PRE-WINDENERGY DEVELOPMENT ASSESSMENT OF THE AVIAN COMMUNITY IN THE CENTRAL TEXAS PANHANDLE

by

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A THESIS

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TABLE OF CONTENTS

ABSTRACT

Wind energy development is a fast growing renewable energy source. Despite the many benefits of wind power, there are some concerns regarding the environmental impact of wind turbines, such as habitat loss, habitat disturbance, soil disturbance and possible erosion, vegetation loss, promotion of invasive species, noise pollution, and collision-related avian mortality. Bird and bat collisions with turbines and other infrastructure are possible direct hazards. Habitat loss, habitat fragmentation, avoidance of structures and other behavioral changes, and increased predation because of increased perching and nesting structures for raptors are some of the potential indirect hazards. Wind farms likely have varying risks and different magnitudes of hazards depending on placement of the facility, topography, weather, wildlife habitat needs, and wildlife migration patterns. Improvements in wind farm placement and new repellant technologies may help reduce mortality at wind facilities. These wildlife impact issues along with the great potential for wind energy development in the Great Plains has increased the need for pre-construction assessments and mitigation to lessen the potential impacts of wind energy development. My intent was to gain a better understanding of grassland bird communities in the Texas Panhandle. I examined avian flight heights to identify possible species at greater risk of collisions with wind turbines and I examined avian diversity and density patterns through the year. Understanding differences in avian diversity between cover types will help wildlife managers and wind energy developers identify areas that may be important to avian conservation. I compared the effectiveness of point-counts and line-transects to help researchers plan avian surveys for future pre-

construction assessments.

During October 2008–August 2009, I recorded flight heights of 65 species at a future wind farm in the Texas High Plains. I observed average flight heights of 29 species were within the potential rotor swept zone (RSZ; 32–124 m). Of those species, 6 were listed as species of concern for the Texas High Plains region by Texas Parks and Wildlife Department. I found that the species (n = 14) with >25% of observed flight heights within the RSZ were composed of 21% raptors/vultures, 50% wetland associated species, and 29% passerine/other species. As indicated by flight heights, I found raptor and waterfowl groups were at greatest risk of collision with wind turbines in the central Texas Panhandle. Turbine placement should be avoided in areas with high concentrations of trees which provide nesting habitat for many raptor species. Turbine placement should also be avoided in areas of high raptor prey densities where raptors may concentrate to feed. For wetland associated species I recommend that turbine placement should be avoided near playa wetlands where these species concentrate to feed, roost, and nest. I stratified our sites into 5 cover types (agriculture, breaks, plateau grasslands, playa wetlands, and prairie dog (*Cynomys ludovicianus*) towns. I calculated Shannon and Simpson's diversity indices for each site, cover type, and season. I found the breaks cover type (H' = 2.96; D_S = 0.8907), closest to historic native grassland, had the highest avian diversity and plateau grasslands, primarily non-native, had the lowest avian diversity (H' = 2.19; D_S = 0.7404). I detected the most avian species (n = 95) in agriculture but the lack of nesting habitat in agriculture may reduce its importance to conservation of native grassland birds. I observed moderate avian diversity at playa wetlands and prairie dog towns. Diversity indices, often considered indicative of ecosystem health, are an important component in the assessment and placement of wind facilities. Based on diversity, I recommend wind energy developers avoid construction of wind energy facilities on the breaks, playa wetlands, and prairie dog town cover types. Breaks, playa wetlands, and prairie dog town cover types provide habitat to unique segments of the avian community in this region such as declining grassland and shorebird populations.

I estimated density using Program Distance 6.0 for 32 of the 163 species observed. While line-transects took more effort they resulted in a greater number of species detected (23 species with point-counts and 29 species with line-transects). This is likely because more area was covered and birds flushed as observers walked along the line. However, differences between survey techniques depended on season and species. For example, non-breeding season sparrows were detected better with line-transects, likely due to flushing of secretive birds. On the other hand, if surveying breeding season sparrows, either survey technique worked well. I recommend line-transect surveys be used when surveying grassland species and non-breeding season surveys. I recommend point-count surveys when survey effort is limited. Potential impacts on wildlife can be reduced during the development phase of a wind facility by relying on pre-construction site assessments. In the Central Panhandle of Texas I recommend placement of wind turbines be avoided near playa wetlands and raptor nesting areas and focused more in agricultural areas. Also, during non-breeding season surveys or when surveying grassland birds, the better survey technique is line-transects.

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Wind energy is a quickly growing renewable energy source in the United States and around the world (Arnett et al. 2007, Kunz et al. 2007). In the United States, government incentives such as federal tax credit programs, the American Recovery and Reinvestment Act of 2009, and other programs have helped create a tenable economical climate for wind energy development (National Research Council 2007, U.S. Government Printing Office 2009). For wind energy production to be economically feasible at a site, average wind speeds of >32 km/hr are needed (Pimentel et al. 2002). Wind energy resources adequate for potential development can be found in 46 U.S. states. Since most states only have voluntary guidelines regarding wind facility placement, few regulations exist for wind energy development (National Research Council 2007). Currently, Texas is the leader in the number of turbines and wind energy production in the U.S. (National Research Council 2007). Texas consists almost entirely of private lands in which there are no regulations for wind energy development (National Research Council 2007, Boydston 2008). Texas also has a large transmission line project underway that will bring even more wind energy facilities to the state (Boydston 2008). Currently there is not adequate transmission capacity to distribute the electricity generated by wind farms to the metropolitan areas where it is needed (Public Utility Commission of Texas 2009).

Wind energy and other renewable energies provide an opportunity for reduced dependence on fossil fuels (Evans et al. 2009). Wind energy has the potential of reducing some aspects of mining activities (habitat loss, land scarring, soil erosion, run off, and water pollution), air pollution, and greenhouse gas emissions associated with non-renewable energy sources (National Research Council 2007). Additionally, wind turbines only take up 2–5% of the land needed to operate the turbine so the surrounding unoccupied land can be used for grazing, crops, or other purposes (Pimentel et al. 2002, National Research Council 2007). However, influences on wildlife may not be confined to areas in the immediate vicinity of turbines. For example, avoidance patterns have been observed in some species which results in reduced available habitat for those species (Osborn et al. 1998, Erickson et al. 2003, Pearce-Higgins et al. 2009, Smallwood et al. 2009). In Washington and Oregon, grasshopper sparrows (*Ammodramus savannarum*) and western meadowlarks (*Sturnella neglecta*) showed decreased use of areas near a wind facility (Erickson et al. 2003). Similarly, Pearce-Higgins et al. (2009) found 7 of 12 breeding bird species had lower frequency of occurrence at a wind facility in the United Kingdom.

Despite the many benefits of wind power, there are some concerns regarding the environmental impact of wind turbines, such as habitat loss, habitat disturbance, soil disturbance and possible erosion, vegetation loss, promotion of invasive species, noise pollution, and collision-related mortality (National Research Council 2007). Each of these may impact populations of birds, bats, and other wildlife species (National Research Council 2007). The effects of wind farms on wildlife have been published in a few European and American scientific studies, but the bulk of information on effects was documented in unpublished reports and other gray literature (Arnett et al. 2007, Kuvlesky et al. 2007).

The impacts of wind power on wildlife can be both direct and indirect. Bird and bat collisions with turbines and other infrastructure are possible direct hazards of wind power (Pimentel et al. 2002, Hoover and Morrison 2005, Arnett et al. 2007, Kuvlesky et al. 2007). Habitat loss, habitat fragmentation, avoidance of structures and other behavioral changes, and increased predation because of increased perching and nesting structures are some of the potential indirect hazards (Osborn et al. 1998, Hoover and Morrison 2005, Piorkowski 2006, Kuvlesky et al. 2007, Lammers and Collopy 2007). Wind farms likely have varying risks and different magnitudes of hazards depending on placement of the facility, topography, weather, wildlife habitat needs, and wildlife migration patterns (Jain 2005, Arnett et al. 2007, Kuvlesky et al. 2007).

Early wind development in California resulted in a large number of birds, especially raptors, being killed each year due to collision and electrocution at 3 major wind facilities, Altamont Pass, San Gorgonio, and Tehachapi Wind Resource Areas (Howe and Noone 1992, Thelander et al. 2003). Reported raptor casualties compiled by the California Energy Commission and other research at these wind facilities found that eagles, burrowing owls (*Athene cunicularia*), hawks, especially red-tailed hawks (*Buteo jamaicensis*) and American kestrels (*Falco sparverius*), were at greatest risk of collisions with turbine blades (Estep 1989, Howe and Noone 1992, Thelander et al. 2003, Smallwood and Karau 2009). At a wind farm in California, Thelander et al. (2003)

documented 50% of bird fatalities were raptors. This wind farm had 5,400 turbines operating at the time of the study. Kerlinger et al. (2006) also reported 50% of bird fatalities at another California facility were raptors.

Other studies have suggested possible reasons for the excessive collision and electrocution mortality in raptor species. These included placement of turbines on ridges in a raptor migration corridor, older lattice style towers that encouraged perching and nesting, smaller blade diameters that rotated at greater revolutions per minute making it hard for raptors to avoid, placement in high prey density areas, and high densities of turbines (Estep 1989, Howe and Noone 1992, Thelander et al. 2003, Kunz et al. 2007, Smallwood and Karau 2009).

Smallwood and Karau (2009) examined how updating older wind turbine designs and technology at Altamont Pass Wind Resource Area could reduce collision fatality rates. They concluded that an 83% reduction in raptor fatalities and an 87% reduction in overall bird fatalities could be mitigated through retooling with newer generation turbine technology. Studies examining newer generation wind facilities in California and other sites in the western U.S. have found avian fatality rates, especially raptors, were much lower than older generation wind facilities in California (Erickson et al. 2000, 2003, 2004; National Research Council 2007). Red-tailed hawks and American kestrels comprised the greatest proportion of raptor fatalities in these California studies (Erickson et al. 2000, 2003, 2004). However, unlike the high proportions of raptor fatalities at Altamont Pass, collision fatalities at a wind farm bordering Washington and Oregon were primarily passerines (50% residents and 25% migrants; Erickson et al. 2004). Overall, mortality rates (1.89 birds/mega watt [MW]/year) at this wind farm were lower than that of the Altamont Pass facility (7.52 birds/MW/year). A Wyoming study also found raptors to be a small portion of overall collision mortality rate which was 1.99 birds/MW/year (Young et al. 2003). This study found an even greater portion of collision fatalities to be passerines (92%) than was found in Washington and Oregon (Young et al. 2003).

Similar to the newer generation wind facilities of the western U.S., studies at wind facilities of Canada and the midwestern U.S. have found passerines to be the greatest portion of collision fatalities (Piorkowski 2006, Howe et al. 2002, Brown and Hamilton 2004, Jain 2005, Brown and Hamilton 2006). These studies also found that raptor deaths were a small portion of overall deaths but also found that red-tailed hawks and American kestrels were the most susceptible to collisions. In southwestern Minnesota, Osborn et al. (1998) found American kestrels and red-tailed hawks often fly at heights within the rotor swept zone but found no American kestrel or red-tailed hawk mortalities during post-construction surveys. They thought this was likely due to low densities of the 2 species and differences associated with newer generation turbines (Osborn et al. 1998). Additionally, wind energy facilities in the eastern U.S. have low raptor fatalities (on average 6% of mortalities). Studies of these facilities report high passerine fatalities ($\leq$76%), with nocturnal migrating passerines (50%) being of special concern (Kerns and Kerlinger 2004, Nicholson et al. 2005, Fielder et al. 2007, Jain et al. 2007, National Research Council 2007).

Across North America, documented bird mortality rates have ranged from 0.04–

9.59 fatalities per turbine per year (National Research Council 2007). The National Research Council (2007) compiled avian mortality statistics from studies across the U.S. and found that for all regions 74% of the fatalities were passerines, 11% game birds, and 6% raptors and vultures. Although the rates of raptor fatalities are low, many raptor species have lower reproductive rates, further amplifying impacts of turbine collisions to their populations (Pimentel et al. 2002, Kuvlesky et al. 2007, National Research Council 2007). Many raptor species are longer lived and have lower reproductive rates leading to low population growth rates (Pimentel et al. 2002, National Research Council 2007). These species will likely undergo impacts on their populations sooner than species with higher reproductive rates (Pimentel et al. 2002, National Research Council 2007).

The variability of collision fatalities among avian species and wind farms is likely due to variation in migration paths, migratory stopover sites, and landscape characteristics (National Research Council 2007). Pimentel et al. (2002) reported <300 bird fatalities for the estimated 13,000 turbines in the U.S. in 2000. While the mortality from wind turbines is a minimal contributor to overall bird fatalities, it is likely additive to other causes of mortality further contributing to declines in some species (National Research Council 2007). More before-after studies are needed to determine how impacts to avian species may influence the entire biotic community. Further study is also needed to determine how fatalities of migrant birds affect local and regional bird populations (National Research Council 2007).

Improvements in wind farm placement and new repellant technologies may help reduce mortality at wind facilities (Pimentel et al. 2002, Jain 2005). New turbine technology has the potential to not only lessen the impacts on wildlife but to increase energy production (Smallwood and Karau 2009). However, more thorough and longer term studies are needed to assess whether changes in bird behavior, habitat loss, habitat fragmentation, other habitat modifications, and increased infrastructure are more harmful than direct mortality (Erickson et al. 2004, Kuvlesky et al. 2007, Arnett et al. 2007).

Many birds have been found to modify their behavior around active wind turbines and tend to fly either above or below the blade radius (Osborn et al. 1998, Howe et al. 2002, Nicholson et al. 2005, Masden et al. 2009). Masden et al. (2009) found that migrating seaducks modified their flight trajectories within 500 m of offshore wind facilities. Also, Smallwood et al. (2009) found species varied in their behavior around wind facilities. For example, some species would avoid flying near turbines while others would fly closer to turbines if they were inoperative or broken. Smallwood et al. (2009) found that mallards (*Ana platyrhynchos*) and horned larks (*Eremophila alpestris*) avoided rotor swept zones. While loggerhead shrikes (*Lanius ludovicianus*) avoided operating turbines, they were less avoidant and more interactive with other birds in areas of non-operating turbines (Smallwood et al. 2009). Smallwood et al. (2009) also observed western meadowlarks primarily exhibited travel behavior near operating turbines and little to no time exhibiting other behaviors.

Other indirect impacts of wind energy facilities are more complicated to understand. Impacts from facility construction and maintenance leading to habitat loss, habitat fragmentation, and behavioral avoidance differ greatly among habitats, species, and habitat conditions prior to construction (National Research Council 2007). Leddy et al. (1999) found evidence that some species of male song birds were found at ≤4 times lower densities ≤180 m of turbines in Conservation Reserve Program (CRP) lands than in CRP land without turbines. Similarly, in the United Kingdom, Pearce-Higgins et al. (2009) found that 7 of 12 species studied were found at lower frequencies within 500 m of turbines. In Minnesota, Johnson et al. (2000) reported displacement of some groups and species in areas within 100 m of turbines.

Along with species being impacted differently, the National Research Council (2007) found that grasslands and agricultural fields had the greatest collision fatalities. Grassland birds are among the most threatened and declining communities of birds in North America due to loss and fragmentation of habitat from other anthropogenic activities such as agriculture and oil and natural gas development (Pruett et al. 2009*a*, National Research Council 2007, Sauer et al. 2008). These communities may be at further risk of declines due to development of wind energy facilities (Pruett et al. 2009*b*). Also, throughout much of the Great Plains there are many migratory stopover sites frequented by migratory shorebirds, waterfowl, and other water birds that may be susceptible to wind energy facilities placed too close to wetlands (Davis and Smith 1998). The National Research Council (2007) report noted migratory stopover sites to be at greater risk for collision fatalities due to the concentration of birds in one area. These wildlife impact issues, along with the great potential for wind energy development in the Great Plains, increase the need for pre-construction assessments and mitigation to lessen the potential impacts of wind energy development. For example, there are 104 priority avian species in the Texas High Plains region, most of which are migratory shorebirds or grassland birds that are already in decline due to habitat loss and fragmentation (Bender et al. 2005). To lessen the impact on wildlife, wind energy developers need to consider these species and key habitat resources when siting facilities and individual turbines.

Most published and unpublished studies to date have been short term (i.e., $\leq$ 1 year), did not examine pre-construction bird abundance or movement patterns, and have used inconsistent surveys and field protocols (Howe et al. 2002, Roberts and Schnell 2005, Piorkowski 2006). My research is part of a long-term pre-construction monitoring project intended to provide baseline data for comparison with research conducted after the construction of a wind farm in Gray County, Texas, USA. My goal was to use 2 methods to assess year round avian species richness, diversity, abundance, and occurrence prior to construction of wind farms in the Texas Panhandle. My study provides baseline data on grassland bird density, diversity, movement patterns, and proportion of the population at risk of collision for eventual comparison with post-construction bird communities.

My intent was to gain a better understanding of grassland bird communities in the Texas panhandle. I examined avian flight heights to identify possible species at greater risk of collisions with wind turbines. I examined avian diversity and density patterns through the year. Understanding differences in avian diversity between cover types will help wildlife managers and wind energy developers identify areas that may be important to avian conservation. I compared the effectiveness of point-counts and line-transects to help researchers plan avian surveys in the Texas Panhandle.

I followed the style and formatting guidelines of *The Journal of Wildlife*

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CHAPTER II

AVIAN FLIGHT HEIGHTS IN THE TEXAS PANHANDLE

ABSTRACT

Wind energy is one of the fastest growing renewable energy sources in the United States. Wind energy has the potential to reduce use of traditional non-renewable energy. However, there is concern for potential short- and long-term influences on wildlife, such as avian collision with turbine blades, habitat loss, habitat fragmentation, and habitat avoidance. Our goal was to examine the flight patterns of avian species to assess which species are at greatest risk of collision with wind turbine blades. During October 2008–August 2009, we recorded flight heights of 65 species at a future wind farm in the Texas High Plains. We observed average flight heights of 29 species were within the potential rotor swept zone (RSZ; 32–124 m). Of those species, 6 were listed as species of concern for the Texas High Plains region by Texas Parks and Wildlife Department. We found that the species (14) with >25% of observed flight heights within the RSZ were composed of 21% raptors/vultures, 50% wetland associated species, and 29% passerine/other species. Identifying these species will facilitate wind facility site assessment and placement to help mitigate potential collision impacts on avian species.

Key Words behavior, flight heights, grassland birds, pre-construction, raptors, Texas High Plains, wetland birds, wind energy

INTRODUCTION

Wind energy has become one of the fastest growing renewable energy sources due to incentive programs, such as the renewable energy production tax credit created in the Energy Policy Act of 1992 and extended in the American Recovery and Reinvestment Act of 2009 (U.S. Government Printing Office 2009). Many consider wind energy to be a positive renewable source of energy because of its potential to reduce the use of non-renewable energy sources and their negative environmental impacts (National Research Council 2007, Pimentel et al. 2002). However there are concerns about potential direct and indirect impacts of wind energy facilities on wildlife, especially birds and bats. Direct impacts are primarily collision fatalities and indirect impacts include habitat loss, habitat fragmentation, habitat avoidance, and behavioral changes (Arnett et al. 2007, Kuvlesky et al. 2007).

Early wind energy impact studies in the United States gained attention and concern for frequent collision and electrocution fatalities of raptors (Smallwood and Karas 2009, Estep 1989). At the time, little was known about the placement and structure of wind facilities to reduce collisions and electrocution fatalities. Studies since have determined that older lattice tower turbines at high densities in areas with high avian populations lead to high rates of collision fatalities (Smallwood and Karas 2009, National Research Council 2007). The major foci in current research have been on post-construction collision fatalities, possible mitigation through newer technology, and better placement of wind facilities.

