted Merganser	0		0		0		0.0235	100.46
Redhead	0		0.1594	40.0	0		0.0157	39.87
Red-tailed Hawk	0.1347	20.35	0.0800	28.16	0.5292	28.56	0.0863	24.36
Red-winged Blackbird	7.990	12.96	24.25	21.64	23.47	26.01	11.04	35.61
Ring-billed Gull	4.197	41.27	35.00	47.22	0.1031	19.86	2.706	24.71
Ring-necked Duck	0		1.076	17.11	0		0.0235	16.0
Roadrunner	0		0		0.0069	5.0	0	
Rock Pigeon	0		0		0.8041	20.70	0	
Ruby-crowned Kinglet	0		0.0717	1.08	0		0.0471	0.31
Rusty Blackbird	0		1.195	9.70	0		0	
Sandhill Crane	5.627	249.62	69.97	94.17	0.5636	236.33	46.35	32.36
Say's Phoebe	0.0207	-3.24	0.0558	11.59	0.0206	-0.57	0.0549	3.88
Sharp-shinned Hawk	0		0.0797	9.79	0.9622	9.24	0.0157	2.61
Short-eared Owl	0		0		0		0.0078	5.38
Song Sparrow	0.0311	-2.36	0.0717	-0.78	0.0275	0.04	0	
Spotted Sandpiper	0		0.0956	-3.56	0.2337	-0.60	0	
Spotted Towhee	0		0		0		0.0078	1.05
Swainson's Hawk	0		0		0.0069	15.0	0	
Townsend's Solitaire	0		0		0		0.0157	6.20
Tree Swallow	0.1658	30.82	0.3665	13.14	0		0.0157	12.5
Turkey Vulture	0.1762	55.63	0.0797	40.62	0		0.0078	16.54
Vesper Sparrow	0		0		0.0069	4.0	0	

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Species	Armendaris		Arrey-Derry		Vado		San Antonio	
	num/hr	height	num/hr	height	num/hr	height	num/hr	height
Violet-green Swallow	0		0.2869	8.41	0.0275	30.0	0	
Virginia Rail	0.0104	0	0		0		0	
Western Bluebird	0.4041	68.92	1.339	12.16	0		1.765	14.95
Western Meadowlark	0		1.546	11.76	0.0069	4.53	0.2118	14.84
Western Sandpiper	0		0.0478	50.0	0.0275	17.64	0	
Western Screech Owl	0		0		0		0.0471	0.31
White-breasted Nuthatch	0		0		0		0.0157	6.21
White Goose	1.026	170.15	0.7331	44.46	0		294.08	197.54
White-crowned Sparrow	0		0.2151	1.28	0.0344	4.0	0.0627	0.50
White-throated Swift	0		0.3904	34.97	7.299	24.76	0	
White-winged Dove	0.4145	17.29	1.299	22.73	8.859	25.96	0.0314	23.93
White-winged Scoter	0.0104	12.0	0		0		0	
Wild Turkey	0.0311	0	0		0		0	
Wilson’s Snipe	0		0		0.0206	15.69	0	
Wood Duck	0.0933	40.75	0.0159	29.07	0.0137	14.0	0.1882	11.06
Yellow-headed Blackbird	0		0.0319	51.98	8.378	31.28	0	
Yellow-rumped Warbler	0.0311	14.0	0.1594	7.87	0.1031	21.73	0.1412	9.68

4. DISCUSSION

4.1. Potential Impacts of New Transmission Lines at the Four Proposed Construction Sites

***Armendaris*:** Our results clearly demonstrate that traffic of most bird species during the fall and early winter 2010 and in the winter-spring period at the Armendaris Ranch site was much lower than at the other sites, and this can be explained by the dearth of agricultural habitats in the vicinity. Very few Sandhill Cranes, white geese, blackbirds, corvids, doves, or ibis were observed at this site. Cormorants were most abundant at Armendaris, but overall rates of passage were low. Songbirds were common at Armendaris, including a large volume in the risk zone. Although songbirds of special concern such as Southwestern Willow Flycatcher (*Empidonax traillii extimus*) and Yellow-billed Cuckoo (*Coccyzus americanus*) undoubtedly occur in the vicinity, we did not observe these species crossing the transmission line route at Armendaris. Ducks were moderately abundant at Armendaris, but ducks in the risk zone were still more abundant at other sites. The Armendaris site, as noted earlier, has been eliminated as an alternative for the SunZia Project primarily because utilization of this alternative would result in a total of three crossings of the Rio Grande. The site was maintained in the study because an existing 345 kV line at that location provided an opportunity to monitor bird/transmission line interactions within the general Project vicinity.

Arrey-Derry: We observed the highest numbers of Sandhill Cranes at Arrey-Derry during both survey periods. These were almost entirely Lesser Sandhill Cranes from the MCP, and were in the midst of daily commuting flights from Caballo Lake to agricultural areas to the south and west. Sandhill Cranes arrived at the Arrey-Derry area *en masse* in mid-October, which corresponds with the fact that the majority are Lessers coming from high-latitude breeding grounds. Bird flights in general and Sandhill Cranes in particular were more vertically dispersed at Arrey-Derry than at the San Antonio sites, with a greater proportion of birds observed flying over 100 meters. The average height of flight of Sandhill Cranes at Arrey-Derry was 114 meters, substantially higher than either of the San Antonio sites (48 meters and 63 meters, respectively). The proportion of the overall Sandhill Crane flight volume at Arrey-Derry that passed through the risk zone was 13.6 percent, a similar proportion to that found at San Antonio. However, unlike the San Antonio sites, the remainder of the flight distribution was higher than the risk zone. The reason for the higher flight may be the steeper angle of the Rio Grande Valley at this latitude. The cranes were roosting at Caballo Lake before flying south over the Arrey-Derry survey point, a vertical differential of approximately 22 meters. In contrast, cranes roosting at the Bosque del Apache begin their commute northward from approximately 6 meters below the elevation of San Antonio, a 28-meter height differential (Source: Google Earth digital elevation coverage). Arrey-Derry was the second best site for ducks, after Vado, with about three individual ducks per hour passing through the risk zone (averaged across the entire survey period). It was also the second best site for songbirds, after Armendaris. It was the best site for gulls, but these were almost entirely above the risk zone, and it was the best site for Canada Goose, but this species was scarce at all sites. Arrey-Derry was the second best site for shorebirds and kingfishers, but these were flying entirely below the risk zone, and were not very abundant. Construction of transmission lines should include measures to reduce collisions in this bird-rich area, and design considerations should take into account the bluffs on the eastern flank of the Rio Grande corridor. Predicted impacts on Sandhill Cranes at this site are discussed further below.