For a better understanding of wind facility placement with the least impact on wildlife, natural resource managers need to conduct pre-construction site assessments. These assessments need to include species occupancy, species density, animal movement through and within a site, and other behaviors of potentially affected wildlife. For example, research into raptor collision fatalities has identified red-tailed hawks (*Buteo jamaicensis*) and American kestrels (*Falco sparverius)* in many regions to have high collision potential possibly due to their flight behavior, hunting techniques, and high densities (Arnett et al. 2007, Hoover and Morrison 2005). Hoover and Morrison (2005) found that red-tailed hawks use the landscape and winds when hunting in a way that can lead to greater collision potential around wind turbines. Other avian species have been shown to modify their behavior around turbines. Northern harriers (*Circus cyaneus*) showed increased caution around a wind facility and avoided turbines (Smallwood et al. 2009). Western meadowlarks (*Sturnella neglecta*) occasionally modified their traveling behavior near turbines but were also recorded perching on turbines (Smallwood et al. 2009, National Research Council 2007). Smallwood et al. (2009) found that some species, such as American crows (*Corvus brachyrhynchos*), cliff swallows (*Petrochelidon pyrrhonota*), red-winged blackbirds (*Agelaius phoeniceus*), and western meadowlarks will fly within 25 m of wind turbines. They also found that some individuals and species of birds were less cautious around turbines when engaged in activities such as foraging and interacting with other birds (Smallwood et al. 2009). Similarly, in Minnesota, Osborn et al. (1998) found 82–84% of birds observed modified their behavior by either flying above or below the rotor swept zone (RSZ; 22–55 m in MN study) of wind turbines.

The focus of our study was to identify species that are at a higher risk of collision fatalities due to heights at which they fly. Our goal was to identify species that may be more susceptible to turbine blade collision by examining mean flight heights and the proportion of flight heights in the RSZ. We also examined seasonal flight heights to determine if risk varies among seasons. Our results, along with results from other avian studies, will inform placement of turbines at future wind facilities in the Texas High Plains and help mitigate short and long-term impacts on avian species.

STUDY AREA

We conducted research on 2 sites in Gray and Donley counties, Texas, USA. Both study areas are part of the Llano Estacado Plateau and surrounding escarpments. The Llano Estacado Plateau is the largest plateau in North America (82,000 km^2; Smith 2003). Land use on the Plateau was a mixture of agriculture and oil and natural gas production; natural land cover was primarily short-grass prairie and playa wetlands (The United Nations University [UNU] Press 1995, United States Forest Service [USFS] 1994). The Plateau is surrounded by relatively abrupt escarpments (breaks) ranging from 50–200 m in height (UNU 1995, USFS 1994). The breaks were primarily used for rangeland and oil and natural gas production (UNU 1995, USFS 1994).

Gray County Site

We conducted research at the Gray County site from October 2008–August 2009 (Fig. 2.1). We sampled the avian community on a 219 km^2 area during October 2008–February 2009. We expanded the Gray County site to 303 km^2 during March 2009–August 2009 because the wind energy company increased the land area leased for its future wind energy facility. The Gray County site consisted of 2 general habitat types: uplands and breaks. The upland area (132 km^2 during Oct 2008–Feb 2009; 170 km^2 during Mar 2009–Aug 2009) was located on top of the caprock of the Llano Estacado

Plateau which is a mostly flat landscape that included cropland, pasture, playas wetlands, and Conservation Reserve Program (CRP) land and other grasslands (Smith 2003). Common crops were corn, cotton, and winter wheat. The playas are shallow depressional recharge wetlands and some of the highest playa densities are located in the Southern High Plains (average 1 per 2.6 km^2; Smith 2003). These playas provide habitat for both waterfowl and shorebirds throughout the year (Smith 2003). The uplands portion of the Gray County site contained 2 cattle feedlots and a dairy operation. Trees were found primarily around human structures and the most common tree was cottonwood (*Populus spp.*).

The breaks habitat type (87 km^2 during Oct 2008–Feb 2009; 133 km^2 during Mar 2009–Aug 2009) was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie. There were few water bodies limited to water tanks for cattle and ephemeral creeks. This area was also used for oil and natural gas extraction and has an extensive infrastructure of roads, oil wells, and other structures. Some trees, primarily cottonwood, were found within the breaks where deeper ravines hold water. Prominent grasses include buffalo grass (*Buchloe dactyoids*), blue grama (*Bouteloua gracilis*), and other grama species (*Bouteloua* sp.; National Resources Conservation Service [NRCS] 2006).

Donley County Site

We conducted research at the Donley County Site (18.7 km^2) during October 2008–February 2009 (Fig. 2.1). This site consisted of breaks and was dominated by honey mesquite (*Prosopis glandulosa*). Other trees or brush occurred throughout the site on ridge tops and drainages, which were spring fed throughout the year. Primary grasses were buffalo grass and grama (NRCS 2006). This study area was used for rangeland with no oil or natural gas production on site.

METHODS

Random Points

We selected 30 random points and conducted surveys from those points during October 2008–February 2009. We ensured that points were spaced $\geq$800 m apart. There were 23 points on the Gray County study area and 7 on the Donley County study area (Fig. 2.1). For the expanded Gray County study area we randomly selected an additional 34 points (49 total points used; 8 of the original 23 points were removed do to land access issues; Fig. 2.1) and conducted surveys from those points during March 2009–August 2009. We proportionally allocated points to ensure that all cover types were represented in the sample. We classified cover types as agriculture, breaks, plateau grasslands, playa wetlands, and prairie dog (*Cynomys ludovicianus)* towns. Our breaks cover type was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie located off the plateau. Also, our plateau grassland cover type was broadly defined as grasslands located on the plateau which included CRP, pasture, and other grasslands. Points were not placed within 400 m of cover edges to avoid overlap into other cover types. On the Gray County site there were 3 highways (U.S. Highway 60, State Highway 152, and State Highway 273) and points were placed $\geq$400 m from highways to avoid traffic noise.

Additionally, we used each random point (except the 10 points in playas or prairie dog towns due to the general size and shape of those features) as the start of an 800-m transect. Each transect was oriented along randomly selected compass bearings. We constrained selected bearings so that transects remained within the study site and respective cover stratum and were spaced ≥400 m apart.

Surveys

We conducted surveys from 0.25 hr before sunrise until about 10:30 am or 3 hrs after sunrise when diurnally active birds were most active and vocal (Diefenbach et al. 2003). We conducted each point survey for 20 min with surveys divided into 2 10-min intervals. We used a weather meter (Kestrel 2000 Pocket Weather Meter, Nielsen-Kellerman, Boothwyn, PA) to measure wind speed and temperature. We did not conduct surveys if average wind speed was >32 km/hr or in severe weather, such as thunderstorms, because of reduced audibility and activity of birds (Diefenbach et al. 2003).

We conducted surveys during 4 seasons with up to 3 samples per technique (point or line-transect) per season. We defined seasons as winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug), and fall (Sep–Nov). The point-counts at playas and prairie dog towns were surveyed twice a month, similar to other point surveys, but without line-transect surveys. We rotated the time of morning in which samples were monitored at each site to avoid bias from reduced bird activity during late morning.

Height Measurements

We measured flight heights when birds were first detected during our surveys. We used clinometers (Suunto Clinometer, Vantaa, Finland) and rangefinders (Nikon

Monarch Gold Laser 1200, Tokyo, Japan) to estimate flight heights. We estimated flight heights from perpendicular distance to the bird or group of birds and the angle (degrees) of incline to the bird at the location originally sighted. For our flight height analysis, we pooled flight height data between the two survey techniques. We estimated range, mean, and standard deviation using Microsoft Office Excel 2007 for each species by season. For species with appropriate sample sizes we compared seasonal means using an analysis of variance (ANOVA) or 2-sample *t*-test (Dytham 2003). We pooled seasonal data if sample size was not appropriate. We used a SAS macro (Cary 1995) to conduct a power analysis to determine appropriate sample size. We estimated effect size using

$$\frac{(x_1 - x_2)}{\mathrm{SD}}$$

where x_1 is largest mean, x_2 is smallest mean, and SD is within-cell standard deviation. We assumed effect size of 1.23, power ($1 - \beta$) of 0.80, and $\alpha = 0.05$. We conducted a general power analysis to determine an appropriate sample size needed for statistical analysis. We determined minimum sample size for 2, 3, and 4 treatments (i.e., seasons). We used program R 2.0 (2009) to conduct ANOVAs and post-hoc pairwise *t*-tests using a Bonferroni's adjustment (Dalgaard 2008). We used turbine measurements provided by Iberdrola Renewables, Inc. to characterize the RSZ (hub height = 78 m, rotor diameter = 90 m; Jason Du Terroil, personal communication). We added 2 m to the rotor diameter in order to define the RSZ (32–124 m) to allow for inaccuracies in flight height measurements. We then identified avian species with mean flight heights within the RSZ as species of possible concern for blade collisions. We also identified species of high concern from a Texas Parks and Wildlife Department (TPWD) species of concern list for the Texas High Plains (Bender et al. 2005; see Appendix B).

We estimated the proportion of flight heights within the RSZ (32–124 m). For species with an appropriate sample size we compared seasonal proportions using χ^2 test in R 2.0 (2009). We pooled seasonal data if sample sizes were not appropriate. We used χ^2 power analysis in R 2.0 (2009) to determine appropriate sample size (Kabacoff 2008). We assumed effect size of 0.5, power of 0.80, and $\alpha = 0.05$. We determined minimum sample size for 2, 3, and 4 treatments (i.e., seasons). We used program R 2.0 to conduct χ^2 test to determine if there were differences in proportions of flight heights within the RSZ between seasons (Dalgaard 2008).

We identified species with mean flight heights within the RSZ as being at greater risk of collisions with turbines. We also assessed the proportion of species' flight heights within the RSZ. We chose to focus on species with >25% of flight heights within the RSZ in order to identify species and avian groups at greatest risk of collision.

RESULTS

We recorded >2 flight heights for 65 avian species. We recorded a total of 2,667 flight heights (Table 2.1). The species most commonly recorded were red-winged blackbirds (n = 457), sandhill cranes (*Grus canadensis*; n = 278), mourning doves (*Zenaida macroura*; n = 276), meadowlarks (both eastern and western; n = 240), horned larks (*Eremophila alpestris*; n = 168), northern harriers (n = 149), and Canada geese (*Branta canadensis*; n = 131). These 7 species accounted for 65% of our flight height records. Raptors and vultures, mainly northern harriers, made up 10% of our observations. Waterfowl, waterbirds, and shorebirds made up 26% of our observations. Passerines made up 29% of our observations. Other species made up 35% of our observations.

Our power analysis for ANOVA and *t*-test suggested we needed 12 observations/season to detect differences in flight heights between 2 seasons, 14 observations/season to detect differences between 3 seasons, and 16 observations/season to detect differences between 4 seasons. We had 10 species with the appropriate number of observations (Table 2.2). We observed no differences among seasons for barn swallows (*Hirundo rustica*; t = 1.56, df = 59, P = 0.125), Canada geese (t = 0.759E-01, df = 129, P = 0.940), horned larks (F = 1.59, df = 164, P = 0.195), longspurs (*Calcarius* spp.; t = 0.207, df = 40, P = 0.837), mallards (t = 0.714, df = 40, P = 0.479), mourning doves (t = 1.58, df = 260, P = 0.115), northern harriers (F= 0.70, df =146, P = 0.500), or red-winged blackbirds (F= 0.14, df =453, P = 0.939; Table 2.2). We observed common grackle flight heights were greater in summer (68.6 ± 27.78; mean ± 95% CI) than spring (33.1 ± 12.59; mean ± 95% CI; t = 2.43, df = 59, P = 0.020). Great-tailed grackle (*Quiscalus mexicanus*) flight heights were greater in summer (52.7 ± 18.99; mean ± 95% CI) than spring (26.2 ± 9.45; mean ± 95% CI; t = 2.25, df = 46, P = 0.029). Killdeer (*Charadrius vociferous*) flight heights were greater in summer (50.8 ± 12.09; mean ± 95% CI) than spring (27.8 ± 10.77; mean ± 95% CI; t = 2.11, df = 71, P = 0.038). Sandhill crane flight heights were greater in winter (63.1 ± 9.65; mean ± 95% CI) than fall (37.1 ± 5.09; mean ± 95% CI; t =5.13, df = 272, P < 0.001). Western kingbird (*Tyrannus verticalis*) flight heights were greater in summer (24.0 ± 4.64; mean ± 95% CI) than spring (12.2 ± 4.70; mean ± 95% CI; t = 3.04, df = 63, P = 0.004). Also, meadowlark spp. flight heights were greater in summer (17.0 ± 3.40; mean ± 95% CI) than spring (11.2 ± 2.08; mean ± 95% CI), fall (8.4 ± 1.61; mean ± 95% CI), or winter (7.2 ± 2.24; mean ± 95% CI; F= 9.32, df = 236, P < 0.001).

We found 29 (45%) of our recorded species had mean flight heights within, and 3 species had mean flight heights above, the RSZ. Six of these species were TPWD species of concern (Bender et al. 2005). The ferruginous hawk with mean flight height of 60.7 m (*Buteo regalis*; SD 55.11; n = 3) was listed as high concern. The bald eagle, which was recently federally delisted but still a species of concern in Texas, had a mean flight height of 57.2 m (*Haliaeetus leucocephalus*; SD 19.36; n = 3). Redhead with mean 34.9 m (*Aythya americana*; SD 6.53; n = 2), Swainson's hawk with mean of 79.3 m (*Buteo swainsoni*; SD 65.39; n = 24), and white-faced ibis with mean of 87.5 m (*Plegadis chihi*; SD 93.93; n = 9) are all species of concern. While the common nighthawk with a mean flight height of 74.4 m (*Chordeiles minor*; SD 93.22; n = 22) was of low concern on the TPWD list.

We found that of the 29 species with mean flight heights in the RSZ, 8 species had their 95% CI contained completely within the RSZ and are therefore thought to be at greater risk of turbine collision. These 8 species were bald eagle (n = 3, 57.23 ± 21.91; mean ± 95% CI), Canada goose (n = 131, 92.79 ± 11.82; mean ± 95% CI), common grackle (*Quiscalus quiscula;* n = 44, 47.63 ± 13.40; mean ± 95% CI), common nighthawk (n = 22, 74.36 ± 38.95; mean ± 95% CI), mallard (*Anas platyrhynchos*; n = 57, 51.60 ± 13.31; mean ± 95% CI), sandhill crane (n = 278, 46.73 ± 4.99; mean ± 95% CI), snow goose (*Chen caerulescens*; $n = 44$, 47.63 ± 17.75; mean ± 95% CI), and Swainson's hawk ($n = 24$, 79.33 ± 26.16; mean ± 95% CI; Fig. 2.2). We also observed American white pelican ($n = 2$, mean = 208.0), cattle egret ($n = 5$, 159.9 ± 78.68; mean ± 95% CI) and Mississippi kite ($n = 5$, 159.6 ± 75.66; mean ± 95% CI) flew above the RSZ.

Our power analysis for χ^2 test suggested we needed 31 observations/season to detect differences in proportion of flight heights within RSZs between 2 seasons, 39 observations/season to detect differences between 3 seasons, and 44 observations/season to detect differences between 4 seasons. We had 7 species with the appropriate number of observations (Table 2.3). Canada geese had no differences in the proportions (π) of flight heights within the RSZ between fall and winter ($\pi = 0.66$, 95% CI = 0.576–0.744; $\chi^2 = 0.055$, df = 1, $P = 0.81$). Horned larks had no differences in the proportions of flight heights within the RSZ between fall and winter seasons ($\pi = 0.19$, 95% CI = 0.128–0.274; $\chi^2 = 1.778$, df = 1, $P = 0.18$). Meadowlark spp. had a greater proportion of flight heights within the RSZ in summer ($\pi = 0.107$, 95% CI = 0.040–0.219) than spring ($\pi = 0.030$, 95% CI = 0.006–0.084) or fall ($\pi = 0.000$, 95% CI = 0.000–0.056; $\chi^2 = 8.358$, df = 2, $P = 0.02$). Mourning doves had no differences in the proportions of flight heights within the RSZ between spring and summer ($\pi = 0.317$, 95% CI = 0.261–0.377; $\chi^2 = 2.956$, df = 1, $P = 0.09$). Northern harriers had no differences between fall and winter ($\pi = 0.172$, 95% CI = 0.120–0.251; $\chi^2 = 1.291$, df = 1, $P = 0.26$). Red-winged blackbirds had no differences between spring, summer, fall, or winter ($\pi = 0.384$, 95% CI = 0.333–0.436; $\chi^2 = 0.384$, $df = 3$, $P = 0.94$). Sandhill cranes had a greater proportion of flight heights within the RSZ in winter ($\pi = 0.628$, 95% CI = 0.526–0.721) than fall ($\pi = 0.506$, 95% CI = 0.429–0.583; $\chi^2 = 3.829$, df = 1, $P = 0.05$).

We observed 14 species (22%) had >25% of the flight heights within the RSZ and considered them at greatest risk of collision (Table 2.1). We found that the array of species with >25% of their flight heights within the RSZ was composed of 21% raptors/ vultures, 50% wetland associated species, and 29% passerine/other species. The 14 species were bald eagle ($n = 3$, $\pi = 1.00$, 95% CI = 0.37 – 1.00), Canada goose ($n = 131$, $\pi = 0.66$, 95% CI = 0.58–0.74), common grackle ($n = 44$, $\pi = 0.46$, 95% CI = 0.30–0.61), greater white-fronted goose (*Anser albifrons*; $n = 20$, $\pi = 0.70$, 95% CI = 0.46–0.88), great-tailed grackle ($n = 51$, $\pi = 0.39$, 95% CI = 0.26–0.54), mallard ($n = 57$, $\pi = 0.53$, 95% CI = 0.39–0.66), mourning dove ($n = 276$, $\pi = 0.32$, 95% CI = 0.26–0.79), northern pintail (*Anas acuta*; $n = 15$, $\pi = 0.53$, 95% CI = 0.27–0.79), northern shoveler (*Anas clypeata*; $n = 10$, $\pi = 0.60$, 95% CI = 0.27–0.88), red-winged blackbird ($n = 457$, $\pi = 0.30$, 95% CI = 0.26–0.34), sandhill crane fall season ($n = 172$, $\pi = 0.51$, 95% CI = 0.43–0.58), sandhill crane winter season ($n = 102$, $\pi = 0.63$, 95% CI = 0.53–0.72), snow goose ($n = 44$, $\pi = 0.64$, 95% CI = 0.48–0.78), Swainson's hawk ($n = 24$, $\pi = 0.54$, 95% CI = 0.33–0.75), and turkey vulture (*Cathartes aura*; $n = 20$, $\pi = 0.65$, 95% CI = 0.41–0.85; Fig. 2.3–2.5).

DISCUSSION

Raptors and vultures made up only 10% of our total observations but we observed 6 raptor species with mean flight heights within or above the RSZ and 5 raptor species below (Table 2.1). Flight heights within or above the RSZ suggested that raptors and vultures may be a group at high risk of collision with turbines. Miller (2008) found that raptors and vultures made up 44% of avian fatalities at a wind facility in the southern Texas Panhandle. Vultures (36%) were the most common fatality observed in Miller's (2008) study.

Not only having mean flight heights within the RSZ but also the proportion of flights within the RSZ may indicate risk of turbine collision. We found that 14 species had >25% of their observed flight heights within the RSZ. Of those 14 species, 10 were from the raptor or waterfowl group (Fig. 2.1). Osborn et al. (1998) also found that flight characteristics of these two groups indicated they were at greatest risk of turbine collision in Minnesota. To lessen the risk of turbine collisions by waterfowl, it may be prudent to avoid placement of wind turbines near playa wetlands and riparian systems.

We documented that over half (51%) of our observed species had mean flight heights below the RSZ. We observed 12% of our species (8) with mean flight heights and 95% CI contained completely within the RSZ indicating that they are at greater risk of collisions with turbines. In the upper Great Plains, Osborn et al. (1998) also found that the majority of birds flew below the RSZ (21–51 m) but fewer (16–18%) birds flew in the RSZ. They, however, observed that waterfowl and raptors were at greatest risk and passerines were at least risk of collision (Osborn et al. 1998). Howe et al. (2002) also found that birds flew below turbines in Northeastern Wisconsin with less than 14% of birds estimated within the RSZ (42–89 m). While, Nicholson et al. (2005) reported that the majority of raptor and vulture species (84%) avoided turbine blades by flying below or in adjacent valleys in the southeastern United States. This suggested that birds can modify their behavior around wind facilities and turbine blades indicating more research is needed on risky behavior for specific species and how specific species modify behaviors around turbines.

Smallwood et al. (2009) found several high-risk behaviors a few species exhibited near wind turbines that may be reflected in flight heights. These behaviors resulted in fatalities during spring and summer for western meadowlarks, which they found were correlated to seasonal flight heights within the RSZ. Behaviors such as territorial displays, breeding displays, and migratory travel can lead to seasonally-higher collision rates (National Research Council 2007, Smallwood et al. 2009). In our study, examination of seasonal differences for 14 species revealed 6 species flew at different heights during different seasons. For common grackles, great-tailed grackles, killdeer, and western kingbirds, we observed summer flight heights were greater than other seasons. Similarly, we found that sandhill cranes had higher mean flight heights in winter than fall. Additionally, we found that meadowlarks had greater flight heights in the summer but also had a greater proportion of flight heights within the RSZ during summer. These greater flight heights may be due to summer juvenile dispersal or late summer and winter migration however more research is needed.

Flight height studies are one type of initial assessment of species that may be at greater risk for collision with turbines, but more detailed documentation of other high risk behaviors such as territorial displays, breeding displays, and foraging behaviors are also needed (Osborn et al. 1998; Smallwood et al. 2009). Some species, such as the western meadowlark, may have mean flight heights below the RSZ but still exhibit other high risk behaviors, such as perching on turbines or interacting with other birds near turbines that lead to collision fatalities (Smallwood et al. 2009). Collision fatalities from such high-risk behaviors have been observed at some currently-operating wind facilities (National Research Council 2007). Osborn et al. (1998) noted that some species typically fly above the RSZ. We also observed American white pelican, cattle egret, and Mississippi kite flew above the RSZ. Those species are likely at greater risk of collision because those species must travel through the RSZ to reach those heights.

MANAGEMENT IMPLICATIONS

Identification of avian species at greater risk of wind turbine blade collision is important to help mitigate avian fatalities at wind energy facilities. As indicated by flight heights, we found raptor and waterfowl groups were at greatest risk of collision with wind turbines in the central Texas Panhandle. Turbine placement should be avoided in areas with high concentrations of trees which provide nesting habitat for many raptor species. Turbine placement should also be avoided in areas of high raptor prey densities where raptors may concentrate to feed. For wetland associated species we recommend that turbine placement should be avoided near playa wetlands where these species concentrate to feed, roost, and nest.

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Table 2.1. Flight height range, mean, and proportion within wind turbine rotor swept zone observed in Gray and Donley counties, Texas, October 2008–August 2009.

Species/Season[1]	*n*	Range Low	Range High	Mean	SD	*π* LCL	*π*	*π* UCL
American crow	8	6.4	75.4	36.5	26.51	0.16	0.50	0.84
American goldfinch	5	7.4	169.7	75.0	83.13	0.00	0.00	0.45
American kestrel	29	3.9	107.5	28.4	22.94	0.15	0.31	0.51
American pipit	15	3.5	57.7	24.8	17.73	0.08	0.27	0.55
American robin	8	6.0	46.5	18.7	13.79	0.03	0.25	0.65
bald eagle	3	36.9	75.4	57.2	19.36	0.37	1.00	1.00
bank swallow	14	3.3	73.1	18.3	18.90	0.02	0.14	0.43
barn swallow	61	1.8	71.1	13.4	12.74	0.02	0.07	0.16
black-crowned night-heron	3	6.1	126.4	71.6	60.85	0.01	0.33	0.91
blue-winged teal	5	17.3	77.5	49.2	24.80	0.15	0.60	0.95
Brewer’s blackbird	13	8.1	173.2	37.2	43.80	0.09	0.31	0.61
brown-headed cowbird	20	3.4	96.3	28.8	20.28	0.19	0.40	0.64
burrowing owl	3	6.3	13.3	10.0	3.53	0.00	0.00	0.63
Canada goose	131	13.6	393.6	92.8	69.01	0.58	0.66	0.74
Cassin’s sparrow	7	1.7	13.8	5.0	4.34	0.00	0.00	0.35
cattle egret	5	65.3	293.7	159.9	89.76	0.15	0.60	0.95
cliff swallow	31	1.7	53.3	12.3	12.50	0.01	0.07	0.21
common grackle	44	3.8	204.3	47.6	45.34	0.30	0.46	0.61
spring	21	3.8	126.4	33.1	29.43	0.18	0.38	0.62
summer	17	10.0	204.3	68.6	58.44	0.28	0.53	0.77
common nighthawk	22	13.5	384.1	74.4	93.22	0.17	0.36	0.59
dickcissel	7	2.7	14.7	6.8	4.58	0.00	0.00	0.35
eastern kingbird	7	2.5	48.9	11.9	16.61	0.00	0.14	0.58
Eurasian collared-dove	30	1.7	63.9	13.1	11.84	0.00	0.03	0.17
European starling	19	5.4	64.8	26.8	19.36	0.13	0.32	0.57
ferruginous hawk	3	20.1	123.4	60.7	55.11	0.09	0.67	0.99
gadwall	4	13.7	130.4	71.6	47.91	0.07	0.50	0.93
grasshopper sparrow	12	2.9	17.1	7.9	5.16	0.00	0.00	0.22

Table 2.1. Continued.

Species/Season[1]	*n*	Range Low	Range High	Mean	SD	π LCL	π	π UCL
great blue heron	6	5.5	322.2	98.8	115.47	0.12	0.50	0.88
greater white-fronted goose	20	26.0	189.4	96.1	47.88	0.46	0.70	0.88
great-tailed grackle	51	3.9	232.7	40.3	41.30	0.26	0.39	0.54
spring	21	3.9	74.5	26.2	22.09	0.11	0.29	0.52
summer	27	5.2	232.7	52.7	50.34	0.29	0.48	0.68
green-winged teal	3	13.7	115.5	53.2	54.57	0.01	0.33	0.91
horned lark	168	1.7	372.2	19.9	35.01	0.10	0.16	0.22
house finch	3	5.8	35.6	18.7	15.28	0.01	0.33	0.91
killdeer	81	1.7	192.5	33.1	37.91	0.22	0.32	0.43
spring	57	1.7	192.5	27.8	41.50	0.07	0.16	0.28
summer	16	2.5	96.7	50.8	24.67	0.54	0.81	0.96
lark sparrow	9	2.2	16.0	8.0	5.27	0.00	0.00	0.28
loggerhead shrike	8	2.3	38.6	10.4	11.94	0.00	0.13	0.53
longspur spp.[2]	45	1.8	271.9	27.2	43.07	0.10	0.20	0.35
mallard	57	2.0	329.4	51.6	51.25	0.39	0.53	0.66
meadowlark spp.[3]	240	1.7	76.5	11.4	10.53	0.02	0.04	0.08
spring	101	1.7	76.5	11.2	10.69	0.01	0.03	0.08
summer	56	2.8	59.0	17.0	12.98	0.04	0.11	0.22
fall	52	1.7	30.5	8.4	5.93	0.00	0.00	0.06
winter	31	1.7	32.1	7.2	6.38	0.00	0.03	0.17
merlin	3	3.4	14.5	7.53	6.09	0.00	0.00	0.63
Mississippi kite	5	82.2	291.4	159.6	86.32	0.05	0.40	0.85
mourning dove	276	1.7	164.7	29.8	23.72	0.26	0.32	0.37
northern harrier	149	1.7	144.8	18.6	20.44	0.12	0.18	0.25
northern mockingbird	9	5.2	42.3	19.3	10.86	0.00	0.11	0.48
northern pintail	15	13.7	142.5	48.1	37.00	0.27	0.53	0.79
northern rough-winged swallow	11	3.7	33.9	12.0	9.43	0.00	0.09	0.41
northern shoveler	10	13.7	111.7	61.7	49.98	0.27	0.60	0.88
prairie falcon	6	1.7	8.3	4.9	2.84	0.00	0.00	0.39

Table 2.1. Continued.

Species/Season[1]	n	Range Low	Range High	Mean	SD	π LCL	π	π UCL
purple martin	3	8.2	275.8	97.5	154.36	0.00	0.00	0.63
red-tailed hawk	15	1.7	79.0	36.0	26.11	0.21	0.47	0.73
ring-necked pheasant	4	2.2	6.6	3.7	2.00	0.00	0.00	0.53
red-winged blackbird	457	1.7	378.8	31.1	35.91	0.26	0.30	0.34
rock pigeon	8	9.2	65.3	30.4	24.49	0.03	0.25	0.65
Ross' goose	4	16.0	87.4	59.9	32.85	0.19	0.75	0.99
rough-legged hawk	6	10.5	58.5	32.8	17.69	0.12	0.50	0.88
sandhill crane	278	3.7	374.8	46.7	42.42	0.49	0.55	0.61
fall	172	3.7	374.8	37.1	34.03	0.43	0.51	0.58
winter	102	4.3	250.6	63.1	49.74	0.53	0.63	0.72
savannah sparrow	6	2.7	26.7	10.9	12.10	0.00	0.00	0.39
scissor-tailed flycatcher	22	1.7	252.0	29.9	51.34	0.05	0.18	0.40
snow goose	44	17.9	281.5	101.9	60.07	0.48	0.64	0.78
song sparrow	7	1.9	11.0	3.9	3.22	0.00	0.00	0.35
Swainson's hawk	24	3.4	238.3	79.3	65.39	0.33	0.54	0.75
tree swallow	7	2.3	47.3	12.0	15.86	0.00	0.14	0.58
turkey vulture	20	4.7	447.9	123.8	104.81	0.41	0.65	0.85
western kingbird	65	1.7	62.8	21.4	15.43	0.11	0.20	0.32
spring	20	1.7	41.7	12.2	10.72	0.00	0.05	0.25
summer	45	4.3	62.8	24.0	15.89	0.15	0.27	0.42
white-faced ibis	9	6.8	253.4	87.5	93.93	0.03	0.22	0.60
yellow-headed blackbird	4	2.2	23.5	8.9	10.03	0.00	0.00	0.53

[1] Season = seasonal calculations are included for species with seasonal differences; n = number of observations; SD = standard deviation; π = proportion of heights within the Rotor Swept Zone (32-124); LCL= 95% lower confidence level of the proportion; UCL= 95% upper confidence level of proportion.

[2] Longspur spp. includes chestnut-collared longspurs (n = 21), lapland longspur (n = 5), and McCown's longspur (n = 19) species.

[3] Meadowlark spp. includes meadowlarks identified to species (eastern meadowlark [n = 2] and western meadowlark [n = 44]) and those not (n = 194).

Table 2.2. Comparison of flight height means among seasons in Gray and Donley counties, Texas, October 2008–August 2009.

Species	Seasons tested	*F*[1]	*t*	df	*P*
barn swallow	spr, sum[2]		1.56	59	0.125
Canada goose	fal, win		0.07	129	0.940
common grackle	spr, sum		0.07	36	0.020
great-tailed grackle	spr, sum		2.25	46	0.029
horned lark	spr, sum, fal, win	1.59		3	0.195
killdeer	spr, sum		2.11	71	0.038
longspur spp.	fal, win		0.21	40	0.837
mallard	spr, fal		0.71	40	0.479
meadowlark spp.[3]	spr, sum, fal, win	9.32		3	>0.001
	spr, sum			155	0.003
	spr, fal			152	0.613
	spr, win			130	0.321
	sum, fal			106	>0.001
	sum, win			85	>0.001
	fal, win			81	1.000
mourning dove	spr, sum		1.58	260	0.115
northern harrier	spr, fal, win	0.70		2	0.500
red-winged blackbird	spr, sum, fal, win	0.14		3	0.939
sandhill crane	fal, win		5.13	272	>0.001
western kingbird	spr, sum		3.04	63	0.003

[1] *F* = *F* statistic for ANOVA; *t* = *t* statistic for 2-sample *t*-test; df = degrees of freedom; *P* = *p*-value.

[2] spr = spring, sum = summer, fal = fall, and win = winter.

[3] Post-hoc pairwise *t*-test using a Bonferroni's adjustment was conducted for meadowlark spp.

Table 2.3. Comparison of the proportions of flight heights within rotor swept zone (32–124 m) among seasons in Gray and Donley counties, Texas, October 2008–August 2009.

Species	Seasons tested[1]	χ^2	df	*P*
Canada goose	fal, win	0.055	1	0.814
horned lark	fal, win	1.778	1	0.182
meadowlark spp.	spr, sum, fal	8.358	2	0.015
mourning dove	spr, sum	2.956	1	0.086
northern harrier	fal, win	1.291	1	0.256
red-winged blackbird	spr, sum, fal, win	0.384	3	0.944
sandhill crane	fal, win	3.829	1	0.050

[1]spr = spring, sum = summer, fal = fall, and win = winter.

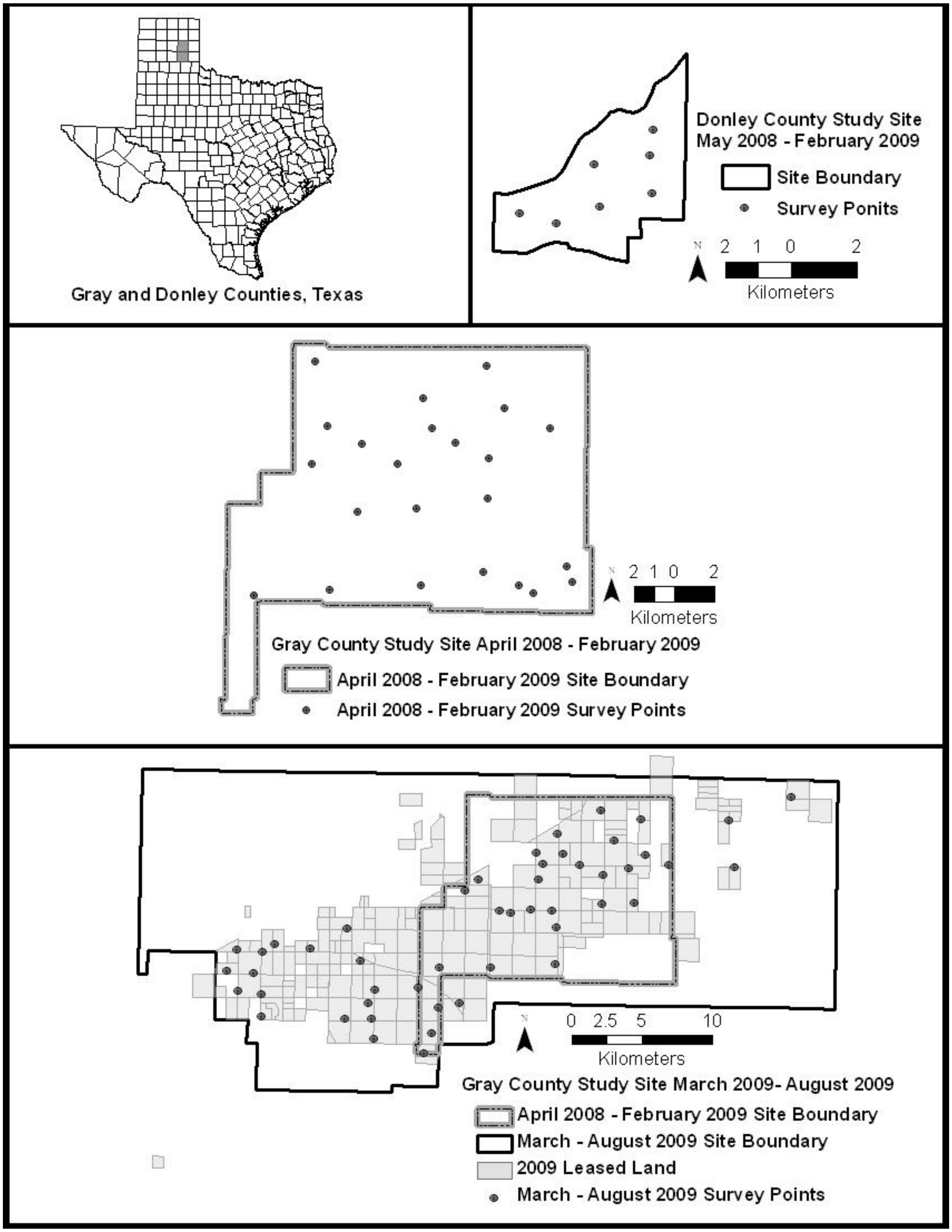

Figure 2.1. Gray and Donley County study sites and avian survey points used during October 2008–August 2009.

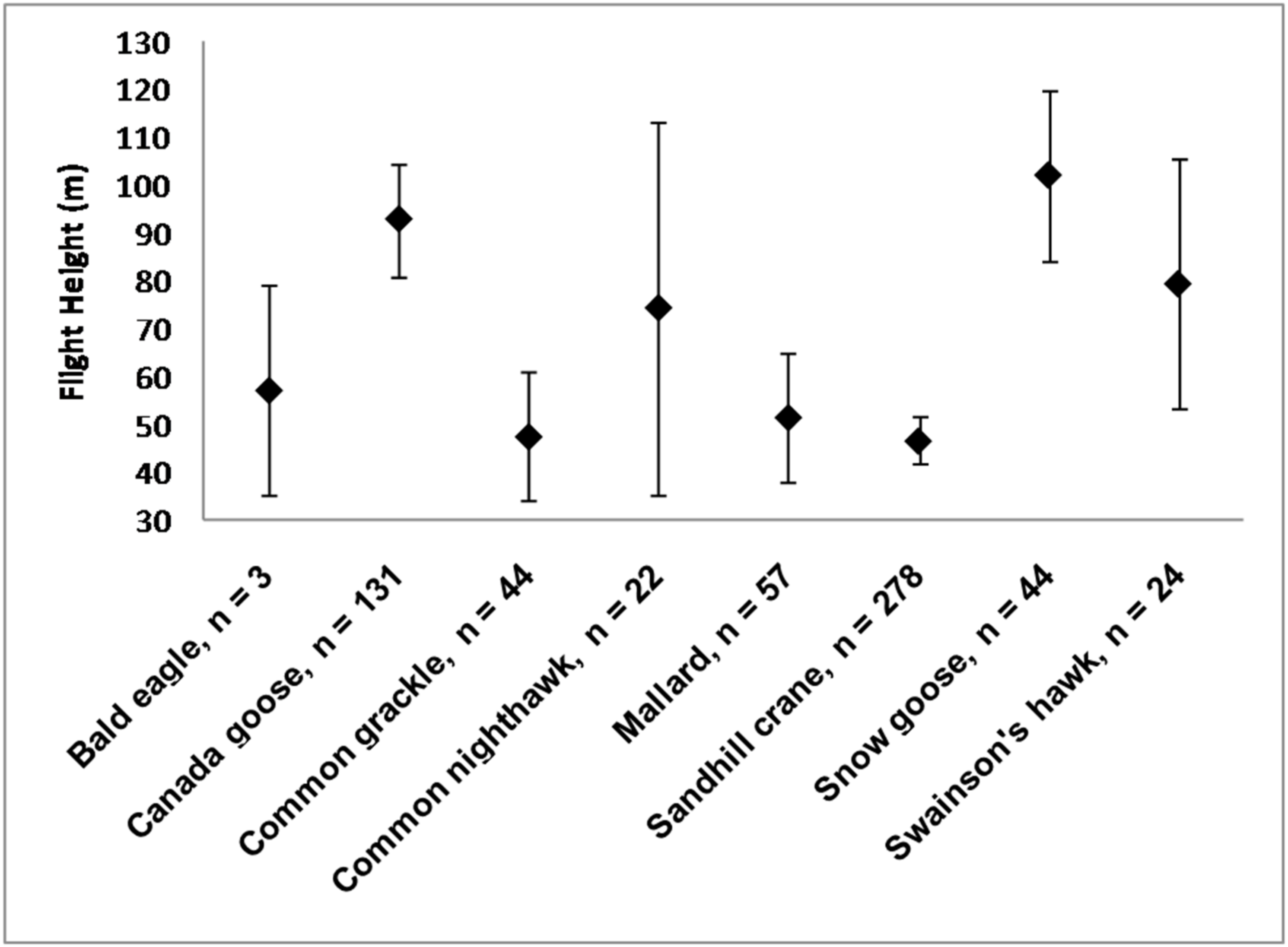

Figure 2.2. Avian species with mean flight heights and 95% CI within the rotor swept zone observed during October 2008–August 2009 at Gray and Donley County study sites, Texas.