***San Antonio*:** The San Antonio area, including the Bosque del Apache NWR is a major bird-watching destination of New Mexico and, as a result, maintaining the unique and valuable aesthetic of this area is of substantial importance. The two survey sites in the vicinity of San Antonio yielded results that were similar across nearly every group of birds, suggesting that the observed flight volumes provide a useful index of collision risk at a hypothetical transmission line at any point in the San Antonio area. The only bird groups that were different among the two sites were ones that were subject to small sample size effects (e.g., kingfishers, nighthawks, pelicans, gulls, and Canada Geese), or reflected differential proximity of concentration points, such as the town of San Antonio or the Bosque del Apache NWR. The latter phenomenon could explain slightly higher numbers of crows, blackbirds, doves, white geese, ducks, and all birds combined at the San Antonio South survey site relative to San Antonio North. In fact, the San Antonio South site had the highest volume of combined bird flight of any site. The two San Antonio sites had the highest numbers of woodpeckers, corvids, and doves. The two San Antonio sites also had the highest numbers of white geese of any site, but more than 90 percent crossed above the height of the risk zone. Furthermore, white geese are not a major conservation concern due to their large population sizes, high recruitment rates, and correspondingly high hunter bag-limits, and large numbers of white geese may actually be harmful to crane populations due to spread of disease (Drewien et al. 2001). Cranes were common at both San Antonio sites, but arrived later in the fall season than at the Arrey-Derry site. The difference in arrival times reflects differences in timing of migration between Lesser Sandhill Cranes from the MCP and Greater Sandhill Cranes from the RMP. While the fall migrant and wintering cranes at Arrey-Derry were comprised of Lesser Sandhill Cranes from the MCP, those recorded in the San Antonio area during the same period were comprised of Greater Sandhill Cranes from the RMP.

Our observations are consistent with those of Stahlecker et al. (1992), who found that most RMP cranes migrate from Colorado to the Middle Rio Grande Valley during the first 3 weeks of November, often with 50–77 percent of the population leaving within a 4-day period. Due to the significant conservation concern associated with the RMP cranes, it would be important that construction of the transmission lines at this site seeks to minimize collision-based mortality via placement and design considerations and post-construction mitigation measures. Maximizing the distance between the planned transmission lines and the Bosque del Apache NWR would be one such consideration. Sandhill Cranes traveled at lower heights at San Antonio North (average 48 meters) than at San Antonio South (63 meters), likely because cranes were actively avoiding the existing 10 to 15 meters high transmission lines at the latter site. This type of behavioral avoidance is not unexpected (Brown and Drewien 1995), especially considering that these cranes coexist with transmission lines in many parts of their distribution and annual cycle. The proportion of passing cranes that were within the risk zone was 13 percent and 22 percent for San Antonio North and San Antonio South, respectively. Since our height data are relative to the observation point on the levee, they were recorded as approximately five meters lower than the actual height of flights relative to the river bank or adjacent agricultural fields. If a correction were made for this five meter differential, it would result in a slight increase of the proportion of flight in the risk zone.

***Vado*:** The Vado survey site near Las Cruces, New Mexico, was characterized by a low-height profile of passing birds. We observed the greatest numbers of blackbirds, ducks, herons, ibis, and raptors flying in the risk zone at Vado during the Fall 2010 surveys. Observations made in Winter 2009 to Spring 2010 were consistent with our fall observations. However, very few cranes and geese were observed at Vado. Although very few of the most vulnerable species, (Sandhill Cranes and geese) were observed at Vado, considerable numbers of low-flying ducks were observed. Ducks are highly vulnerable to line collisions (Anderson 1978; Brown and Drewien 1995; surveyor observations), thus care must be taken to reduce collision rates given the high volumes of ducks in the risk zone at Vado. Flight diverters have been demonstrated to reduce duck collision rates with transmission lines (Brown and Drewien 1995). In addition, substantial numbers of low-flying herons and White-faced Ibis were observed at Vado in Fall 2010. Most of the herons were Cattle Egrets. These bird species are also vulnerable to line collisions (Bevanger 1998), although neither species is of any imminent conservation concern. Raptors were also most abundant at the Vado site. The Aplomado Falcon that was observed several times in Spring 2010, was also (but less frequently) observed during Fall 2010.

Width of the Flight Corridor: Flight direction for all birds at all sites was overwhelmingly oriented along a north-south axis during all data collecting efforts in both sampling periods, reflecting the concentration of high-quality bird habitats along the north-south Rio Grande corridor relative to surrounding xeric scrublands. The width of the corridor of high-quality habitat defines the potential zone of interaction between transmission lines and birds for a planned east-west transmission line corridor. All of the species identified as being particularly vulnerable to collision are associated with riparian and wetland habitats and the adjacent agricultural matrix and none are associated with xeric uplands. The width of this habitat corridor could serve as a general guideline for the extent of mitigation efforts. We estimate the width of this habitat corridor to be 4.0 kilometers (km) at San Antonio, 1.24 km to 3.0 km at Armendaris, 2.5 km at Arrey-Derry, and 9.0 km at Vado. Note that at Armendaris the precise width of the habitat corridor would depend on the angle of crossing of the transmission line. We also note that at Arrey-Derry, where the river makes a slight bend to the west, many birds that are passing through effectively cut the corner and pass over desert bluffs to the east of the habitat corridor at that point. Although the birds straying from the immediate riparian corridor were nearly always flying higher than the risk zone within the alluvial basin, their above-ground height becomes considerably lower above the elevated bluffs. We gathered data on the above-ground height of flight of cranes flying over the bluffs by positioning an observer with a rangefinder and inclinometer in a secluded position on top of the bluffs during surveys in December 2010. These conditions should be considered during transmission-line design and placement across this unique topography, especially because commuting Sandhill Cranes were among the many bird species using this flight route.