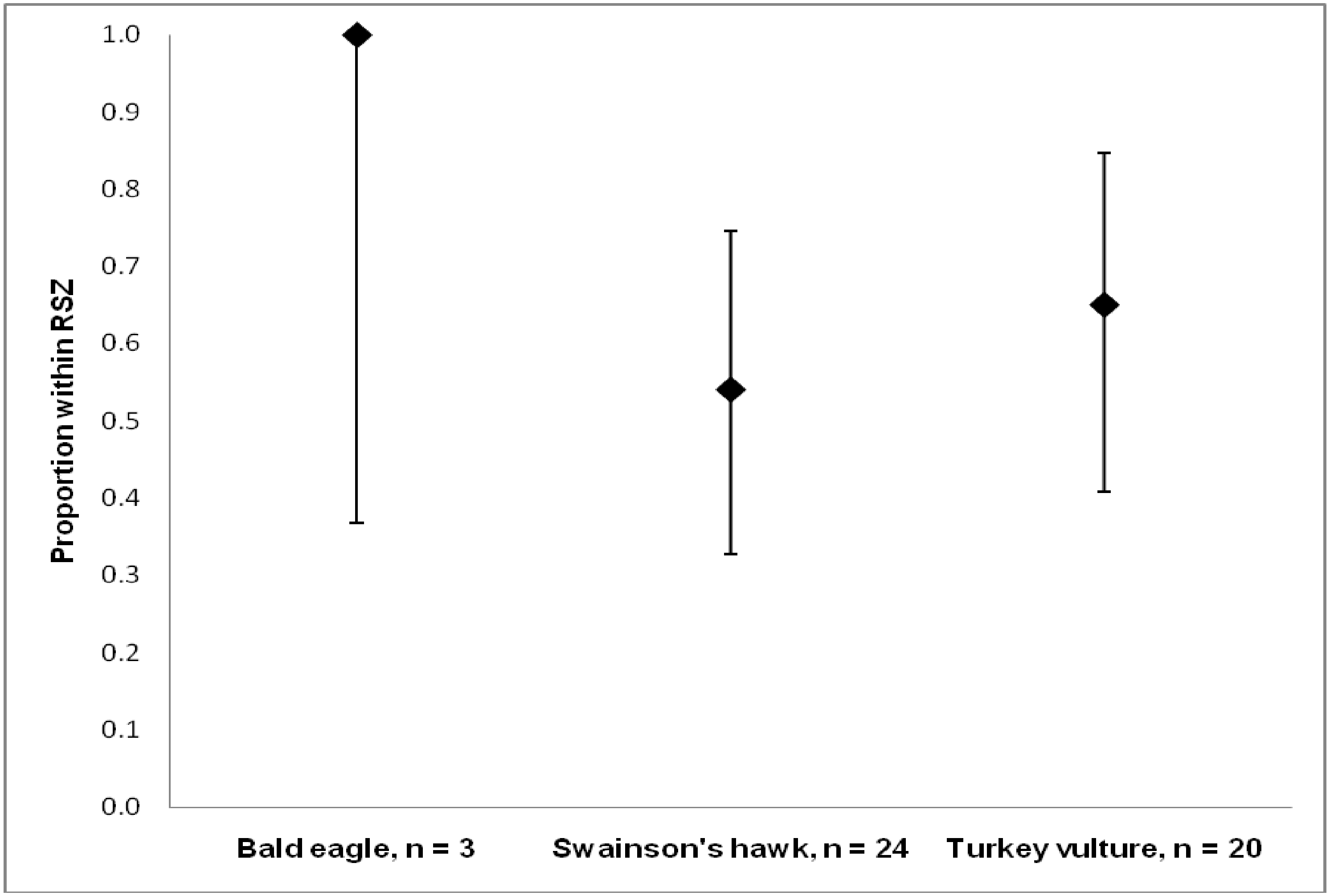

Figure 2.3. Species from the raptor group with >25% flight heights within the rotor swept zone (RSZ) in Gray and Donley counties, Texas, October 2008–August 2009.

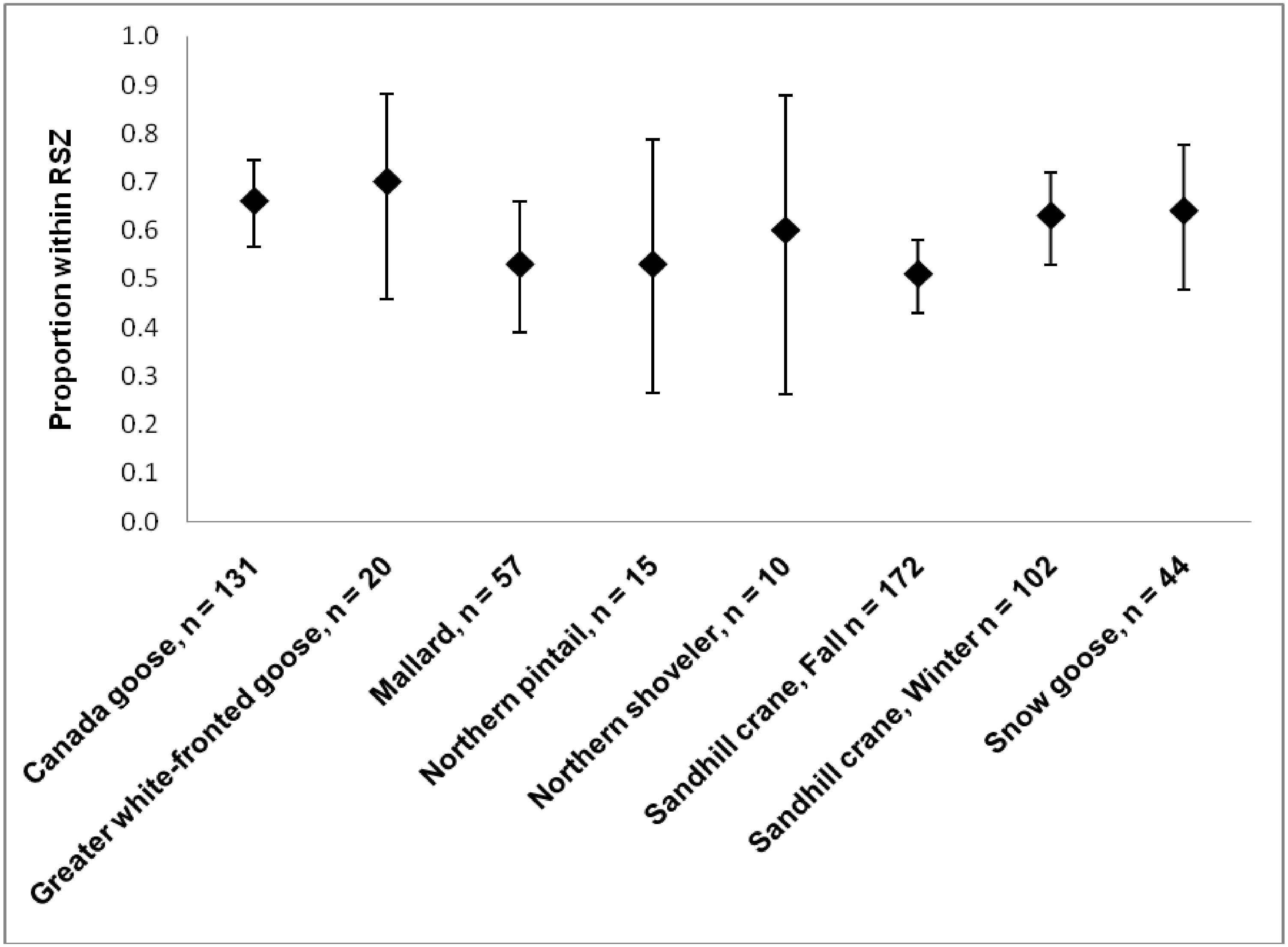

Figure 2.4. Wetland associated species with >25% flight heights within the rotor swept zone (RSZ) in Gray and Donley counties, Texas, October 2008–August 2009.

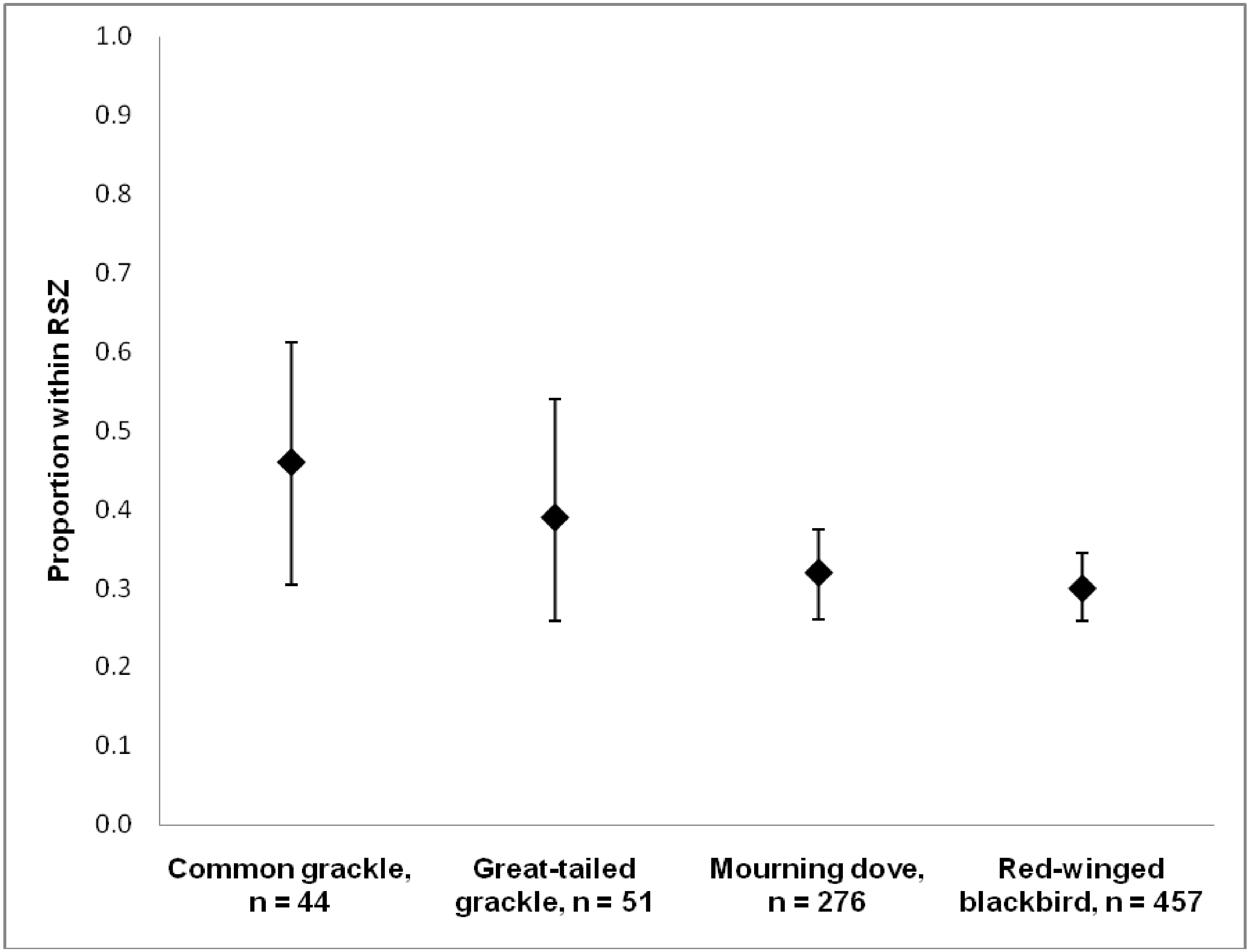

Figure 2.5. Other species with ≥25% flight heights within the rotor swept zone (RSZ) in Gray and Donley counties, Texas, October 2008–August 2009.

CHAPTER III

COMPARISON OF AVIAN SURVEY TECHNIQUES IN THE TEXAS PANHANDLE

ABSTRACT

Grassland bird communities have been declining for decades, likely due to loss and degradation of native grasslands. The Southern High Plains of the Texas Panhandle are one of the most intensely cultivated regions of North America resulting in great losses of native grasslands. However, it is an important geographic region for grassland birds. Our objectives were to compare and contrast 2 commonly used techniques for estimating avian densities. We monitored avian populations using point- counts and line–transect-based distance sampling at 2 proposed Texas High Plains wind facilities. We estimated density using Program Distance 6.0 for one fifth (*n* = 32) of the 163 species observed. While line-transects took more effort they resulted in a greater number of species detected (23 species with point-counts and 29 species with line-transects). This is likely because more area was covered and birds flushed as we walked along the line. However, differences between the survey techniques depended on season and species. For example, non-breeding season sparrows (*Calcarius* spp. and *Passerculus* spp.) were detected more often with line-transects, likely due to the flushing of secretive birds while walking transects. Line-transect surveys may be most efficient during the non-breeding season and when surveying grassland species.

Key Words avian density, distance sampling, grassland birds, line-transect, point-count, pre-construction, survey comparison, Texas Panhandle, wind energy

INTRODUCTION

Grassland communities are important for over 50% of breeding bird species in the continental United States (Berthelsen and Smith 1995). However, grassland bird populations have been declining for decades and have declined more than any other bird group in North America (Sauer et al. 2008, North American Bird Conservation Initiative, U.S. Committee 2009). The most likely causes are loss and degradation of native grasslands and changes in agricultural practices (McCoy et al. 1999, Murphy 2003). Murphy (2003) reviewed trends of avian population declines and the change in the agricultural landscape in the eastern and central United States from 1980–1998. Murphy (2003) concluded that changes in the agricultural landscape, loss of rangeland, and increases in Conservation Reserve Program (CRP) land had negative effects on bird populations.

Several studies have reported that while CRP may attract many birds, avian breeding success in CRP was generally less than required for positive population trajectories (Berthelsen and Smith 1995, McCoy et al. 1999, Murphy 2003). Though the Southern High Plains of Texas is one of the most intensively cultivated regions in North America (Berthelsen and Smith 1995), there are more than 1.2 million hectares of CRP in the region. Berthelsen and Smith (1995) found that CRP land may positively affect grassland species such as grasshopper sparrows (*Ammodramus savannarum*), Cassin's sparrows (*Aimophila cassinii*), red-winged blackbirds (*Agelaius phoeniceus*), and western meadowlarks (*Sturnella neglecta*).

More recently, concerns of negative impacts on grassland bird communities due to habitat loss and degradation have risen with increased development of wind energy across the grasslands of North America. Some research has examined the effects of wind energy on birds in a variety of habitat types. Most research has focused on direct impacts (i.e., collision related fatalities; National Research Council 2007). These studies have been conducted post-construction of wind facilities primarily using carcass searches (Anderson et al.1999, National Research Council 2007). Few studies have been conducted on indirect impacts to birds such as habitat loss, habitat fragmentation, habitat avoidance, and displacement. Erickson et al. (2004) found some decrease in use of a wind facility in Washington and Oregon by grasshopper sparrows and western meadowlarks. The pre-construction assessment in this study was <1 year and does not rule out seasonal and migration effects.

Another important aspect of research into grassland bird population trends and causes is identification of proper survey techniques. Diefenbach et al. (2003) found the most common survey techniques used in grassland bird studies from 1985–2001 were fixed-width line-transects and fixed-radius point-count surveys. However, modern survey techniques that employee bias correction for incomplete detectability is now considered most appropriate (Anderson 2001, Rosenstock et al. 2002, Thompson 2002).

Fletcher et al. (2000) compared fixed-radius point-counts and rope-dragging line-transects in the prairies of the Florida Everglades. They examined how the two techniques compared for non-breeding birds. They found more species were detected during line-transects while greater numbers of birds were detected during point-counts. Fletcher et al. (2000) concluded that line-transects were more effective, but required more effort. Roberts and Schnell (2006) compared survey techniques for non-breeding birds in southwestern Oklahoma. They compared line-transects and area-searches for 16 grassland bird species. They found that area-search density estimates tended to be higher for savannah sparrows (*Passerculus sandwichensis*), song sparrows (*Melospiza melodia*), and eastern meadowlarks (*S. magna*; Roberts and Schnell 2006). Area-searches were thought to result in higher densities for some species that escaped detection on the line by hiding. They surmised that missed detections resulted in estimates that were biased low (Roberts and Schnell 2006). Overall, both studies found varying results depending on the species.

The goal of our study was to assess seasonal densities of avian species on 2 study sites in the Texas panhandle. We also wanted to compare point-counts and line-transect distance sampling for breeding and non-breeding grassland birds. Our purpose was to determine the best technique for collecting baseline grassland bird densities for wind energy impact studies. Our data will be used as part of a pre-construction study to assess potential impacts from wind energy development on grassland birds in the Texas Panhandle.

STUDY AREA

We conducted research on 2 sites in Gray and Donley counties, Texas, USA. Both study areas are part of the Llano Estacado Plateau and surrounding escarpments. The Llano Estacado Plateau is the largest plateau in North America (82,000 km^2; Smith 2003). Land use on the Plateau was a mixture of agriculture and oil and natural gas production; natural land cover was primarily short-grass prairie and playa wetlands

(United States Forest Service [USFS] 1994, The United Nations University [UNU] Press 1995). The Plateau is surrounded by relatively abrupt escarpments (breaks) ranging from 50–200 m in height (USFS 1994, UNU 1995). The breaks were primarily used for rangeland and oil and natural gas production (USFS 1994, UNU 1995).

Gray County Site

We conducted research at the Gray County site from April 2008–August 2009 (Fig. 3.1). We sampled the avian community on a 219 km^2 area during April 2008–February 2009. We expanded the Gray County site to 303 km^2 during March 2009–August 2009 because the wind energy company increased the land area leased for its future wind energy facility. The Gray County site consisted of 2 general habitat types: uplands and breaks. The upland area (132 km^2 during Apr 2008–Feb 2009; 170 km^2 during Mar 2009–Aug 2009) was located on top of the caprock of the Llano Estacado Plateau which was a mostly flat landscape that included cropland, pasture, playas, and CRP and other grasslands (Smith 2003). Common crops were corn, cotton, and winter wheat. The playas are shallow depressional recharge wetlands and some of the highest playa densities are located in the Southern High Plains (average 1 per 2.6 km^2; Smith 2003). These playas provided habitat for both waterfowl and shorebirds throughout the year (Smith 2003). The uplands portion of the Gray County site contained 2 cattle feedlots and a dairy operation. Trees were found primarily around human structures and the most common tree was cottonwood (*Populus* spp.).

The breaks habitat type (87 km^2 during Apr 2008–Feb 2009; 133 km^2 during Mar 2009–Aug 2009) was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie. There were few water bodies which were limited to water tanks for cattle and ephemeral creeks. This area was also used for oil and natural gas extraction and had an extensive infrastructure of roads, oil wells, and other structures. Some trees, primarily cottonwood, were found within the breaks where deeper ravines hold water. Prominent grasses included buffalo grass (*Buchloe dactyoids*), blue grama (*Bouteloua gracilis*), and other gramas(*Bouteloua* sp.; National Resources Conservation Service [NRCS] 2006).

Donley County Site

We conducted research at the Donley County Site (19 km^2) during May 2008–February 2009 (Fig. 3.1). We stopped surveys after February 2009 when the wind energy company changed focus of wind development to the Gray County site only. This site consisted of breaks and was dominated by honey mesquite (*Prosopis glandulosa*). Other trees or brush occurred throughout the site on ridge tops and drainages, which were spring fed throughout the year. Primary grasses were buffalo grass and grama (NRCS 2006). This study area was used for rangeland with no oil production on site.