4.1.1. Crane Mortality Estimates

Platte River Power Line Collision Study: Although Sandhill Crane mortality as a result of collisions with transmission lines is well-documented, few studies exist that actually quantify numbers of Sandhill Crane collision-caused deaths relative to the amount of Sandhill Crane traffic across particular transmission line arrays. These types of studies are essential to understand the effects of transmission line collision-caused mortality on the long-term stability of Sandhill Crane populations. One relevant study bearing on this issue is by Murphy et al.

(2009), who measured Sandhill Crane mortality caused by collisions with two 69 kV overhead power line arrays over the Platte River, Nebraska (Rowe Sanctuary, Buffalo County). That study estimated that 50 to 93 Sandhill Cranes were killed by the two power lines in 2008, and 37 to 70 were killed in 2009. These estimates were one-half to one-third of the collision rates observed in a previous study at the same site in 2007, before FireFly bird flight diverters were installed (Wright et al. 2009). Importantly, Murphy et al. (2009) also conducted evening surveys in March to April 2009, during which they counted numbers of cranes flying past the power lines and tallied collisions and their outcomes. Based on their observations, we calculated a mean collision rate or proportion of passing cranes that collide with the marked lines of 4.8×10^{-5}, corresponding to approximately five birds out of every 100,000 crossings. Of these collisions, Murphy et al. (2009) estimate that approximately 79 percent result in death or injury that may lead to death. This leads to an adjusted mortality rate of $3.8 \times 10^{-5} \times \text{crossings}^{-1}$, which we use here to predict mortality at hypothetical transmission lines along the Rio Grande Valley.

San Luis Valley Power Line Collision Study: Brown and Drewien (1995) conducted a study of Sandhill Crane interactions with overhead power lines in the San Luis Valley of Colorado, the major spring and fall migration stopover area for RMP Greater Sandhill Cranes. The study spanned 3 years (1988 to 1991) and was designed to compare collision rates between unmarked lines and lines that were marked with two types of flight diverters. Both 7.2 kV and 69 kV power lines were included in the study, with line heights ranging from 7 to 22 meters. The investigators quantified the number of overflights within ≤15 meters of the power lines, counted the number of carcasses found under the power lines, and estimated the proportion of carcasses not found to model the mortality rate as a portion of the overall flight volume. Separate mortality rates were estimated by season and flight-diverter treatment. To conservatively predict mortality at the planned Rio Grande transmission lines, we used the highest and lowest mortality estimates for marked and unmarked lines, respectively, averaged across the 3 years of the study: $0.7 \times 10^{-5} \times \text{crossings}^{-1}$ (lowest estimate, marked lines), $10.6 \times 10^{-5} \times \text{crossings}^{-1}$ (highest estimate, marked lines), $2.5 \times 10^{-5} \times \text{crossings}^{-1}$ (lowest estimate, unmarked lines), and $30.4 \times 10^{-5} \times \text{crossings}^{-1}$ (highest estimate, unmarked lines).

Predicted Mortality Rates: We calculated the total number of crossings by Sandhill Cranes for the period including October 1 to December 15 at each of our three survey points that had substantial numbers of cranes: Arrey-Derry, San Antonio North, and San Antonio South. We used the average hourly rate of passage at each site for each 2-week interval and extrapolated based on the total daylight hours (including 1 hour before sunrise to 1 hour after sunset) to calculate total numbers of crossings. The resulting estimates for total number of crossings between October 1 and December 15, 2010, were 226,125 at Arrey-Derry, 41,333 at San Antonio North, and 26,449 at San Antonio South. The corresponding numbers of expected fatal or crippling collisions based on the Murphy et al. (2009) rate are 8.6 at Arrey-Derry, 1.6 at San Antonio North, and 1.0 at San Antonio South (Figure 17). Using the rate estimates from Brown and Drewien (1995) for lines fitted with flight diverters, the predicted number of mortalities would be 1.6 to 24.0 at Arrey-Derry, 0.3 to 4.4 at San Antonio North, and 0.2 to 2.8 at San Antonio South (Figure 17). Using the rate estimates from Brown and Drewien (1995) for unmarked lines, the predicted number of mortalities would be 5.6 to 68.7 at Arrey-Derry, 1.0 to 12.6 at San Antonio North, and 0.7 to 8.0 at San Antonio South (Figure 17).

Assumptions and Concerns in Predicting Mortality Rate: These estimates are dependent on many assumptions, but are likely to be conservative. First, the power lines at the Platte River site were lower voltage (69 kV) and lower height (10 to 15 meters) than the planned transmission lines across the Rio Grande. In the San Luis Valley study, the overhead lines ranged from 7.2 kV to 69 kV and 7 to 22 meters in height. The Platte River power lines were fitted with FireFly diverters that were known to reduce collision rates by one-half to one-third at that site, so the predicted fatality rate assumes that similar mitigation measures would be taken on the planned Rio Grande transmission lines. Similarly, the lines in the San Luis Valley that were marked, were marked with spiral vibration dampers or marking plates that clearly caused substantial reductions in the fatal-collision rates. The predicted mortality rates were likely biased upwards (i.e., conservative bias), by our extrapolation of dawn and dusk surveys to hourly passage rates throughout daylight hours, because flight activity typically peaks close to dawn and dusk, causing hourly passage rates to be overestimated.

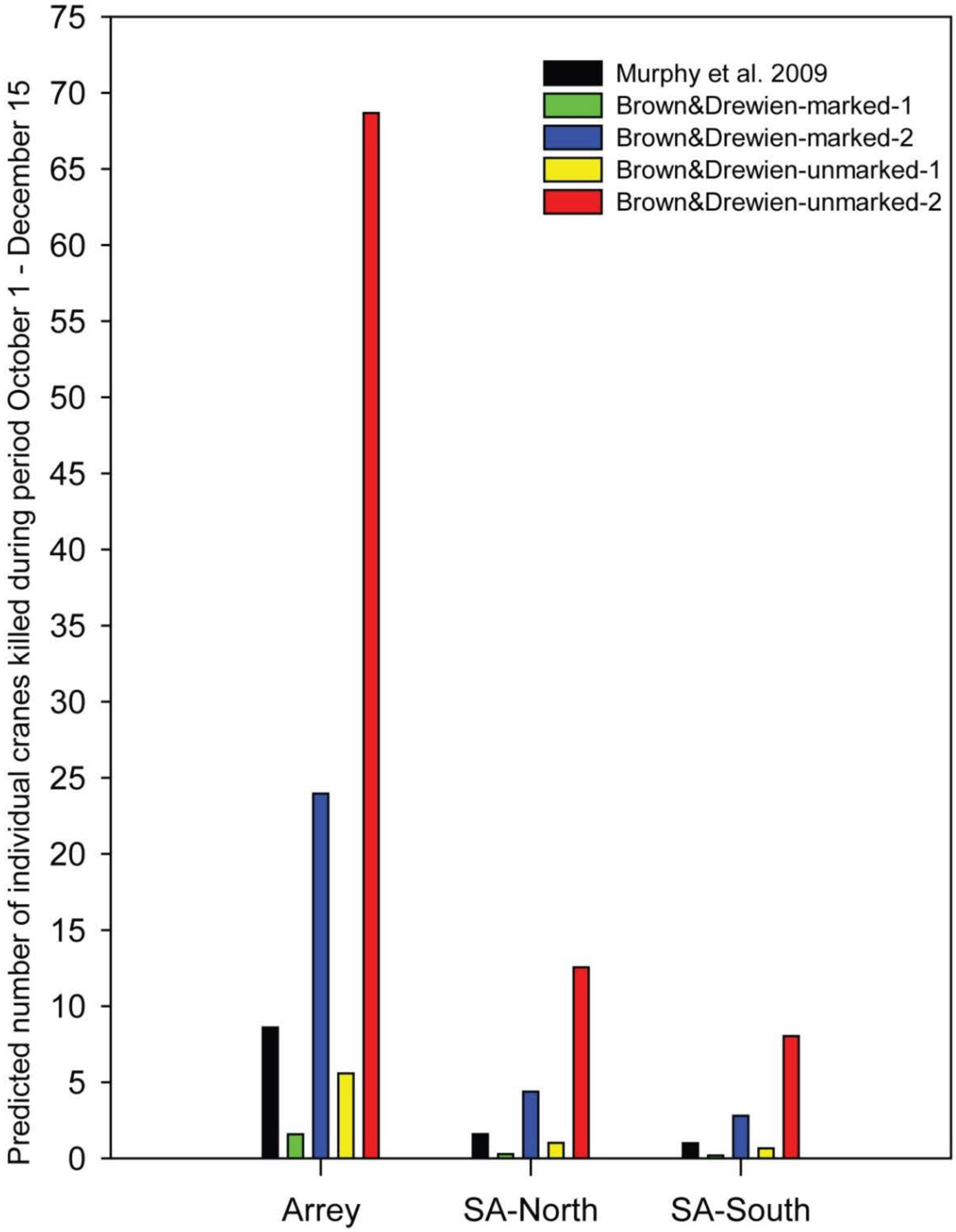

Figure 17. Predicted Number of Sandhill Cranes to Suffer Fatal Collisions at Hypothetical Transmission Lines at Three Survey Sites During the Period from October 1 to December 15, under Different Estimated Rates of Fatal Collision

- **Black** – (3.8×10^{-5} x crossings^{-1}) derived from Murphy et al. (2009), Platte River, Nebraska, assuming the use of FireFly diverters
- **Green** – lowest (7.0×10^{-6} x crossings^{-1})
- **Blue** – highest (1.1×10^{-4} x crossings^{-1}) 3-year estimated rate for marked lines
- **Yellow** – lowest (2.5×10^{-5} x crossings^{-1})
- **Red** – highest (3.0×10^{-4} x crossings^{-1}) rates for unmarked lines in the San Luis Valley, Colorado (Brown and Drewien 1995).

An additional source of conservative bias is provided by the height of flight, though we can't address this directly in the absence of data on the height profile of crane flight at the Platte River site. The majority of the volume of crane traffic at Arrey-Derry was higher than the potential height range of the proposed transmission lines and therefore not vulnerable to collision, and this was unlikely to have been true at least at the Platte River site where crane traffic was primarily associated with the adjacent roost (but note that the Platte River and San Luis Valley overhead lines are also lower than the planned transmission lines by 15 to 43 meters). At San Antonio, more cranes passed by below the height of the hypothetical transmission lines than above them, probably reflecting a shorter average distance of flight for commuting and feeding cranes in that area. In the San Luis Valley study, Brown and Drewien (1995) counted only cranes that were ≤15 meters above the highest power line, whereas we included cranes from the entire height spectrum in estimating flight volumes that were used in mortality predictions. That difference will cause predicted mortality at the Rio Grande sites to be overestimated.

Importantly, the Platte River power lines were located immediately adjacent to a major roost site for Sandhill Cranes along the Platte River, and the highest rates of collision were observed when roosting cranes within 600 meters of the power lines were disturbed and flew up *en masse* under low light conditions after sunset. Thus, if power lines are not located in the immediate vicinity of major nocturnal roost sites, collision-based mortality can be expected to be substantially lower, in part because a larger proportion of crossing events can be expected to take place during daylight conditions. Although small numbers of cranes (less than 50 individuals) have been found to roost on islands in the Rio Grande in the San Antonio area previously (Maliakal-Witt and Witt 2010), we found no evidence of major Sandhill Crane roost sites in the immediate vicinity (more than 1 km radius) of any of the survey points during fall and early winter of 2010. Nocturnal roost sites are known to be flexible within and among years, particularly because the ideal roost sites are shallow-water wetlands such as found at the edges of rivers and lakes, a habitat that is often ephemeral. However, there are major, traditional roosting areas within daily flight range of the San Antonio and Arrey-Derry sites that may serve to attract roosting cranes and keep them away from the planned transmission lines: (1) the Bosque del Apache NWR (5 to 18 km south of San Antonio) which is managed for maintenance of shallow-water wetlands; and (2) Caballo Lake (8.5 to 28 km north of Arrey-Derry survey site), where Sandhill Cranes find appropriate shallow water roost sites along the lake's edge and commute daily to agricultural fields to the south (Mitchusson 2003). That these roosting sites were the heavily used by the cranes observed during this study is evidenced by the fact that the vast majority of the early morning flight was comprised of cranes heading north at the San Antonio sites and south at the Arrey-Derry site. The major flight direction at those sites was reversed on afternoon-evening surveys.