METHODS

Random Points

We selected 30 random points and conducted surveys from those points during April 2008–February 2009. We ensured that points were spaced $\geq$800 m apart. There were 23 points on the Gray County study area and 7 on the Donley County study area (Fig. 3.1). For the expanded Gray County study area we randomly selected an additional 34 points (49 total points used; 8 of the original 23 points were removed do to land access issues; Fig. 3.1) and conducted surveys from those points during March 2009–August 2009. We proportionally allocated points across cover types to ensure that all cover types were represented in the sample. We classified 3 main cover types as agriculture, breaks, and plateau grasslands. We classified 2 secondary cover types as playa wetlands and prairie dog (*Cynomys ludovicianus*) towns. Our breaks cover type was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie located off the plateau. Our plateau grassland cover type was broadly defined as grasslands located on the plateau which included CRP, pasture, and other grasslands. Points were not placed within 400 m of cover edges to avoid overlap into other cover types. On the Gray County site there were 3 highways (US Highway 60, State Highway 152, and State Highway 273), Donley County study site was bordered on the North by I-40, and points were placed ≥400 m from highways to avoid traffic noise.

Additionally, we used each random point (except the 10 points in playas or prairie dog towns due to their general size and shape of those features) as the start of an 800-m transect. Each transect was oriented along randomly selected compass bearings. We constrained selected bearings so that transects remained within the study site and respective 3 main cover stratum (agriculture, breaks, and plateau grasslands) and were spaced ≥400 m apart.

Surveys

We conducted surveys from 0.25 hr before sunrise until about 10:30 am or 3 hrs after sunrise when diurnally active birds were most active and vocal (Diefenbach et al. 2003). We conducted each point survey for 20 min with surveys divided into 2 10-min intervals. We used a weather meter (Kestrel 2000 Pocket Weather Meter, Nielsen-Kellerman, Boothwyn, PA) to measure wind speed and temperature. We did not conduct surveys if average wind speed was >32 km/hr or in severe weather, such as thunderstorms because of reduced audibility and activity of birds (Diefenbach et al. 2003). We measured all bird distances using a laser rangefinder (Nikon Monarch Gold Laser 1200, Tokyo, Japan). During line-transect surveys, we recorded distance and compass angles for each bird or flock of birds to estimate perpendicular distance to the transect. We counted the number of birds in flocks and recorded 1 distance to the center of the flock where it was first detected (Thompson et al. 1998, Buckland et al. 2001).

We conducted surveys during 4 seasons with up to 3 samples per technique (point or line-transect) per season. We defined seasons as winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug), and fall (Sep–Nov). The point-counts at playas and prairie dog towns were surveyed twice a month, similar to other point surveys, but without line-transect surveys. We rotated the time of morning in which samples were monitored at each site to avoid bias from reduced bird activity during late morning.

Density Estimates

We estimated density per km^2 for species with at least 40 observations for both point-count and line-transect surveys using Program Distance 6.0 (Thomas et al. 2010). This program uses individual distances from a point or line to fit a detection function which accounts for individuals not detected during surveys (Buckland et al. 2001, Thomas et al. 2002, Thomas et al. 2010). As recommended by Buckland et al. (2001:47), we used 9 a priori models of detection functions in the analysis. We assessed each model for fit using detection function histograms, q-q plots, and χ^2tests. Point-count surveys were 20 min but only the first 10 min of the surveys were used for density analyses to reduce bias due to movements of birds. We organized survey records into seasons to examine seasonal differences in density. For common species with at least 40 records in each season, we used Distance 6.0 to fit a detection function for each season and estimate seasonal density (Tables 3.2 and 3.3). For species with at least 40 records but not present in each season, we fit one overall detection function to all the records and seasonal estimates were based on the overall detection function (Tables 3.2 and 3.3). For all species, we used the size-bias regression method to improve density estimates by accounting for potential bias from increased detection probabilities associated with large flocks (Buckland et al. 2001). We used AIC_c and multimodel inference to estimate density and coefficients of variation (Burnham and Anderson 2002).

Techniques Comparison

We compared survey techniques by examining the number of species detected and species densities for each technique. We compared density estimates for each species using 95% confidence intervals; non overlapofconfidence intervals suggested techniques differed for that species. We examined density estimates for each season when available for both techniques. We were able to compare playa wetland and prairie dog town cover types even though we did not conduct line-transects on the 10 points specified for them because we surveyed the 2 cover types along many of our line-transects. We also estimated effort by averaging the amount of time it took to complete each line-transect survey.

RESULTS

Density Estimates

We recorded 163 species of birds at our 2 study sites. For point-counts, we fit seasonal detections functions for 8 species and overall detection functions for 15 species (Tables 3.4). The 5 most common species based on point-counts were meadowlarks (both eastern and western meadowlarks; spring 2008, D = 458.2, CV = 9.51%; summer 2008, D = 89.2, CV = 10.06%; fall 2008, D =96.1, CV = 36.17%; winter 2008–2009, D = 91.9, CV = 20.14%; spring 2009, D = 128.9, CV = 16.10%; summer 2009, D = 62.9, CV = 10.57%), red-winged blackbirds (*Agelaius phoeniceus*; spring 2008, D = 117.2, CV = 17.54 %; summer 2008, D = 182.4, CV = 23.80%; fall 2008, D = 54.3, CV = 48.12%; winter 2008–2009, D = 135.7, CV = 53.02%; spring 2009, D = 227.0, CV = 12.50%; summer 2009, D = 139.4, CV = 16.82%), horned larks (*Eremophila alpestris*; spring 2008, D = 320.4, CV = 16.45 %; summer 2008, D = 117.5, CV = 26.18%; fall 2008, D = 78.5, CV = 32.27%; winter 2008–2009, D = 169.3, CV = 22.04%; spring 2009, D = 36.5, CV = 13.35%; summer 2009, D = 27.5, CV = 21.62%), grasshopper sparrows (*Ammodramus savannarum* ; spring 2008, D = 116.5, CV = 13.42 %; summer 2008, D = 59.8, CV = 17.67%; spring 2009, D = 39.8, CV = 13.14%; summer 2009, D = 33.9, CV = 12.95%), and common grackles (*Quiscalus quiscula*; spring 2008, D = 168.0, CV = 60.68 %; summer 2008, D = 1.9, CV = 44.37%; spring 2009, D = 9.7, CV = 37.19%; summer 2009, D = 15.9, CV = 53.67%).

For line-transects, we fit seasonal detections functions for 9 species and overall detection functions for 20 species (Tables 3.4). The 5 most common species according to density for line-transects were red-winged blackbirds (spring 2008, D = 138.3, CV = 25.74%; summer 2008, D = 178.1, CV = 24.66%; fall 2008, D = 892.3, CV = 45.07%; winter 2008–2009, D = 194.0, CV = 55.38%; spring 2009, D = 81.7, CV = 21.63%; summer 2009, D = 53.2, CV = 19.58%), meadowlarks (spring 2008, D = 379.5, CV = 9.07%; summer 2008, D = 161.9, CV = 10.15%; fall 2008, D = 242.4, CV = 18.86%; winter 2008–2009, D = 105.1, CV = 21.43%; spring 2009, D = 100.2, CV = 9.06%; summer 2009, D = 50.0, CV = 10.57%), horned larks (spring 2008, D = 107.5, CV = 14.05%; summer 2008, D = 99.0, CV = 14.98%; fall 2008, D = 298.1, CV = 0.30%; winter 2008–2009, D = 182.1, CV = 29.83%; spring 2009, D = 43.1, CV = 24.22%; summer 2009, D = 25.5, CV = 15.29%), sandhill cranes (*Grus canadensis*; fall 2008, D = 261.3, CV = 48.47%; winter 2008–2009, D = 83.0, CV = 45.33%), and grasshopper sparrows (spring 2008, D = 106.9, CV = 14.75%; summer 2008, D = 72.3, CV = 12.37%; spring 2009, D = 63.8, CV = 13.07%; summer 2009, D = 19.0, CV = 15.25%).

Density analysis was possible for about a fifth of the species for both point-counts (23 species) and line-transects (29 species; Tables 3.4). We were able to estimate densities for species associated with playa wetland and prairie dog town cover types with line-transect surveys as they were along many of our transects. This allowed us to compare with point-count surveys.

Techniques Comparison

We found that line-transects detected more species (133 species) than point-count surveys (122 species). Our line-transect surveys (*n* = 484; mean = 34.1 min; SD = 11.63) on average took more effort to conduct than our 20-min point-count surveys. We were able to fit seasonal detection functions for both survey techniques for Cassin's sparrow (*Aimophila cassinii*), grasshopper sparrow, horned lark, killdeer (*Charadrius vociferus*), meadowlark spp., mourning dove (*Zenaida macroura*), and red-winged blackbirds. For sandhill cranes we able to fit seasonal detection functions for only line-transects. We found that Cassin's sparrow densities did not differ among techniques for all seasons (Table 3.3). We found that grasshopper sparrows density estimates did not differ among techniques for all seasons except summer 2009 in which point-count estimates were greater (point-count, D = 33.9, CV = 12.95%; line-transect, D = 19.0, CV = 15.25%). We found the density estimates for horned larks did not differ among techniques for all but spring 2008 in which point-count surveys were greater (point-count, D = 320.4, CV = 16.45%; line-transect, D = 107.5, CV = 14.05%). For killdeers, we found that point-count density estimates for summer 2009 were greater than line-transect density estimates (point-count, D = 9.6, CV = 25.36%; line-transect, D = 3.3, CV = 21.43%). For meadowlark spp., we found that line-transect density estimates were greater than point-count density estimates during summer 2008 (point-count, D = 89.2, CV = 10.06%; line-transect, D = 161.9, CV = 10.15%). We found the line-transect density estimates were greater than point-count density estimates for mourning doves during spring 2008 (point-count, D = 25.3, CV = 22.12%; line-transect, D = 71.1, CV = 17.77%), summer 2008 (point-count, D = 39.1, CV = 16.83%; line-transect, D = 88.6, CV = 12.77%), and fall 2008 (point-count, D = 4.4, CV = 29.46%; line-transect, D = 42.3, CV = 36.86%). We found that for red-winged blackbirds point-count densities were greater than point-count density estimates during spring 2009 (point-count, D = 227.0, CV = 12.50%; line-transect, D = 81.7, CV = 21.63%) and summer 2009 (point-count, D = 139.4, CV = 16.82%; line-transect, D = 53.2, CV = 19.58%) but this is likely due to point-count surveys being conducted specifically on playa cover types in 2009. For sandhill cranes we were able to fit seasonal detection function for line-transects but only an overall detection function for point-counts. We found that density estimates were similar for both survey techniques for both fall and winter seasons.

For the 23 species that we were able to calculate density estimates with one overall detection function only 12 species were estimated for both survey types. The species we were able to estimate density using pooled detection functions were barn swallows (*Riparia riparia*), common grackles, common nighthawks (*Chordeiles minor*), dickcissels (*Spiza americana*), eastern meadowlarks, great-tailed grackles (*Quiscalus mexicanus*), lark sparrows (*Chondestes grammacus*), northern bobwhites (*Colinus virginianus*), northern harriers (*Circus cyaneus*), northern mockingbirds (*Mimus polyglottos*), ring-necked pheasants (*Phasianus colchicus*), and western kingbirds (*Tyrannus verticalis*). We found that density estimates for both techniques were similar for barn swallows, common grackles, common nighthawks, great-tailed grackles, larks sparrows, northern mockingbirds, and ring-necked pheasants. We found point-count surveys resulted in greater density estimates for dickcissels in summer 2009 (point-count, D = 24.8, CV = 12.38%; line-transect, D = 9.7, CV = 25.56%) and western kingbirds in spring 2008 (point-count, D = 13.4, CV = 27.10%; line-transect, D = 3.3, CV = 29.30%) and summer 2009 (point-count, D = 23.1, CV = 23.91%; line-transect, D = 6.0, CV = 22.74%). We found line-transects have higher densities for northern bobwhites for summer 2008 (point-count, D = 3.3, CV = 13.89%; line-transect, D = 10.3, CV = 17.50%) and spring 2009 (point-count, D = 0.7, CV = 14.88%; line-transect, D = 3.9, CV = 18.73%) but point-count estimates were higher in fall 2008 (point-count, D = 0.8, CV = 11.40%; line-transect, D = 0.2, CV = 100.42%). We found for northern harriers that line-transect density estimates were greater for winter 2008–2009 (point-count, D = 0.8, CV = 38.66%; line-transect, D = 4.3, CV = 23.24%) but all other seasons were similar.

We were able to calculate density estimates with an overall detection function for 11 species using only one survey technique. For point-counts, we found that those species were American kestrels (*Falco sparverius*), blue-winged teal (*Anas discors*), and sandhill cranes. We found that brown-headed cowbirds (*Molothrus ater*), Canada geese (*Branta canadensis*), cliff swallows, mallards, savannah sparrows, scissor-tailed flycatchers (*Tyrannus forficatus*), Swainson's hawks (*Buteo swainsoni*), and turkey vultures (*Cathartes aura*) density estimates were calculated with an overall detection function for line-transects only.

DISCUSSION

Meadowlarks, red-winged blackbirds, horned larks, and grasshopper sparrows were the most common species at our study sites. Survey methods were similar, in that our line-transects resulted in detection of 133 species and point-count surveys resulted in detections of 122 species. We were able to estimate density for 29 species with line-transects and only 23 with point-counts. We also found that in 12 out of 16 cases, point-counts resulted in higher density estimates than line-transects for at least one season. Fletcher et al. (2000) compared how well point-counts and rope-dragging transects compared in the prairies of the Florida Everglades for non-breeding season birds. They also found that transects resulted in detections of more species but point-counts detected greater numbers of individuals. Similarly, Wilson et al. (2000) found that the use of line-transects detected more species and more individuals than point-counts during spring migration in forested wetlands in the Mississippi Alluvial Valley. We suspect more species of birds we detected along transects because walking along the transect may result in secretive species flushing. We also found, that we were able to obtain density estimates for raptors and winter resident sparrows slightly more often with line-transect surveys (line-transect raptor and winter sparrow species n = 5; point-count raptor and winter sparrow species n = 2), likely for same reason.

We found variation in season and species can play a role in deciding which technique would be better to use. For example, if the study of winter or non-breeding season species was the goal, then line-transects may be the more appropriate survey technique. Time may also influence which survey techniques would be more appropriate as line-transects in general take more effort than point-counts. Fletcher et al. (2000) also found that more secretive bird species and non-breeding season studies benefited from the use of the transect technique over point-counts. Similarly, during migration, Wilson et al. (2000) found more species with line-transects than point-counts. Dobkin and Rich (1998) found no difference between line-transects and point-count during migratory and breeding seasons. These studies occurred in different regions and habitats of the United States along with varying protocols. Our study results indicated that using different survey techniques was important due to species and seasonal differences. Understanding season-specific patterns of grassland bird presences and densities is important for conservation and management, and will facilitate the ability of managers and developers to assess the influences of landscape changes.

With the continued decline of grassland birds, managers need to continue to conduct regional assessments of avian populations. Also, as wind energy development accelerates, pre-construction assessments are needed to identify avian species presence, densities, and priority species that may be more susceptible to disturbance. These assessments will help researchers to assess the potential impacts that wind energy facilities or other human development may have on grassland bird communities in hopes of leading to better mitigation of negative impacts.

MANAGEMENT IMPLICATIONS

Our study examined how 2 survey techniques, point-counts and line-transects, may be best used in the central Texas Panhandle to assess bird species occurrence and abundance. The use of line-transects may maximize the detection of grassland bird species. Additionally, line-transects will likely enhance detection rates of non-breeding birds and secretive species. However, we found that in 12 out of 16 cases, point-counts resulted in higher density estimates than line-transects for at least one season. Further, less effort is required to conduct point-counts; therefore, if researchers are logistically constrained, point-counts may be the better choice. Knowledge of species of interest and seasons that studies are going to be conducted are important when choosing an appropriate survey technique.

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Table 3.1. Avian point-count surveys conducted from April 2008–August 2009 in Gray and Donley counties, Texas. We analyzed data in Distance 6.0 and estimated density with detection functions fitted globally or seasonally.

Species	Records	Detection function (Global/Seasonal) [1]
American kestrel (*Falco sparverius*)	40	Global
barn swallow (*Hirundo rustica*)	54	Global
blue-winged teal (*Anas discors*)	43	Global
Cassin's sparrow (*Aimophila cassinii*)	203	Seasonal
common grackle (*Quiscalus quiscula*)	62	Global
common nighthawk (*Chordeiles minor*)	68	Global
dickcissel (*Spiza americana*)	116	Global
eastern meadowlark[2] (*Sturnella magna*)	66	Global
grasshopper sparrow (*Ammodramus savannarum*)	368	Seasonal
great-tailed grackle (*Quiscalus mexicanus*)	54	Global
horned lark (*Eremophila alpestris*)	445	Seasonal
killdeer (*Charadrius vociferous*)	218	Seasonal
lark sparrow (*Chondestes grammacus*)	118	Global
meadowlark spp.[2] (*Sturnella* spp.)	1199	Seasonal
mourning dove (*Zenaida macroura*)	421	Seasonal
northern bobwhite (*Colinus virginianus*)	119	Global
northern harrier (*Circus cyaneus*)	85	Global
northern mockingbird (*Mimus polyglottos*)	43	Global
red-winged blackbird (*Agelaius phoeniceus*)	915	Seasonal
ring-necked pheasant (*Phasianus colchicus*)	86	Global
sandhill crane (*Grus canadensis*)	121	Global
western kingbird (*Tyrannus verticalis*)	79	Global
western meadowlark[2] (*Sturnella neglecta*)	511	Seasonal

[1] Global detection functions were assigned to data with no seasonal strata to provide density estimates. Seasonal detection functions were fitted to seasonal data if there were enough records in each stratum to provide seasonal density estimates.

[2] Meadowlarks were not separated by species until spring 2009 so analyzed as separate species and as a group (meadowlark spp.).

Table 3.2. Avian line-transect surveys conducted from April 2008–August 2009 in Gray and Donley counties, Texas. We analyzed data in Distance 6.0 and estimated density with detection functions fitted globally or seasonally.

Species	Records	Detection function (Global/Seasonal) [1]
barn swallow (*Hirundo rustica*)	70	Global
brown-headed blackbird (*Molothrus ater*)	42	Global
Canada goose (*Branta canadensis*)	74	Global
Cassin's sparrow (*Aimophila cassinii*)	377	Seasonal
cliff swallow (*Petrochelidon pyrrhonota*)	57	Global
common grackle (*Quiscalus quiscula*)	68	Global
common nighthawk (*Chordeiles minor*)	100	Global
dickcissel (*Spiza americana*)	153	Global
eastern meadowlark[2] (*Sturnella magna*)	75	Global
grasshopper sparrow (Ammodramus savannarum)	660	Seasonal
great-tailed grackle (*Quiscalus mexicanus*)	86	Global
horned lark (*Eremophila alpestris*)	902	Seasonal
killdeer (*Charadrius vociferous*)	303	Seasonal
lark sparrow (*Chondestes grammacus*)	204	Global
longspur spp. (*Calcarius* spp.)	67	Global
mallard (*Anas platyrhynchos*)	74	Global
meadowlark spp.[2] (*Sturnella* spp.)	2044	Seasonal
mourning dove (*Zenaida macroura*)	770	Seasonal
northern bobwhite (*Colinus virginianus*)	191	Global
northern harrier (*Circus cyaneus*)	141	Global
northern mockingbird (*Mimus polyglottos*)	86	Global
red-winged blackbird (*Agelaius phoeniceus*)	1043	Seasonal
ring-necked pheasant (*Phasianus colchicus*)	104	Global
sandhill crane (*Grus canadensis*)	217	Seasonal
savannah sparrow (*Passerculus sandwichensis*)	84	Global
Swainson's hawk (*Buteo swainsoni*)	40	Global
turkey vulture (*Cathartes aura*)	46	Global
western kingbird (*Tyrannus verticalis*)	100	Global
western meadowlark[2] (*Sturnella neglecta*)	585	Seasonal

[1] Seasonal detection functions were fitted if there were enough records in each season; otherwise, a global detection function was fit.

[2] Meadowlarks were not separated by species until spring 2009 and we were not always able to identify to species so analyzed as separate species and as a group (meadowlark spp.).

Table 3.3. Model averaged avian density estimates from point-count and line-transect surveys conducted from April 2008–August 2009 in Gray and Donley counties, Texas.

	2008								2009			
	Spring		Summer		Fall		Winter		Spring		Summer	
Technique[1]	D[2]	CV	D	CV	D	CV	D	CV	D	CV	D	CV
American kestrel												
PC (G)			0.4	38.20	1.2	38.20	1.5	37.98	0.5	38.20	0.3	38.19
Barn swallow												
LT (G)	2.0	50.79	13.2	37.79	11.3	43.90			2.9	36.74	9.7	39.15
PC (G)	1.7	28.12	6.8	32.48	6.1	40.23			5.7	45.32	39.7	36.16
Blue-winged teal												
PC (G)	16.1	69.59	0.9	78.49			0.4	28.21	4.8	44.23	3.3	40.74
Brown-headed cowbird												
LT (G)			707.3	377.81	14.5	88.09	19.6	157.25	3.9	82.96	6.1	77.61
Canada goose												
LT (G)					27.1	94.27	336.1	52.34				
Cassin's sparrow												
LT(S)[2]	50.8	13.47	43.8	15.31	21.9	63.76			13.5	24.36	8.3	35.34
PC (S)	46.7	18.37	26.5	12.70					3.6	54.74	8.2	20.19
Cliff swallow												
LT (G)	1.9	84.49	62.9	32.03	4.8	109.91			5.7	145.09	6.4	54.52
Common grackle												
LT (G)	17.5	45.34	28.5	51.79	1.4	102.32	17.7	58.31	8.3	73.34	9.1	75.81
PC (G)	168.0	60.68	1.9	44.37					9.7	37.19	15.9	53.67
Common nighthawk												
LT (G)	1.5	57.32	10.0	21.40					1.7	32.78	0.9	41.92
PC (G)	1.5	16.43	5.7	14.79	0.1	14.03					0.7	14.03
Dickcissel												
LT (G)	14.4	29.92	12.3	32.94	0.3	100.23			7.8	23.58	9.7	25.56
PC (G)	10.6	17.94	23.1	14.82	0.8	12.24			7.5	19.40	24.8	12.38

Table 3.3. Continued.

	2008								2009			
	Spring		Summer		Fall		Winter		Spring		Summer	
Technique[1]	D[2]	CV	D	CV	D	CV	D	CV	D	CV	D	CV
Eastern meadowlark												
LT (G)									8.0	21.21	5.8	25.53
PC (G)					5.2	35.71			5.0	20.62	6.0	21.82
Grasshopper sparrow												
LT (S)	106.9	14.75	72.3	12.37					63.8	13.07	19.0	15.25
PC (S)	116.5	13.42	59.8	17.67					39.8	13.14	33.9	12.95
Great-tailed grackle												
LT (G)	13.7	42.73	5.9	49.98	0.8	101.90	2.3	65.40	2.5	47.29	5.8	43.29
PC (G)	10.4	54.31	14.6	44.01	5.4	22.01	3.5	34.43	5.8	44.48	37.2	59.70
Horned lark												
LT (S)	107.5	14.05	99.0	14.98	298.1	0.30	182.1	29.83	43.1	24.22	25.5	15.29
PC (S)	320.4	16.45	117.5	26.18	78.5	32.27	169.3	22.04	36.5	13.35	27.5	21.62
Killdeer												
LT (S)	16.1	22.07	17.8	14.92	2.4	54.18			14.9	18.63	3.3	21.43
PC (S)	11.9	24.09	8.5	138.95	7.8	74.37			22.6	19.31	9.6	25.36
Lark sparrow												
LT (G)	32.1	18.63	93.5	17.77	3.8	62.66			9.2	30.44	30.2	27.17
PC (G)	24.0	13.97	49.3	14.05	1.7	35.73			12.1	30.57	27.3	20.61
Longspur spp.												
LT (G)	0.7	70.75			79.4	49.03	211.8	55.26				
Mallard												
LT (G)	5.6	45.10	5.3	53.69	14.5	65.29	0.9	164.88	1.6	45.40	0.1	73.35
Meadowlark spp.[3]												
LT (S)	379.5	9.07	161.9	10.15	242.4	18.86	105.1	21.43	100.2	9.06	50.0	9.16
PC (S)	458.2	9.51	89.2	10.06	96.1	36.17	91.9	20.14	128.9	16.10	62.9	10.57

Table 3.3. Continued

	2008								2009			
	Spring		Summer		Fall		Winter		Spring		Summer	
Technique[1]	D[2]	CV	D	CV	D	CV	D	CV	D	CV	D	CV
Mourning dove												
LT (S)	71.1	17.77	88.6	12.77	42.3	36.86	6.9	40.75	19.3	15.88	16.0	14.25
PC (S)	25.3	22.12	39.1	16.83	4.4	29.46			20.2	21.04	16.7	17.38
Northern bobwhite												
LT (G)	1.1	34.80	10.3	17.50	0.2	100.42	0.2	70.13	3.9	18.73	3.9	16.75
PC (G)			3.3	13.89	0.8	11.40	0.2	11.41	0.7	14.88	2.8	12.10
Northern harrier												
LT (G)	1.9	29.63	0.8	41.26	6.4	25.00	4.3	23.24	0.9	40.34		
PC (G)	0.8	28.33	0.3	34.7	2.1	33.60	0.8	38.66	0.4	33.36		
Northern mockingbird												
LT (G)	2.8	34.15	6.4	28.06	0.2	100.33			2.5	28.43	4.1	24.75
PC (G)	1.3	21.99	2.7	22.20					0.9	22.40	3.6	22.66
Red-winged blackbird												
LT (S)	138.3	25.74	178.1	24.66	892.3	45.07	194.0	55.38	81.7	21.63	53.2	19.58
PC (S)	117.2	17.54	182.4	23.80	54.3	48.12	135.7	53.02	227.0	12.50	139.4	16.82
Ring-necked pheasant												
LT (G)	1.5	35.48	2.4	36.08	11.6	89.01	0.5	49.74	3.0	28.04	2.6	25.04
PC (G)	2.5	25.92	1.6	35.63	0.1	15.49	0.2	15.49	1.7	16.06	1.4	15.52
Sandhill crane												
LT (S)					261.3	48.47	83.0	45.33				
PC (G)	0.6	20.71			22.7	27.95	18.2	38.40	2.3	94.37		
Savannah sparrow												
LT (G)	4.2	80.73			239.4	55.34	15.8	71.64				
Scissor-tailed flycatcher												
LT (G)	2.1	41.52	4.7	46.58					2.2	40.90	2.0	47.29

Table 3.3. Continued

	2008								2009			
	Spring		Summer		Fall		Winter		Spring		Summer	
Technique[1]	D[2]	CV	D	CV	D	CV	D	CV	D	CV	D	CV
Swainson's hawk												
LT (G)	0.4	59.94	2.9	37.86	0.8	66.49			1.0	37.70		
Turkey vulture												
LT (G)	1.1	38.23	1.0	39.72	0.2	60.48			0.3	50.38	0.4	129.35
Western kingbird												
LT (G)	3.3	29.30	5.2	26.12					11.7	20.07	6.0	22.74
PC (G)	13.4	27.10	6.4	36.79					8.1	31.73	23.1	23.91
Western meadowlark												
LT (S)									79.1	8.45	28.2	9.46
PC (S)									79.7	8.89	45.5	9.28

[1] LT = line-transect; PC = point-count; S = density estimates were obtained with detections functions fit to each season; G = density estimates were obtained with one overall detection function.

[2] D =density (birds/km^2); CV= coefficient of variation.

[3] meadowlark spp. = western and eastern meadowlarks were grouped together.

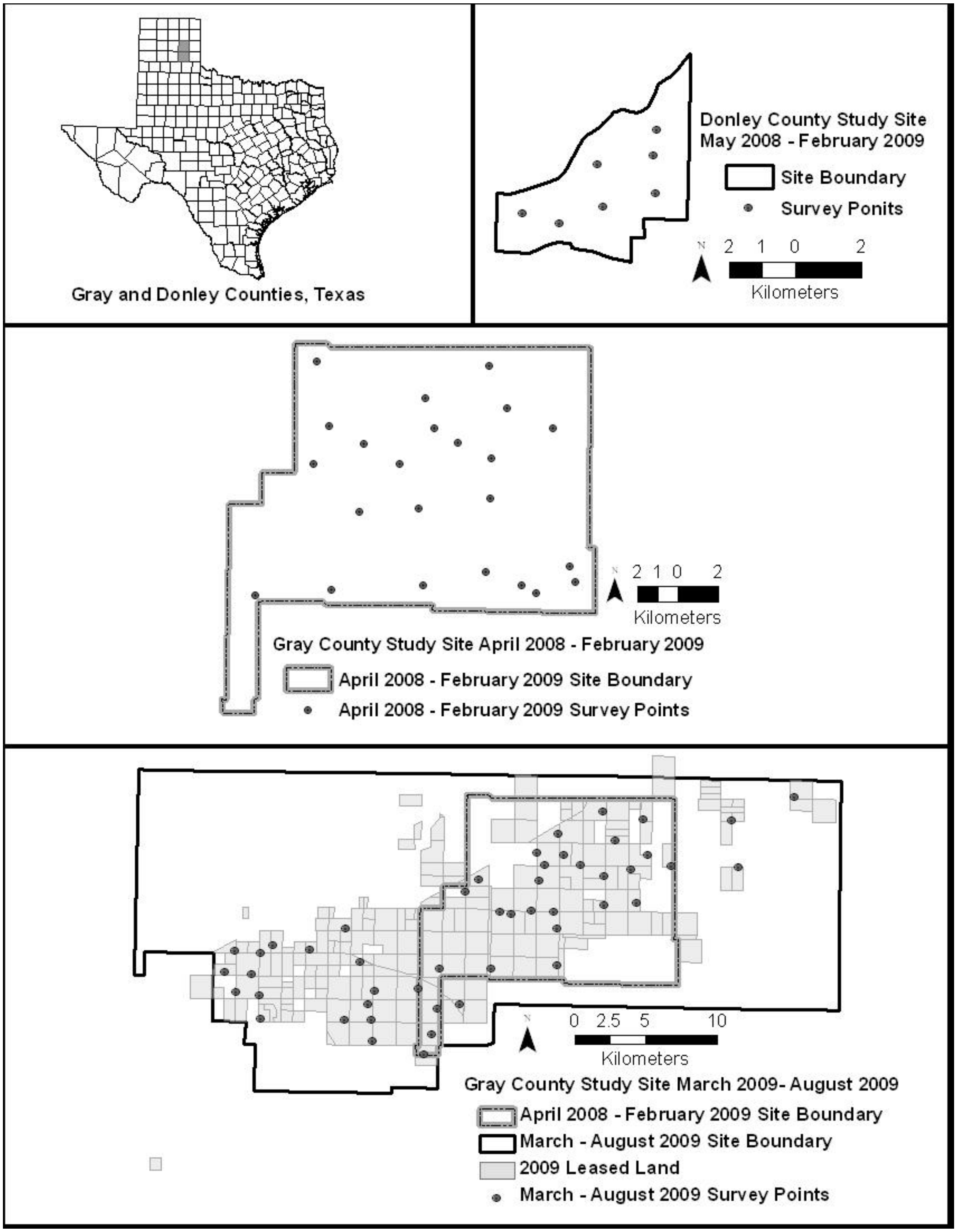

Figure 3.1. Gray and Donley County study sites and avian survey points from April 2008–August 2009.

CHAPTER IV

PATTERNS OF AVIAN DIVERSITY IN THE TEXAS PANHANDLE: IMPLICATIONS FOR WIND ENERGY DEVELOPMENT

ABSTRACT

Wind energy, a fast growing renewable energy source in the United States, is an topic of interest to wildlife managers. Early wind facilities were found to have many bird collision fatalities due to, at least in part, a lack of pre-construction wildlife assessments which resulted in poor placement of turbines and other facilities. Placement of wind facilities in areas of high avian diversity and use can lead to negative impacts on bird species. We surveyed 2 study sites in the Texas panhandle for 1.5 years prior to wind energy development. We stratified our sites into 5 cover types (agriculture, breaks, plateau grasslands, playa wetlands, and prairie dog [*Cynomys ludovicianus*] towns). We calculated Shannon and Simpson's diversity indices for each site, cover type, and season. We found the breaks cover type, which was closest in representing historic native grassland, had the highest avian diversity and plateau grasslands (primarily non-native cover), had the lowest avian diversity. We detected the most avian species in agriculture cover but the lack of nesting habitat in agriculture cover may reduce its importance to conservation of native grassland birds. We observed moderate avian diversity at playa wetlands and prairie dog towns. Diversity indices, often considered indicative of ecosystem health, are an important component in the assessment for placement of wind facilities.

Key Words: agriculture, avian diversity, grassland, playa wetland, prairie dog town, Shannon diversity index, Simpson's diversity index, species richness, Texas, wind energy

INTRODUCTION

Wind energy is a fast growing renewable energy source in the United States, and is thought to be a means to reducing our nation's dependence on oil while inflicting minor impacts on society and the environment (Evans et al. 2009). However, wind energy has gained attention and concern from the public because of aesthetic degradation, noise, and wildlife impacts, particularly bird collision fatalities (National Research Council 2007, Evans et al. 2009). Early wind energy facilities in California were found to result in a large number of bird mortalities, especially raptors (Estep 1989). These collision fatalities led to heightened public concern. Researchers found that poor placement of wind energy facilities was likely the primary reason for the great number of raptor collision fatalities (Estep 1989). Early California wind energy facilities were placed in a high density raptor migration area, in areas with high prey abundance, and along the edges of ridges that many raptors used to hunt (Howe and Noone 1992, Hoover and Morrison 2005). More recent studies have determined that pre-construction assessment can help mitigate wildlife impacts, particularly turbine collisions (National Research Council 2007). Wildlife assessments can identify sites with higher risk species and areas of high use, such as nesting areas and migration paths or stopover sites (National Research Council 2007). A post-construction study in Minnesota found that placement of a wind energy facility in low raptor density areas resulted in no raptor fatalities at that facility (Osborn et al.1998).

Grassland communities are important for over 50% of breeding bird species in the continental United States (Berthelsen and Smith 1995). However, grassland bird populations have been declining for decades and have declined more than any other bird group in North America (Sauer et al. 2008). The most likely causes are loss and degradation of native grasslands and changes in agricultural practices (McCoy et al. 1999, Murphy 2003, Brennan and Kuvlesky 2005). Murphy (2003) reviewed avian population trends in agricultural landscapes of eastern and central United States from 1980–1998. Murphy (2003) concluded that the change in the agricultural landscape, loss of rangeland, and increases of Conservation Reserve Program (CRP) land had negative effects on bird populations. Berthelsen and Smith (1995) and Murphy (2003) found that while CRP land may attract many birds, breeding success in CRP was generally less than required for positive population trajectories.

Though the Southern High Plains of Texas is one of the most intensively cultivated regions in North America**,** there are more than 1.2 million hectares of CRP in the region (Berthelsen and Smith 1995). Berthelsen and Smith (1995) found that CRP may positively affect grassland species such as grasshopper sparrows (*Ammodramus savannarum*), Cassin's sparrows (*Aimophila cassinii*), red-winged blackbirds, and western meadowlarks (*Sturnella neglecta*). However, they suggested that prior to CRP, grassland birds had little nesting habitat primarily limited to the playa wetlands and uncultivated areas (Berthelsen and Smith 1995). Thompson (2003) found that CRP planted with native grasses positively influenced avian species compared to CRP without native grasses. Vickery and Herkert (2001) reviewed grassland bird research and found that grassland bird populations exhibited variable trends across their range. Vickery and Herkert (2001) theorized that the variations were due to habitat patch size, vegetation composition (whether native or CRP), and landscape configuration.

Research has found that pre-construction assessments are key to identifying areas at greater risk of impacts on wildlife (Arnett et al. 2007, National Research Council 2007). Across the United States, laws, regulations, and guidelines for wind energy facilities vary. In Texas, wind energy facilities on private land have no regulations though the State is drafting voluntary guidelines (Boydston 2008). Due to the lack of regulations, few pre-construction wildlife assessments have been conducted (Arnett et al. 2007, National Research Council 2007). The few existing pre-construction studies have been short (<1 year) and few have been peer reviewed (Arnett et al. 2007, National Research Council 2007).

We studied avian diversity and species richness at 2 Texas Panhandle study sites prior to wind energy development. Diversity indices incorporate species richness and relative abundance into their measures (Magurran 1988). Thus, many suggest high diversity is an indication that an ecosystem is healthy while low diversity suggests a disturbed ecosystem (Magurran 1988). Our goal was to identify areas of high avian species diversity where wind facility placement might have greater negative impacts relative to other cover types.

STUDY AREA

We conducted research on 2 sites in Gray and Donley counties, Texas, USA. Both study areas are part of the Llano Estacado Plateau and surrounding escarpments.

The Llano Estacado Plateau is the largest plateau in North America (82,000 km^2; Smith 2003). Land use on the Plateau was a mixture of agriculture, CRP, and oil and natural gas production. Natural land cover was primarily short-grass prairie and playa wetlands (United States Forest Service [USFS] 1994, The United Nations University [UNU] Press 1995). The Plateau is surrounded by relatively abrupt escarpments (breaks) ranging from 50–200 m in height (USFS 1994, UNU 1995). The breaks were primarily used for rangeland and oil and natural gas production (USFS 1994, UNU 1995).

Gray County Site

We conducted research at the Gray County site from April 2008–August 2009 (Fig. 4.1). We sampled the avian community on a 219 km^2 area during April 2008–February 2009. We expanded the Gray County site to 303 km^2 during March 2009–August 2009 because the wind energy company increased the land area leased for its future wind energy facility. The Gray County site consisted of 2 general habitat types: uplands and breaks. The upland area (132 km^2 during Apr 2008–Feb 2009; 170 km^2 during Mar 2009–Aug 2009) was located on top of the Caprock of the Llano Estacado Plateau which was a mostly flat landscape that included cropland, pasture, playas, and CRP and other grasslands(Smith 2003). Common crops were corn, cotton, and winter wheat. The playas are shallow depressional recharge wetlands and some of the highest playa densities are located in the Southern High Plains (average 1 per 2.6 km^2; Smith 2003). These playas provided habitat for both waterfowl and shorebirds throughout the year (Smith 2003). The uplands portion of the Gray County site contained 2 cattle feedlots and a dairy operation. Trees were found primarily around human structures and the most common tree was cottonwood (*Populus* spp.).

The breaks habitat type (87 km^2 during Apr 2008–Feb 2009; 133 km^2 during Mar 2009–Aug 2009) was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie. There were few water bodies limited to water tanks for cattle and ephemeral creeks. This area was also used for oil and natural gas extraction and had an extensive infrastructure of roads, oil wells, and other structures. Some trees, primarily cottonwood, were found within the breaks where deeper ravines hold water. Prominent grasses include buffalo grass (*Buchloe dactyoids*), blue grama (*Bouteloua gracilis*), and other gramas (*Bouteloua* sp.; National Resources Conservation Service [NRCS] 2006).

Donley County Site

We conducted research at the Donley County Site (19 km^2) during May 2008–February 2009 (Fig. 4.1). We stopped surveys after February 2009 when the wind energy company changed focus of wind development to include only the Gray County site. This site consisted of breaks and was dominated by honey mesquite (*Prosopis glandulosa*). Other trees or brush occurred throughout the site on ridge tops and drainages, which were spring fed throughout the year. Primary grasses were buffalo grass and gramas (NRCS 2006). This study area was used for rangeland with no oil or natural gas production on site.