Mortality Rate in the Context of Crane Demography: Given the above considerations, the fatality estimates illustrated in Figure 17 are highly likely to be overestimates of the number of fatalities that will be caused by the proposed transmission lines. Regardless, these conservative estimates should be considered in the context of population sizes, recruitment rates, and anthropogenic mortality. The Greater Sandhill Cranes from the RMP would be the population most affected if the transmission lines were built at San Antonio. The RMP Greater Sandhill Cranes have a population size of approximately 20,000 that has been relatively stable since the mid-1980s and is subject to annual hunter take of 4–5 percent and annual recruitment of 8 percent. Our estimates of crane mortality associated with a potential transmission line in the

San Antonio area would correspond to a range of 0.0009 percent to 0.06 percent of the population between 1 October and 15 December. The Lesser Sandhill Cranes from the MCP would be the population most affected if the transmission lines were built at Arrey-Derry. The MCP has a population size of approximately 380,000 individuals and is subject to annual hunter take of approximately 10 percent of the population and annual recruitment of approximately 11 percent (measured by proportion of juveniles in winter). Our estimates of crane mortality associated with a potential transmission line at Arrey-Derry would correspond to a range between 0.0004 percent and 0.02 percent of the population between October 1 and December 15. These rates of mortality alone would be insufficient to have any significant effect on overall rates of human-caused mortality in either crane population at current population levels. However, the effects would be additive with other sources of mortality and would become more significant if the populations were to decline due to unrelated reasons of food shortage or disease outbreak. The predicted mortality rates should be interpreted with caution given the uncertainties described above. Among the most important uncertainties is the potential for future shifts in the wintering ranges or roosting sites of each crane population. A synthetic analysis of this fall to early winter crane flight data with crane flight data from winter to early spring at these sites (Maliakal-Witt and Witt 2010) will allow for predictions of total annual crane mortality at each hypothetical transmission line site. This analysis is currently underway.

4.1.2. Site Considerations

Factors Affecting Collisions: Collisions occur at highest frequencies when transmission lines bisect habitats with high bird densities. Therefore, one key preconstruction consideration is to limit the extent to which lines cross high quality habitats. This is especially important for large, heavy-bodied bird species that are the most vulnerable to collision. Furthermore, the largest species tend to have smaller population sizes and lower reproductive rates than smaller species, factors that increase their sensitivity to decline. For example, Sandhill Cranes have the lowest reproduction rates and longest lives of any hunted species in North America. Along the Rio Grande, some other species that fit these criteria include American White Pelican, Canada Goose (including the rare "Cackling" Goose subspecies, *Branta canadensis hutchinsoni*), Snow Goose, Ross' Goose, White-faced Ibis, Neotropic and Double-crested Cormorants, Great Egret, and Great Blue Heron. Ducks are also known to be highly vulnerable (Brown and Drewien 1995), especially when lifting off from the ground or water habitats adjacent to overhead lines (Martin and Shaw 2010), and this is consistent with two observed collisions during a previous study (Maliakal-Witt and Witt 2010), both of which occurred while birds were rapidly gaining altitude. The altitudinal distribution of flying birds and the rate of passage, or flight volume, are key considerations in placing new lines. Collision risk also varies with visibility, with collisions more likely in low light, foggy conditions (Yee 2008). High winds reduce flight control and are known to dramatically increase the likelihood of collision (Brown and Drewien 1995). Intermittent human activity and disturbance also have the effect of increasing the rate of collision because birds that are escaping perceived danger have a higher probability of colliding with lines (Murphy et al. 2009, APLIC 2010). Multiple transmission lines that are clustered closely together may have lower impacts than those that are widely spaced. Existing overhead power line crossings at the Armendaris and Vado sites, and in the vicinity of San Antonio (e.g., San Antonio South survey site) thus provide opportunities to minimize aesthetic and biodiversity impacts of new transmission lines (APLIC 2010).

4.2. Additional Concerns

4.2.1. Limitations and Future Directions

The current study assessed bird activity during a single fall to early-winter season and an early winter to spring season, reflecting only the flight patterns that occurred between late-August and mid-December 2010 and December 2009 to March 2010. Inter-annual variation in bird populations and, more importantly, local habitat and food resources, could strongly effect the assessment of potential impacts. On the other hand, many of the striking inter-site differences can be explained by regional differences in habitat composition that are likely to dampen interannual fluctuations. Fog, high winds, precipitation, and human-caused disturbance are all risk factors for transmission line collisions, but we rarely encountered these conditions in our 1,149.5 survey hours (more than 2,299 man-hours assigning two people at each site for each survey), making it impossible to address the comparison among sites with statistical adequacy. The implications of inter-seasonal variation for the relative impacts of transmission lines at each of the four sites were not addressed in this study. We focused on the fall migration to early winter season, the period during which overall numbers of birds are largest. Our first survey effort focused on the winter to spring period when most winter visitors were present and continued on as those populations left the area during spring migration. The survey encompassed nearly the entire fall migration period, including the primary periods of southward movement for key taxa such as Sandhill Cranes and waterfowl and captured most of the spring migration period when key taxa left the area for more northerly breeding grounds.

The majority of surveys included in this study were carried out during daylight hours, but morning surveys and evening surveys both included low-light hours during which birds may be especially vulnerable to collision with transmission lines. Importantly, we found that the relative volume and height profiles of each site were not significantly different between low-light (before sunrise and after sunset) and high-light conditions. Thus, these visible-light surveys likely provide a reasonably accurate index of relative mortality risks among sites. Estimation of absolute mortality rates is considerably more problematic for the reasons described in section 4.3.4, above. More studies of existing transmission lines are needed to find a way to accurately predict the collision rates based on bird flight volume, flight height, and line characteristics.

Potential Impacts on Nocturnal Migrant Songbirds: In addition to cranes and waterfowl, the Rio Grande Valley is known to be a concentration point and an important migratory corridor for migrant songbirds which fly at night during spring and fall migrations (Finch and Wang 2000), including a tremendous array of species diversity. Nocturnal passage migrants include endangered and threatened species such as the Southwestern Willow Flycatcher and Yellow-billed Cuckoo, respectively. While addressing the potential impacts of the transmission lines on this component of the avifauna is beyond the scope of the surveys reported here, NEXRAD radar studies of nocturnal migration along the Rio Grande at Albuquerque show that the middle 50 percent of nocturnal migrant birds fly between approximately 350 meters and 1,400 meters above ground level during spring, and between approximately 670 meters and 1,400 meters during fall (Felix et al. 2008). While these radar-observed heights document that large numbers of migrants pass through the Rio Grande Valley at significantly higher altitudes than the proposed transmission lines, it must be noted that the NEXRAD data do not reliably detect low-flying birds.

4.2.2. Avian Collision Mitigation Technologies

Avian collision mitigation measures may include initial siting and design considerations, burying of lines, elimination of static lines, placement of bird diverters, or a combination of these options. Most mitigation efforts will not totally eliminate avian losses but are effective to varying degrees depending on a variety of factors including bird species involved and method(s) employed. Both tower design and placement can be critical to the effectiveness of avian collision mitigation efforts (Avery 1979). Design and siting elements involved include configuration, spacing, height, natural lighting, and tower placement within the terrain. Siting must consider local topography, weather, and avian flight paths (APLIC 1994). Potentially, small differences in locations for siting towers may significantly affect the level of hazard presented to birds. Employing pre-development design and siting considerations is preferable to implementing post-development avian collision abatement efforts based on effects identified after construction. Additional post development mitigation efforts may be needed if design and siting efforts do not reduce avian collisions to target or acceptable levels.

Burial of lines, while highly effective at preventing collisions presents other issues including human safety, risks to wildlife, and excessive cost. Due to these factors, underground placement of lines is usually practical only for very short distances or in cases of last resort (APLIC 1994; Bevanger et al. 2009; USFWS 2005).

As mentioned previously most avian fatalities associated with transmission lines involve collision with the overhead static wire. Elimination of the static lines has been proven to be highly effective in minimizing avian collisions (APLIC 1994; Bevanger and Broseth 2001). In one study that looked at removal of the static lines (Brown et al. 1987 *in*: Jenkins et al. 2010), crane collisions were reduced over 80 percent. Unfortunately, removal of static lines is seldom an option due to the level of lightning strike potential and economic factors (Brown and Drewien 1995). In some cases replacement with lightning arresters or optical fiber groundwires (OPGW) may be a viable alternative (APLIC 1994)..

Placement of a variety of bird diverter devices on static lines has been shown to effectively reduce collisions between 50 and 90 percent (APLIC 1994; Brown and Drewien 1995; Jenkins et al. 2010; Morkill and Anderson 1991). Results of mitigation studies have varied with location and species of birds involved and a single all-purpose diverter has not been developed (Jenkins et al. 2010). What is apparently critical however, is achieving the result of making the lines visible to birds so that they can navigate around them. Koops and de Jong (1982 *in* APLIC 1994) considered the spacing of diverters to be the most critical factor, but stated that this could be compensated for to some degree by an increase in the size of the diverters used. Jenkins et al. (2010) stated that the key element of effective diverters is not design, but size. Results of almost all diverter studies show significant positive effects in reducing avian collisions regardless of design, but requiring minimum dimension parameters to be effective. Therefore the key element of effective diverter design appears to be a minimum dimensional threshold. So long as this threshold is attained, most diverter systems should be effective in reducing collisions. Along with proper size, diverters must have a minimum spacing to retain the visual effectiveness of the system. Jenkins et al. lists the required minimum dimensions for diverters that will increase the apparent width of the line as being at least 20 centimeters, with spacing at a maximum of 5 to 10 meters (Jenkins et al. 2010).

Intuitively, diverter designs that may be more effective incorporate movement (flappers; swivels) as opposed to static designs, and use of colors and patterns that are more visible to birds. Such diverters have been experimented with but to date there is apparently no field data supporting the effectiveness of these concepts (Jenkins et al. 2010). Static stainless steel balls have been used with apparent success in South Africa. The balls are weather resistant and are visible in low light conditions (Rooyen 2006).

Some problems with bird diverters include length of service of units and costs of installation, maintenance and/or replacement. Many diverters have components with limited life in exposed situations. The effect of long exposure to sun may result in deterioration of plastics and commonly results in fading of colored units. Other considerations of diverter placement are the effects on lines of added weight (design load), the effects of wind, ice loading, line tension, structure design, line wear resulting from movement of diverters, and vandalism (APLIC 1994).

However, even with appropriately sized and spaced diverters, there are still the issues of the effects of inclement weather and night flight of birds on collision potential. Conceivably diverters could be lit at night using luminescent materials that are solar charged or some form of lighting that uses the corona field of conductors to supply low wattage power to activate small lights. Commercial bird lights (Mace Bird Lite) are available and have been used successfully in South Africa and Botswana (Rooyen 2006). Lighting however, becomes potentially problematic in that different species of birds will react to obstacles in different ways. Lighting of wires could adversely affect collision rates for certain bird species that avoid the lights by moving laterally, resulting in collision with unlit line segments. Presence of lights on the structures at night may actually draw birds to the area increasing the potential for collisions, interfere with natural celestial navigation capabilities of birds, and add to visual pollution. Because of these potential problems lighting of lines may not be an effective deterrent for some species, and could potentially have a net negative effect in preventing avian collisions (APLIC 1994).

A recent review of avian transmission line collision field studies that incorporated an evaluation of at least one mitigation method was performed by Jenkins et al. (2010). Thirteen of the 16 papers reviewed focused at least partially on crane species, and 5 specifically addressed cranes in the United States. Results varied widely by location and application. Some studies have demonstrated the effectiveness of bird diverters in reducing transmission line collisions for cranes and waterfowl between 54 percent (cranes only) and 63 percent (cranes and waterfowl) for different diverter styles (Brown and Drewien 1995; Morkill and Anderson 1991).

The best mitigation from the bird collision perspective is line routing that avoids avian hot spots, travel corridors and migration routes to the extent practicable. Placement of lines at adequate distances from avian resources has been shown to be effective in mitigating potential avian collisions (Brown et al. 1984, 1987 *in* APLIC 1994). Design elements that are effective in minimizing avian collision hazards include low height placement of lines, close spacing of support structures, and use of large diameter conductors. Placement of transmission lines of similar design in close parallel, and separating lines of differing configurations well apart from one another can help minimize collision potential. Vertically separated conductor bundles on structures are less desirable because they present a more complex obstacle for birds (APLIC 1994; Jenkins et al. 2010).