METHODS

Random Points

We selected 30 random points and conducted surveys from those points during April 2008–February 2009. We ensured that points were spaced $\geq$800 m apart. There were 23 points on the Gray County study area and 7 on the Donley County study area (Fig. 4.1). For the expanded Gray County study area we randomly selected an additional 34 points (49 total points used; 8 of the original 23 points were removed due to land access issues; Fig. 4.1) and conducted surveys from those points during March 2009–August 2009. We proportionally allocated points across cover types to ensure that all cover types were represented in the sample. We classified cover as agriculture, breaks, plateau grasslands, playa wetlands, and prairie dog (*Cynomys ludovicianus*) towns. Our breaks cover type was a broken landscape of gully washes and ravines, composed mostly of short-grass prairie located off the plateau. Also, our plateau grassland cover type was broadly defined as grasslands located on the plateau which included CRP, pasture, and other grasslands. Points were not placed within 400 m of cover edges to avoid overlap into other cover types. On the Gray County site there were 3 highways (US Highway 60, State Highway 152, and State Highway 273). The Donley County study site was bordered on the North by I-40. Points were placed ≥400 m from highways to avoid traffic noise.

Surveys

We conducted surveys from 0.25 hr before sunrise until about 10:30 am or 3 hrs after sunrise when diurnally active birds were most active and vocal (Diefenbach et al. 2003). We conducted each point survey for 20 min with surveys divided into 2 10-min intervals. We used a weather meter (Kestrel 2000 Pocket Weather Meter, Nielsen-Kellerman, Boothwyn, PA) to measure wind speed and temperature. We did not conduct surveys if average wind speed was >32 km/hr or in severe weather, such as thunderstorms because of reduced audibility and activity of birds (Diefenbach et al. 2003).

We conducted surveys during 4 seasons with up to 3 samples per season. We defined seasons as winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug), and fall (Sep–Nov). The point-counts at playas and prairie dog towns were surveyed twice a month, similar to other point surveys. We rotated the time of morning in which samples were monitored at each site to avoid bias from reduced bird activity during late morning.

Diversity

We stratified the study sites into 5 cover types (agricultural, breaks, plateau grasslands, playa wetland, and prairie dog town). We calculated diversity indices for each cover type by season. We estimated the Shannon and Simpson's diversity indices. Both indices are based on species richness and evenness (Magurran 1988).

The Shannon diversity index assumes individuals were randomly sampled from an indefinitely large population and that all species are represented in the sample (Magurran 1988). This index is moderately sensitive to sample size with species richness more dominant than evenness (Magurran 1988). We used the natural log in the Shannon diversity index as commonly used according to Magurren (1988). We conducted *t*-tests to compare Shannon diversity indices among the cover types and our two study sites using the critical *p*-value of 0.05. Although the Shannon diversity index takes evenness into account, we also examined species evenness using the Shannon evenness index.

The Simpson's index, unlike the Shannon index, has low sensitivity to sample size and is weighted more towards the abundance of the most common species (Magurran

1988). Since the Simpson's index (D) has an inverse relationship with diversity we transformed the index (D_S = 1 - D) (Table 4.1). We also compared study sites and cover types for the Simpson's diversity indices using *t*-tests with the critical *p*-value of 0.05 (Brower et al. 1998).

RESULTS

We observed 163 avian species (134 on the Gray County site and 39 on the Donley County site). We found 95 species on agriculture cover, 79 on breaks, 86 on plateau grasslands, 81 on playa wetlands, and 43 on prairie dog towns. The Shannon diversity index on the Gray County study site (H'= 2.89) was higher than on the Donley County site (H' = 2.65; t = 5.32, df = 781.8, P < 0.001; Table 4.1 and 4.2). The Simpson's diversity index on the Gray County site (D_S = 0.875) and the Donley County site (D_S =0.889) were different (t = 2.26, df = 785.9, P = 0.02).

We found breaks had the highest diversity (H' = 2.96; D_S = 0.891) followed by agriculture (H' = 2.72; D_S = 0.887), playa wetlands (H' =2.45; D_S = 0.801), prairie dog towns (H' = 2.37; D_S = 0.808), and plateau grasslands (H' = 2.19; D_S = 0.741; Table 4.1). Our analyses indicated that Shannon diversity index differed among all cover types (P < 0.001) except playa wetlands and prairie dog towns (t =1.81, df = 2292.2, P = 0.07; Table 4.2). We also found playa wetlands and prairie dog towns were similar based on the Simpson's index (t = 0.07, df = 2283.3, P = 0.94). Additionally, agriculture and breaks cover types were similar based on the Simpson's index (t = 0.96, df = 4532.6, P = 0.34; Table 4.2)

We found breaks contained the most even (E= 0.68) avian community. We found that plateau grasslands were the most uneven (E = 0.49). The most common species for breaks were meadowlark spp. (*Sturnella* spp.), mourning doves (*Zenaida macroura*), and horned larks (*Eremophila alpestris*). We found that the most common species for agriculture were red-winged blackbirds, sandhill cranes (*Grus canadensis*), Canada geese (*Branta canadensis*), and meadowlarks. For playa wetlands we found that red-winged blackbirds, great-tailed grackles (*Quiscalus mexicanus*), northern shovelers (*Anas clypeata*), and blue-wing teals (*Anas discors*) were the dominant species. We found red-winged blackbirds and meadowlarks were the common species for prairie dog towns. Finally, for plateau grasslands we found that red-winged blackbirds, sandhill cranes, Canada geese, meadowlarks, and European starlings (*Sturnus vulgaris*) were the dominant species.

We found that 29 species were found in all cover types. Those species were bank swallows (*Riparia riparia*), barn swallows (*Hirundo rustica*), Cassin's sparrows, clay-colored sparrows (*Spizella pallida*), cliff swallows (*Petrochelidon pyrrhonota*), dickcissels (*Spiza americana*), European collared-doves (*Streptopelia decaocto*), grasshopper sparrows, horned larks, killdeers (*Charadrius vociferus*), lark buntings (*Calamospiza melanocorys*), lark sparrows (*Chondestes grammacus*), mallards (*Anas platyrhynchos*), meadowlarks, mourning doves, northern bobwhites (*Colinus virginianus*), northern harriers (*Circus cyaneus*), northern mocking birds (*Mimus polyglottos*), northern rough-winged swallows (*Stelgidopteryx serripennis*), red-winged blackbirds, ring-necked pheasants (*Phasianus colchicus*), sandhill cranes, scissor-tailed flycatchers (*Tyrannus forficatus*), song sparrows (*Melospiza melodia*), turkey vultures

(*Cathartes aura*), western kingbirds (*Tyrannus verticalis*), and white-crowned sparrows (*Zonotrichia leucophrys*). We also found 38 species that were only found in one cover type. Many were rare species that were only observed once such as the American redstart (*Setophaga ruticilla*). We observed burrowing owls (*Athene cunicularia*) were only associated with the prairie dog town cover type. We had 15 species that were only found in playa wetlands and they were primarily shorebird and waterfowl species such as long-billed dowitchers (*Limnodromus scolopaceus*) and American wigeons (*Anas americana*).

Seasonal diversity for each cover type was quite variable (Table 4.1). We found that agriculture (H' = 1.93) had lower diversity than breaks (H' = 2.38) in winter (t = 7.37, df = 396.7, P = <0.001) with the Shannon index. We found that agriculture had lower diversity summer (agriculture D_S = 0.871; breaks D_S = 0.888; t = 2.90, df = 3,254.6, P = 0.004), fall (agriculture D_S = 0.799; breaks D_S = 0.838; t = 3.42, df = 940.1, P = <0.001), and winter (agriculture D_S = 0.783; breaks D_S = 0.863; t = 8.69, df = 436.8, P = <0.001) with the Simpson's index (Table 4.2). We found agriculture was higher in avian diversity from plateau grasslands except for summer (agriculture H' = 2.61, D_S = 0.871; plateau grasslands H' = 2.65, D_S = 0.858) with both the Shannon (t = 0.95, df = 3,736.2, P = 0.341) and Simpson's indices (t = 1.82, df = 3,674.5, P = 0.069; Table 4.2). We found agriculture was lower from playa wetlands in spring (agriculture H' = 2.58, D_S = 0.843; playa wetlands H' = 2.80, D_S = 0.898; t = 6.62, df = 6,108.5, P = <0.001) and higher in the summer (agriculture H' = 2.61, D_S = 0.871; playa wetlands H' = 1.47, D_S = 0.594; t = 38.75, df = 7,656.1, P = <0.001; Table 4.2). We found that agriculture (H' = 2.58, D_S = 0.843) higher than prairie dog towns (H' = 2.01, D_S = 0.739) in spring with the

Shannon (*t* = 10.80, df = 1,962.1, *P* = <0.001) and Simpson's (*t* = 8.41, df = 1,538.9, *P* = <0.001) indices (Table 4.2). We found the breaks cover in summer (H' = 2.66, D_S = 0.888) was similar with plateau grasslands in the summer (H' = 2.65) with Shannon index (*t* = 0.23, df = 3,340.1, *P* = 0.818), and prairie dog towns in the summer (H' = 2.71, D_S = 0.898) with the Shannon (*t* = 0.91, df = 1,104.0, *P* = 0.361) and Simpson's (*t* = 1.30, df = 1,077.5, *P* = 0.193) indices (Table 4.2). We found that plateau grasslands (H' = 1.54, D_S = 0.528) were lower than playa wetlands (H' = 2.80, D_S = 0.898) in spring (Shannon *t* = 36.45, df = 6,839.0, *P* = <0.001; Simpson's *t* = 37.81, df = 4,319.5, *P* = <0.001) and plateau grasslands (H' = 2.65, D_S = 0.858) were higher than playa wetlands (H' = 1.47, D_S = 0.594) in summer (Shannon *t* = 30.93, df = 4,129.1, *P* = <0.001; Simpson's *t* = 31.12 df = 6,165.7, *P* = <0.001; Table 4.2). We found that plateau grasslands (H' = 1.54, D_S = 0.528) were lower than prairie dog towns (H' = 2.01, D_S = 0.739) in spring (Shannon *t* = 8.73, df = 2,140.1, *P* = <0.001; Simpson's *t* = 14.14, df = 2,840.1, *P* = <0.001) and that plateau grasslands (H' = 2.65, D_S = 0.858) were lower than prairie dog towns (H' = 2.71, D_S = 0.898) in summer (Shannon *t* = 24.28, df = 1,107.0, *P* = <0.001; Simpson's *t* = 4.52, df = 1,530.1, *P* = <0.001; Table 4.2). We found that playa wetlands (H' = 2.80, D_S = 0.898) higher than prairie dog towns (H' = 2.01, D_S = 0.739) in spring (Shannon *t* = 16.06, df = 1,496.1, *P* = <0.001; Simpson's *t* = 13.71, df = 1,188.4, *P* = <0.001; Table 4.2). Also, we found that playa wetlands (H' = 1.47, D_S = 0.594) lower than prairie dog towns (H' = 2.71, D_S = 0.898) in summer (Shannon *t* = 24.28, df = 794.8, *P* = <0.001; Simpson's *t* = 33.97, df = 1,685.8, *P* = <0.001; Table 4.2).

DISCUSSION

The breaks cover type was the closest to the native grasslands that historically occurred in the Texas Panhandle and as expected this cover type had the highest avian diversity. The breaks cover type did not have the highest number of species but it had the greatest evenness. The influence of species eveness in diversity calculations allowed the breaks cover type to have the greatest diversity index even though it did not have the greatest number of species relative to our other cover types. In other words, having high evenness means that abundance among species is closer to equal and there is less dominance by few species. Wiens (1974) looked at avian diversity in the Texas Panhandle during June in areas with heavy grazing and no grazing. He found that diversity in ungrazed ($H = 0.95$) grasslands was greater than heavily grazed grasslands ($H = 0.74$). Our diversity in the breaks cover types during the same period are much higher but this may be due to longer survey periods not just one month of a year. We likely observed more species and greater numbers with multiple month surveys.

The agriculture cover type showed the second greatest diversity, possibly due to an abundance of food sources. Because few species nest in croplands, this cover type likely has less positive impacts on populations (Berthelsen and Smith 1995). Playa wetland and prairie dog town cover types had moderate diversity among the cover types in our study. Playa wetlands and prairie dog towns both had some fairly dominant species reducing their evenness. They also had only moderate species richness but both cover types were surveyed as often as the others. They both provide nesting habitat and had a fair number of species (playa wetland, $n = 81$; prairie dog town, $n = 43$). Prairie dog towns had a fair number of species dependent upon that cover type, such as burrowing owls (*Athene cunicularia*) which use abandoned prairie dog burrows for nesting (Seyffert 2001). Playa wetlands support many wetland dependent species including many migrating shorebirds (Davis and Smith 1998). Also, Playa wetlands are one of the few cover types that provide nesting habitat for birds in the Texas Panhandle as the native grasslands have given way to agriculture (Berthelsen and Smith 1995).

We found the lowest diversity in the plateau grassland cover type. This was similar to what others have found. In Missouri, McCoy et al. (1999) found evidence that CRP likely contributed to the conservation of grasshopper sparrows, field sparrows (*Spizella pusilla*), and eastern meadowlarks (*Sturnella magna*) but not dickcissels and red-winged blackbirds. However, the most common species recorded on plateau grasslands during our study was red-winged blackbirds. The plateau grasslands generally contain the largest portions of playa wetlands on our study sites suggesting the cover type should be more diverse. The CRP, part of the plateau grassland cover type, in our study area was generally composed of exotic monocultures of grass with some areas containing exotic mixes which could possibly affect avian diversity. Grassland species in this region may not be adapted to the exotic grass mixes of CRP and may not be able to use those grasses as well as native grasses. Thompson (2003) examined how CRP seeded with native grasses influenced the avian community compared to CRP with non-native grasses. He found diversity was generally greater for native seeded CRP land for both breeding ($H = 0.52 \pm 0.07$; $D = 0.52 \pm 0.04$; diversity index $\pm$ SE) and winter ($H = 1.08 \pm 0.06$; $D = 0.41 \pm 0.02$; diversity index $\pm$ SE) seasons than for non-native seeded CRP during breeding (H = 0.76 $\pm$ 0.07; D = 0.59 $\pm$ 0.04; diversity index $\pm$ SE) and winter (H = 0.59 $\pm$ 0.10; D = 0.57 $\pm$ 0.08; diversity index $\pm$ SE) seasons. Our study had higher diversity in all plateau grasslands, including CRP grassland, during breeding seasons with Shannon index and during winter with Simpson's index (Table 4.1) than the Thompson et al. (2009) study. However, with Shannon's index we had similar diversity indices with winter and with Simpson's index we had similar breeding season diversity (Table 4.1) to the Thompson et al. (2009) study.

MANAGEMENT IMPLICATIONS

Our 5 cover types had varying avian diversities with breaks being the highest. Breaks along with playa wetland cover types provide good nesting habitat for native grassland birds (Berthelsen and Smith 1995). Based on diversity, species richness, and occurrence of habitat specialists, we recommend wind energy developers avoid construction of wind energy facilities on the breaks, playa wetlands, and prairie dog town cover types. Breaks, playa wetlands, and prairie dog town cover types provide habitat to unique segments of the avian community in this region such as declining grassland bird and shorebird populations (Smith 2003, Brennan and Kuvlesky 2005). The plateau grassland cover type should be an important cover type for the grassland avian community but the use of non-native grass mixes has likely reduce its value. Further study is needed to determine the effectiveness of CRP for the conservation of the grassland bird community. Finally, agriculture showed fairly high diversity but provided little nesting habitat (Berthelsen and Smith 1995). Further study of how cover types are used and how they contribute to conservation of species is needed. Also, identification of any high priority species that may use specific cover types is important for mitigating impacts from a wind energy development.

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Table 4.1. Diversity and evenness by study sites and cover types. Indices based on point-counts conducted during April 2008–August 2009 in Gray and Donley counties, Texas.

	S[1]	N	H’	H’E	D_S
Gray County[2]					
Total	134	48,989	2.89	0.59	0.875
Donley County					
Total	39	740	2.65	0.72	0.889
Agriculture					
Total	95	19,442	2.72	0.60	0.887
Spring	67	3,257	2.58	0.61	0.843
Summer	47	2,760	2.61	0.68	0.871
Fall	49	5,148	2.29	0.59	0.799
Winter	41	8,277	1.93	0.52	0.783
Breaks					
Total	79	3,757	2.96	0.68	0.891
Spring	51	1,343	2.64	0.67	0.850
Summer	45	1,407	2.66	0.70	0.888
Fall	36	647	2.39	0.67	0.838
Winter	27	360	2.38	0.72	0.863
Plateau grasslands					
Total	86	13,812	2.19	0.49	0.740
Spring	57	3,966	1.54	0.38	0.528
Summer	51	2,106	2.65	0.67	0.858
Fall	32	4,443	1.62	0.47	0.697
Winter	29	3,297	1.76	0.52	0.769
Playa wetland					
Total	81	11,054	2.45	0.56	0.808
Spring	72	5,304	2.80	0.65	0.898
Summer	48	5,750	1.47	0.38	0.594

Table 4.1. Continued.

	S[1]	N	H'	H'E	D_S
Prairie dog town					
Total	43	1,664	2.37	0.63	0.808
Spring	31	1,118	2.01	0.59	0.739
Summer	32	546	2.71	0.78	0.898

[1]S= number of species (western and eastern meadowlarks were combined in the diversity indices); N= number of individuals; H'= Shannon Index; H' E= Shannon evenness; D_S = 1 – Simpson's Index (transformed so relationship is not inverse).

[2] Gray County = individuals from the Gray County study site for point-counts from April 2008–August 2009; Donley County = individuals from the Donley County study site for point-counts from May 2008–February 2009; Breaks = breaks habitat from both Donley County and Gray County study sites from April 2008–August 2009; Agriculture = cropland habitat from April 2008–August; plateau grasslands = Conservation Reserve Program land, pasture, and other grasslands from April 2008–August; Playa wetland = playa wetlands from March 2009–August 2009; Prairie dog town = prairie dog town from March 2009–August 2009.

Table 4.2. Comparison of diversity indices with *t*-tests for study sites and cover types by season from April 2008–2009 in Gray and Donley counties, Texas.

Analysis[1]/Season	Shannon Index			Simpson's Index		
	t	df	*P*	*t*	df	*P*
Gray –Donley						
total	5.32	781.8	<0.001	2.26	785.9	0.024
spring	12.86	216.0	<0.001	0.71	206.1	0.481
summer	2.67	333.9	0.008	4.44	333.6	<0.001
fall	3.15	145.9	0.002	2.18	142.5	0.031
winter	1.25	114.0	0.214	0.03	112.9	0.979
Agriculture – Breaks						
total	9.48	5,167.6	<0.001	0.96	4,532.6	0.339
spring	1.14	2,667.4	0.255	0.76	2,365.9	0.449
summer	1.21	2,545.4	0.227	2.90	3,254.6	0.004
fall	1.67	864.6	0.095	3.42	940.1	<0.001
winter	7.37	396.7	<0.001	8.69	436.8	<0.001
Agriculture - Plateau grasslands						
total	29.67	25,488.4	<0.001	38.62	16,524.7	<0.001
spring	26.15	7,221.4	<0.001	29.39	5,797.4	<0.001
summer	0.95	3,736.2	0.341	1.82	3,674.5	0.069
fall	24.19	9,590.8	<0.001	14.21	9,338.9	<0.001
winter	6.86	6,594.1	<0.001	2.98	7,395.5	0.003
Agriculture - Playa wetlands						
total	14.73	20,108.7	<0.001	23.16	13,807.9	<0.001
spring	6.62	6,108.5	<0.001	10.40	4,400.6	<0.001
summer	38.75	7,656.1	<0.001	39.03	8,450.6	<0.001
Agriculture - Prairie dog towns						
total	8.99	1,914.2	<0.001	10.05	1,735.6	<0.001
spring	10.80	1,962.1	<0.001	8.41	1,538.9	<0.001
summer	1.93	772.0	0.054	3.60	936.9	<0.001
Breaks - Plateau grasslands						
total	27.65	6,950.0	<0.001	29.46	11,947.6	<0.001
spring	22.39	2,951.7	<0.001	25.78	4,666.9	<0.001
summer	0.23	3,340.1	0.818	3.99	3,492.2	<0.001
fall	14.01	834.8	<0.001	11.97	1,002.1	<0.001
winter	9.75	438.5	<0.001	9.87	490.3	<0.001

Table 4.2. Continued.