Ultimately, one of the most effective and practical measures for minimizing avian collisions with transmission lines is placement of adequately sized and spaced static (or combined static and dynamic) bird diverters on static lines. Staggering diverters on parallel static lines of equal height reduces installation effort and cost while maintaining maximum avian visibility (Brown and Drewien 1995). Birds have a visual acuity 2 to 8 times greater than that of mammalians and see a wider color range that includes wavelengths in the ultraviolet portion of the spectrum (Bevanger et al. 2009). Use of dual colored or contrasting color schemes for diverters increases visibility in varying light conditions and vegetation (APLIC 1994; Brown and Drewien 1995). Colors in the yellow and green range that have a significant ultraviolet element in their spectrum may be highly visible to birds without adding to the visual impacts of transmission lines visible to people (Bevanger et al. 2009). Unfortunately, current knowledge and technology do not provide a methodology for totally eliminating bird/transmission-line collisions. The potential effects of Project avian collisions on bird species and local bird populations need to be assessed on a case-by-case basis, with significant consideration given to the cumulative effects on birds.

4.3. Site-Specific Mitigations

Development of site-specific mitigations for bird collisions is made difficult by the potentially unique conditions inherent at a given transmission line crossing location (Bevanger et al. 2009). Avian flight corridors along the Rio Grande occur in a general north-south orientation, reflecting the relatively narrow strips of preferred habitat along the river, and contrasting abruptly with the arid desertscrub outside of the floodplain area. Widths of avian corridors vary with the width of the floodplain and associated agricultural habitats that are attractive to birds. The functional widths of these corridors were estimated to be: 4.0 km at San Antonio, 2.0 km at Arrey-Derry, and 9.0 km at Vado (Maliakal-Witt and Witt 2010). Avian flight corridor width likely closely corresponds with the limits of the zone of significant avian impact potential associated with the transmission lines.

4.3.1. San Antonio

The site supports an overall high volume of avian traffic, including high volumes of Sandhill Cranes, and is the only site among the three that had high volumes of white geese. Avian traffic within the risk zone was found to be high for Sandhill Cranes and white geese (Maliakal-Witt and Witt 2010), although a large volume of traffic by white geese occurs well above the risk zone in both survey periods. This site is a candidate for undergrounding of the lines within the identified flight corridor. However, the crossing area is within designated Critical Habitat for two federally listed endangered species—the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) and the Rio Grande Silvery Minnow (*Hybognathus amarus*). Impacts to critical habitat for these species resulting from installation of underground lines may represent a greater environmental impact than potential avian collision impacts resulting from overhead lines.

Alignment of conductors (or wires) in a horizontal configuration (at the same height above the ground) is preferable to use of vertically spaced conductors. The use of nonspecular conductors provides visibility issues for birds and should be avoided. Mitigations for this crossing could include use of lightning arresting devices or OPGW in lieu of static lines, and placement of bird diverter devices within the avian flight corridor. Large, brightly colored coils and FireFly-brand markers, which incorporate low-light luminescence and wind induced movement properties have been shown effective in collision reduction with suites of species similar to those occurring at the crossing (Brown and Drewien 1995; Yee 2008).

4.3.2. Arrey-Derry

The Arrey-Derry site has a combination of an intermediate level of overall bird activity combined with the highest numbers of Sandhill Cranes, and was second of the four potential sites in the number of total traffic volume of birds in the risk zone. It was the site with the highest numbers of Sandhill Cranes and songbirds within the risk zone during the December 2009 to March 2010 sampling period (Maliakal-Witt and Witt 2010). The same held true for the August to December 2010 sampling period except that more songbirds were observed in the risk zone at the Armendaris sampling site. This site would also potentially be a candidate for undergrounding the lines. Alternatively, mitigation measures might include those discussed above for the San Antonio crossing.

4.3.3. Vado

The Vado crossing site has abundant bird activity (high total volume). However, most birds observed flying in the hazard zone were species with greater mobility, such as blackbirds, corvids, and doves. A significant number of ducks were recorded in the hazard zone, but very few cranes or geese, which are highly collision susceptible, were present (Maliakal-Witt and Witt 2010). Mitigations for this crossing could include those discussed above for the San Antonio crossing.

4.3.4. Post Construction Surveys

To evaluate effectiveness of applied avian collision mitigation efforts, post construction mortality surveys should be conducted at the Project crossing of the Rio Grande.

5. SUMMARY AND CONCLUSIONS

The objective of this study was to document the extent and nature of passage of a select group of birds in the Rio Grande Valley of central and southern New Mexico in relation to proposed crossings of the river by the SunZia 500 kV electrical transmission line project. The study's genesis resulted from agency and others' concerns about potential impacts to the charismatic and enormously popular Sandhill Crane. Sandhill Cranes winter in large numbers at the Bosque del Apache NWR and on Caballo Reservoir to the south of the refuge. They make daily flights from the refuge and the reservoir to foraging areas north of the refuge and south of the reservoir. They return to the refuge and reservoir every afternoon and evening, passing through potential river crossings of the SunZia project coming and going.

Over the past century, Sandhill Crane numbers have shown significant declines, but, through vigorous management and conservation, they have returned to the point that the Sandhill Crane is a legal game bird throughout its range in the United States and Canada. In addition to the Sandhill Crane, there was concern for white geese (Ross's and Snow Goose), waterfowl in general (primarily ducks), and raptors. All of these species are known to be victims of overhead transmission line collisions and were, therefore, the focal point of this study. During the course of the study, all bird species observed crossing through proposed transmission-line crossing locations on the Rio Grande were recorded, not just the target species.

This study involved four locations on the Rio Grande during the winter-spring sampling period in 2009-2010, and five during the late summer-late fall period of 2010. The Armendaris Ranch site studied during both periods was dropped as a possible crossing site for the SunZia Project in 2009, but maintained as a study site because of an existing 230 kV transmission line crossing the river at that point. It provided an opportunity to collect data on collisions, bird use, and apparent hazard. Similarly, the San Antonio South site was added to the summer-fall 2010 effort to document collision, bird use, and apparent hazard at an existing transmission-line crossing of the Rio Grande south of the Highway 360 bridge at San Antonio.

Over the course of the two study periods, 1,149.5 hours were spent collecting data or a minimum of 2,299 man-hours expended (two researchers minimum at each sampling site). The five sites we studied provided very different results with respect to numbers of birds, species of birds, and possible risk to birds traveling up and down the Rio Grande:

Armendaris Ranch – The Armendaris Ranch had the lowest number of bird passages during both study periods. However, it had the highest numbers of passing cormorants of any site and the most songbird passages during the summer-fall sampling period of 2010. This site was also the only location we recorded fatal bird collisions with an existing transmission line. During the December 2009 to March 2010 sampling period, field crews recorded fatal collisions by one Cinnamon Teal and one Mallard.

Arrey–Derry – The Arrey-Derry site had the highest passage of Sandhill Cranes, primarily Lesser Sandhill Cranes, during both sampling periods. Also, most Sandhill Crane flight was in excess of 100 meters above the ground, well above the 30-to-50 meter risk zone. About 13 percent of Sandhill Crane passages occurred within the risk zone. Arrey-Derry had the greatest passage of songbirds during the December 2009 to March 2010 sampling period and was second only to the Armendaris site in the late summer-late Fall 2010 period. Passage of ducks at Arrey-Derry was second only to the Vado site and had the most Canada Geese overflights of any site although the latter were quite sparse. This site also had the most passage by gulls of any site, but virtually all gull passage occurred above the risk zone.

San Antonio North and South – San Antonio South (south of the Highway 360 bridge crossing of the Rio Grande) had the highest volume of bird flight of any site (summer-fall 2010 sampling period only). This was likely a function of the proximity of the site to the town of San Antonio and the associated large numbers of crows and ravens. Both San Antonio North and South had the largest passages of white geese of any site by far. The vast majority of white goose passage occurred well above the risk zone. Passage of Sandhill Cranes at these sites consisted mostly of Greater Sandhill Cranes and most occurred above the risk zone. An estimated 13 percent of Greater Sandhill Crane passages at San Antonio North occurred within the risk zone.

No collisions by birds with the existing transmission line at San Antonio South were observed although some birds were observed to take evasive actions to avoid colliding with the lines.

Vado – The Vado site, which is little more than an irrigation canal, had the most blackbirds, ducks, herons (mostly Cattle Egrets), and raptors passing within the risk zone of any site. Three apparently non-fatal collisions were observed at this location. During the December 2009-March 2010 period, two Mallards were observed striking the existing transmission line, but both ducks continued flying until out of sight, apparently unharmed. During the August-December 2010 period, a White-winged Dove was observed striking the line and continuing on, also apparently unhurt.

During the course of this study we did not observe a single incident of Sandhill Crane, white goose, or raptor collision with any of the existing lines at our study sites. The only non-waterfowl collision we witnessed was the White-winged Dove mentioned above. No interactions between the existing line(s) at Vado were observed involving the large numbers of blackbirds, and lesser numbers of herons and raptors passing through the area.

Few studies exist that examine the rates of passage versus collision with electrical lines. However, we were able to calculate collision rates from two studies of Sandhill Cranes, one in Nebraska on the Platte River and a second in the San Luis Valley of Colorado. For the Platte River study, we calculated a mean collision rate of cranes colliding with marked lines (FireFly diverters installed) of 4.8×10^{-5} or approximately 5 collisions out of every 100,000 crossings. An estimated 79 percent of such collisions resulted in death or injury that may lead to death. The 79 percent fatality rate leads to an adjusted mortality rate of 3.8×10^{-5} per crossing. We used this value, in part, to predict mortality at potential crossings of the Rio Grande.

In the San Luis Valley study, which lasted 3 years, collision rates at marked (two different types of flight diverters) and unmarked lines were compared. The researchers recorded the number of overflights within 15 meters of the lines, the numbers of carcasses found under the lines, and estimated the proportion of carcasses not found to model mortality rate as a portion of overflight volume. In an attempt to conservatively predict mortality at possible crossings of the Rio Grande, we used the highest and lowest mortality rates for marked and unmarked lines in this study.

Based on these studies, and the passage data for Sandhill Cranes we collected in Fall 2010, we estimated that the numbers of fatal or crippling collisions during that period would be 8.6 at Arrey-Derry, 1.6 at San Antonio North, and 1.0 at San Antonio South. These estimates are based on the Platte River study mentioned above. Using the collision rates calculated for the San Luis Valley study, we calculated the following: lines marked with diverters 1.6 to 14.0 at Arrey-Derry, 0.3 to 4.4 at San Antonio North and 0.2 to 2.8 at San Antonio South. Using the San Luis rates for unmarked lines the predicted mortalities would be 5.6 to 68.7 at Arrey-Derry, 1.0 to 12.6 at San Antonio North, and 0.7 to 8.0 at San Antonio South.

Key factors to consider in predicting mortality rates for the SunZia Projects are that these studies were based on the Platte River and San Luis mortality studies, which involved 69 kV or smaller (i.e., 7.2 kV) lines that were located in areas of heavy bird use where many takeoffs and landings were occurring. The lines were fairly close to the ground (within 25 meters), and the conductors on such lines are very small in diameter (1 inch or less) compared with the bundled set of conductors on a 500 kV system, which may be 4 or 5 inches in diameter, and over 100 feet above the ground. The 500 kV conductors are substantially more visible than 69 kV conductors in clear weather or foul weather. Moreover, none of the proposed Rio Grande crossings for the SunZia Project are in major foraging or staging areas for Sandhill cranes, geese, or other waterfowl.

Based on the Platte River and San Luis Valley studies, as many as 68.7 cranes could be killed during the fall-winter period at Arrey-Derry. This is an overstatement of potential mortality, given the studies that were used to make the estimate and the size of the transmission facilities in those studies, compared to the size of the SunZia Project facilities. We suspect that the actual number of crane fatalities occurring from collisions with the SunZia lines would be more similar to the actual numbers of collisions we observed with other birds in this study—5 recorded collisions (none involving Sandhill Cranes) more than 1,100 hours of observation = 0.0043 collisions/hour = 38 collisions/year/24-hour day. By contrast, legal hunters killed nearly 1,200 Sandhill Cranes in New Mexico in 2009.

Based on our review of the current literature coupled with more than 1,100 hours of field observations on the Rio Grande, it is our conclusion that construction of the SunZia Project across the river would have no significant effects on the population status of any species living in or migrating through the Rio Grande Valley. There would almost certainly be incidents of birds colliding with conductors, static lines, or even tower structures associated with this Project, but those incidents would not contribute to measureable population declines in any species. Furthermore, proposed mitigation measures would be effective in reducing the number of bird collisions.

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