Analysis[1]/Season	Shannon Index			Simpson's Index		
	t	df	*P*	*t*	df	*P*
Breaks - Playa wetlands						
total	18.19	7,207.6	<0.001	17.17	10,079.3	<0.001
spring	3.73	1,957.7	<0.001	5.72	1,515.4	<0.001
summer	30.69	2,754.0	<0.001	39.12	6,092.4	<0.001
Breaks - Prairie dog towns						
total	13.39	3,088.2	<0.001	9.64	2,404.6	<0.001
spring	10.41	2,329.3	<0.001	7.98	2,075.9	<0.001
summer	0.91	1,104.0	0.361	1.30	1,077.5	0.193
Plateau grasslands - Playa wetlands						
total	12.01	24,239.5	<0.001	13.85	24,865.9	<0.001
spring	36.45	6,839.0	<0.001	37.81	4,319.5	<0.001
summer	30.93	4,129.1	<0.001	31.12	6,165.7	<0.001
Plateau grasslands - Prairie dog towns						
total	4.65	2,232.2	<0.001	7.93	2,456.6	<0.001
spring	8.73	2,140.1	<0.001	14.14	2,840.1	<0.001
summer	24.28	1,107.0	<0.001	4.52	1,530.1	<0.001
Playa wetlands - Prairie dog towns						
total	1.81	2,292.2	0.071	0.07	2,283.3	0.943
spring	16.06	1,496.1	<0.001	13.71	1,188.4	<0.001
summer	24.28	794.8	<0.001	33.97	1,685.8	<0.001

[1] Gray County = individuals from the Gray County study site for point-counts from April 2008–August 2009; Donley County = individuals from the Donley County study site for point-counts from May 2008–February 2009; Breaks = breaks habitat from both Donley County and Gray County study sites from April 2008–August 2009; Agriculture = cropland habitat from April 2008–August; plateau grasslands = Conservation Reserve Program land, pasture, and other grasslands from April 2008–August; Playa wetland = playa wetlands from March 2009–August 2009; Prairie dog town = prairie dog town from March 2009–August 2009.

Texas Tech University, Sarah Wulff, December 2010

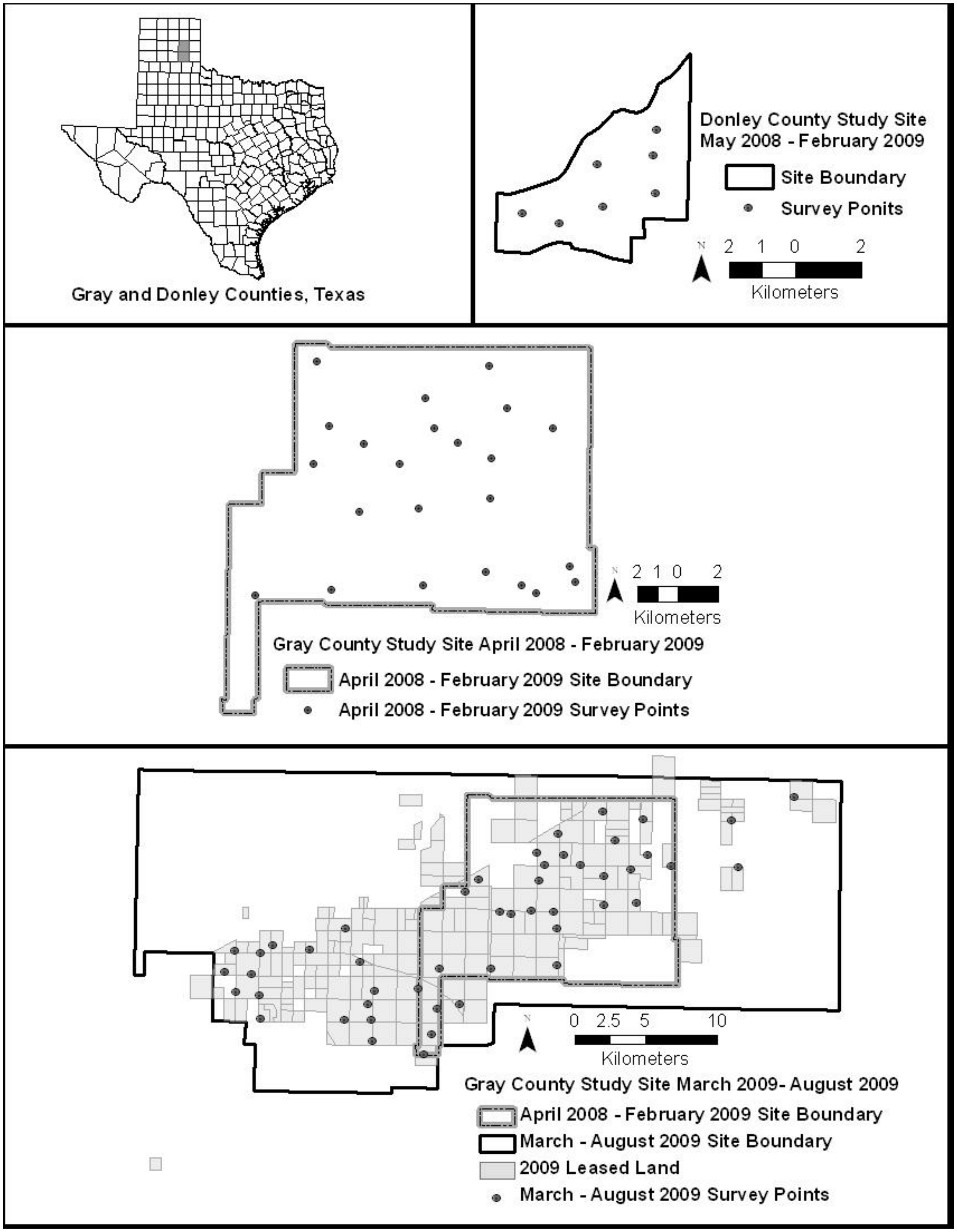

Figure 4.1. Gray and Donley County study sites and avian survey points from April 2008–August 2009.

APPENDIX A

STUDY AREA SPECIES LIST AND TEXAS HIGH PLAINS PRIORITY SPECIES LIST

Table A.1. List of avian species and their conservation status observed during point-counts or line-transects at Gray County and Donley County study sites between April 2008 and August 2009.

		Status		
Species	Scientific Name	Priority[1]	Federal	State
American avocet	*Recurvirostra Americana*	Medium	SC	SC
American coot	*Fulica americana*			
American crow	*Corvus brachyrhynchos*			
American goldfinch	*Carduelis tristis*			
American kestrel	*Falco sparverius*			
American pipit	*Anthus rubescens*			
American redstart	*Setophaga ruticilla*			
American robin	*Turdus migratorius*			
American wigeon	*Anas americana*			
American white pelican	*Pelecanus erythrorhynchos*	Low	SC	SC
bald eagle	*Haliaeetus leucocephalus*	Medium	FT	ST
bank swallow	*Riparia riparia*			
barn swallow	*Hirundo rustica*			
Bewick's wren	*Thryomanes bewickii*			
Baird's sandpiper	*Calidris bairdii*			
black-bellied plover	*Pluvialis squatarola*			
black-crowned night-heron	*Nycticorax nycticorax*			
black-necked stilt	*Himantopus mexicanus*	Low	SC	SC
black-throated green warbler	*Dendroica virens*			
black-throated sparrow	*Amphispiza bilineata*	Low	SC	SC
blue-gray gnatcatcher	*Polioptila caerulea*			
blue grosbeak	*Passerina caerulea*			
blue jay	*Cyanocitta cristata*			
blue-winged teal	*Anas discors*			

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
bobolink	*Dolichonyx oryzivorus*			
Brewer's blackbird	*Euphagus cyanocephalus*			
Brewer's sparrow	*Spizella breweri*	Low	SC	SC
brown-headed cowbird	*Molothrus ater*			
bufflehead	*Bucephala albeola*			
Bullock's oriole	*Icterus bullockii*			
burrowing owl	*Athene cunicularia*	High	SC	SC
Canada goose	*Branta canadensis*			
Cassin's sparrow	*Aimophila cassinii*	Medium	SC	SC
cattle egret	*Bubulcus ibis*			
chestnut-collared longspur	*Calcarius ornatus*			
Chihuahuan raven	*Corvus cryptoleucus*			
chimney swift	*Chaetura pelagic*	Low	SC	SC
chipping sparrow	*Spizella passerina*			
cinnamon teal	*Anas cyanoptera*			
clay-colored sparrow	*Spizella pallida*			
cliff swallow	*Petrochelidon pyrrhonota*			
common goldeneye	*Bucephala clangula*			
common grackle	*Quiscalus quiscula*			
common nighthawk	*Chordeiles minor*	Low	SC	SC
common snipe (also Wilson's snipe)	*Gallinago gallinago*	Low	SC	SC
Cooper's hawk	*Accipiter cooperii*			
curve-billed thrasher	*Toxostoma curvirostre*	Low	SC	SC
dark-eyed junco	*Junco hyemalis*			
dickcissel	*Spiza Americana*	Low	SC	SC

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
double-crested cormorant	*Phalacrocorax auritus*			
dunlin	*Calidris alpina*			
eastern bluebird	*Sialia sialis*			
eastern kingbird	*Tyrannus tyrannus*	Low	SC	SC
eastern meadowlark	*Sturnella magna*	High	SC	SC
eastern phoebe	*Sayornis phoebe*			
eastern screech-owl	*Otus asio*			
Eurasian collared-dove	*Streptopelia decaocto*			
European starling	*Sturnus vulgaris*			
ferruginous hawk	*Buteo regalis*	High	SC	SC
field sparrow	*Spizella pusilla*	Low	SC	SC
Franklin's gull	*Larus pipixcan*			
gadwall	*Anas strepera*			
golden eagle	*Aquila chrysaetos*			
grasshopper sparrow	*Ammodramus savannarum*	Low	SC	SC
gray catbird	*Dumetella carolinensis*			
great blue heron	*Ardea herodias*			
great crested flycatcher	*Myiarchus crinitus*	Low	SC	SC
great egret	*Ardea alba*			
greater roadrunner	*Geococcyx californianus*			
greater scaup	*Aythya marila*			
greater yellowlegs	*Tringa melanoleuca*	Low	SC	SC
greater white-fronted goose	*Anser albifrons*			
great horned owl	*Bubo virginianus*			
great-tailed grackle	*Quiscalus mexicanus*			

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
green-winged teal	*Anas crecca*			
horned lark	*Eremophila alpestris*	Medium	SC	SC
house finch	*Carpodacus mexicanus*			
house sparrow	*Passer domesticus*			
indigo bunting	*Passerina cyanea*			
killdeer	*Charadrius vociferus*			
ladder-backed woodpecker	*Picoides scalaris*	Low	SC	SC
lapland longspur	*Calcarius lapponicus*			
lark bunting	*Calamospiza melanocorys*			
lark sparrow	*Chondestes grammacus*	Low	SC	SC
lazuli bunting	*Passerina amoena*			
least flycatcher	*Empidonax minimus*			
least sandpiper	*Calidris minutilla*			
lesser scaup	*Aythya affinis*	Medium	SC	SC
lesser yellowlegs	*Tringa flavipes*	Low	SC	SC
Lincoln's sparrow	*Melospiza lincolnii*			
loggerhead shrike	*Lanius ludovicianus*	Medium	SC	SC
long-billed curlew	*Numenius americanus*	High	SC	SC
long-billed dowitcher	*Limnodromus scolopaceus*			
mallard	*Anas platyrhynchos*			
marbled godwit	*Limosa fedoa*	Low	SC	SC
McCown's longspur	*Calcarius mccownii*	Low	SC	SC
merlin	*Falco columbarius*			
Mississippi kite	*Ictinia mississippiensis*	Low	SC	SC
mountain bluebird	*Sialia currucoides*			

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
mourning dove	*Zenaida macroura*			
Nashville warbler	*Vermivora ruficapilla*			
northern bobwhite	*Colinus virginianus*			
northern cardinal	*Cardinalis cardinalis*			
northern flicker	*Colaptes auratus*			
northern harrier	*Cirus cyaneus*	High	SC	SC
northern mockingbird	*Mimus polyglottos*			
northern parula	*Parula americana*			
northern pintail	*Anas acuta*	High	FE	SE
northern rough-winged swallow	*Stelgidopteryx serripennis*			
northern shoveler	*Anas clypeata*			
olive-sided flycatcher	*Contopus cooperi*			
orange-crowned warbler	*Vermivora celata*			
orchard oriole	*Icterus spurious*	Medium	SC	SC
pectoral sandpiper	*Calidris melanotos*			
peregrine falcon	*Falco peregrinus*			
pied-billed grebe	*Podilymbus podiceps*			
pine siskin	*Carduelis pinus*			
prairie falcon	*Falco mexicanus*	Low	SC	SC
purple martin	*Progne subis*			
red-bellied woodpecker	*Melanerpes carolinus*			
redhead	*Aythya Americana*	Medium	SC	SC
red-headed woodpecker	*Melanerpes erythrocephalus*			
red-necked phalarope	*Phalaropus lobatus*			
red phalarope	*Phalaropus fulicaria*			

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
red-tailed hawk	*Buteo jamaicensis*			
red-winged blackbird	*Agelaius phoeniceus*			
ring-necked duck	*Aythya collaris*			
ring-necked pheasant	*Phasianus colchicus*			
rock pigeon	*Columba livia*			
rock wren	*Sapinctes obsoletus*			
Ross's goose	*Chen rossii*			
rough-legged hawk	*Buteo lagopus*	Low	SC	SC
ruby-crowned kinglet	*Regulus calendula*			
ruddy duck	*Oxyura jamaicensis*			
rufous-crowned sparrow	*Spizella arborea*			
sandhill crane	*Grus canadensis*			
savannah sparrow	*Passerculus sandwichensis*			
Say's phoebe	*Sayornis saya*			
scaled quail	*Callipepla squamata*	Low	SC	SC
scissor-tailed flycatcher	*Tyrannus forficatus*	Low	SC	SC
short-billed dowitcher	*Limnodromus griseus*	Medium	SC	SC
snow goose	*Chen caerulescens*			
solitary sandpiper	*Tringa solitaria*	Low	SC	SC
song sparrow	*Melospiza melodia*			
stilt sandpiper	*Calidris himantopus*	Low	SC	SC
Swainson's hawk	*Buteo swainsoni*	Medium	SC	SC
Tennessee warbler	*Vermivora peregrina*			
tree swallow	*Tachycineta bicolor*			
tufted titmouse	*Baeolophus bicolor*			

Table A.1. Continued.

Species	Scientific Name	Status		
		Priority[1]	Federal	State
turkey vulture	*Cathartes aura*			
upland sandpiper	*Bartramia longicauda*	Low	SC	SC
vesper sparrow	*Pooecetes gramineus*			
western kingbird	*Tyrannus verticalis*			
western meadowlark	*Sturnella neglecta*	Low	SC	SC
white-breasted nuthatch	*Sitta carolinensis*			
white-crowned sparrow	*Zonotrichia leucophrys*			
white-faced ibis	*Plegadis chihi*	Medium	SC	SC
white-throated sparrow	*Zonotrichia albicollis*			
wild turkey	*Meleagris gallopavo*			
willet	*Catoptrophorus semipalmatus*			
Wilson's phalarope	*Phalaropus tricolor*	Low	SC	SC
yellow-headed blackbird	*Xanthocephalus xanthocephalus*			
yellow warbler	*Dendroica petechia*			

[1]Status based on Texas Parks and Wildlife Department Conservation Plan for 2005—2010; FE= federally endangered species or population; FT= federally threatened species or population; SE=state endangered species or population; ST= state threatened species or population; SC= species of concern at the federal or state level.

APPENDIX B

DISTANCE 6.0 MODELS FOR POINT-COUNT SURVEYS: MULTIMODLE INFERENCE

Table B.1. Cassin's sparrow seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season Density							
HAZARD	471.64	2	475.91	0.00	0.84	46.44	0.19
HALF COSINE	475.51	2	479.77	3.86	0.12	47.87	0.13
HALF	480.18	1	482.27	6.36	0.04	48.66	0.13
UNIFORM SIMPLE	483.90	3	490.45	14.53	0.00	28.51	0.15
UNIFORM COSINE	523.35	2	527.61	51.70	0.00	15.33	0.21
UNIFORM	689.95	0	689.95	214.04	0.00	1.95	0.09
Model Average						**46.68**	**0.18**
Summer Season Density							
HAZARD	799.73	2	803.88	0.00	0.99	26.39	0.12
HALF	811.37	1	813.42	9.54	0.01	36.57	0.12
UNIFORM SIMPLE	853.74	2	857.90	54.01	0.00	14.00	0.17
UNIFORM COSINE	956.05	1	958.10	154.22	0.00	6.22	0.13
UNIFORM	1131.09	0	1131.09	327.20	0.00	1.92	0.07
Model Average						**26.47**	**0.13**
Spring 2 Season Density							
HAZARD	87.81	2	93.53	0.96	0.33	2.47	0.36
HALF COSINE	92.63	2	98.34	5.78	0.03	3.70	1.23
HALF	94.63	1	97.13	4.57	0.06	4.98	0.81
UNIFORM SIMPL	90.06	1	92.56	0.00	0.54	4.23	0.45
UNIFORM COSINE	92.11	2	97.83	5.27	0.04	3.44	0.31
UNIFORM	139.32	0	139.32	46.76	0.00	0.17	0.22
Model Average						**3.64**	**0.55**
Summer 2 Season Density							
HAZARD	696.22	2	700.41	0.00	0.75	8.16	0.20
HALF COSINE	699.13	2	703.32	2.91	0.17	9.30	0.14
HALF	704.84	1	706.91	6.49	0.03	6.89	0.11
UNIFORM SIMPLE	699.34	3	705.74	5.33	0.05	6.18	0.08
UNIFORM COSINE	744.13	1	746.19	45.78	0.00	2.56	0.14
UNIFORM	858.72	0	858.72	158.31	0.00	0.76	0.03
Model Average						**8.22**	**0.20**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.2. Grasshopper sparrow seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	637.19	2	641.36	0.00	1.00	116.50	0.13
HALF COSINE	663.71	3	670.05	28.69	0.00	154.37	0.69
HALF	685.42	1	687.47	46.11	0.00	193.45	0.17
UNIFORM COSINE	701.85	4	710.44	69.07	0.00	105.88	0.22
UNIFORM	1096.02	0	1096.02	454.66	0.00	2.82	0.08
Model Average						**116.50**	**0.13**
Summer Season							
HAZARD SIMPLE	681.40	3	687.75	1.12	0.27	53.90	0.17
HAZARD	684.78	2	688.95	2.32	0.15	50.07	0.13
HALF	684.58	1	686.64	0.00	0.48	64.58	0.11
UNIFORM COSINE	678.98	5	689.89	3.26	0.09	68.00	0.22
UNIFORM	1065.97	0	1065.97	379.34	0.00	1.70	0.04
Model Average						**59.78**	**0.18**
Spring 2 Season							
HAZARD	791.78	2	795.93	0.00	0.99	39.65	0.13
HALF COSINE	796.02	4	804.52	8.59	0.01	47.32	0.15
HALF	821.77	1	823.81	27.88	0.00	37.33	0.05
UNIFORM COSINE	890.94	2	895.09	99.16	0.00	16.51	0.04
UNIFORM	1258.80	0	1258.80	462.87	0.00	1.08	0.03
Model Average						**59.78**	**0.18**
Summer 2 Season							
HAZARD SIMPLE	1415.31	3	1421.49	0.00	0.38	33.81	0.15
HAZARD	1417.94	2	1422.03	0.54	0.29	32.65	0.13
HALF COSINE	1415.66	3	1421.84	0.35	0.32	35.07	0.09
HALF	1456.96	1	1458.99	37.49	0.00	22.52	0.06
UNIFORM COSINE	1423.61	4	1431.92	10.43	0.00	25.22	0.08
UNIFORM	1899.36	0	1899.36	477.87	0.00	1.61	0.02
Model Average						**33.86**	**0.13**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.3. Horned lark seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	781.94	2	786.08	0.00	0.69	301.52	0.15
HALF	785.60	1	787.65	1.56	0.31	361.59	0.13
UNIFORM COSINE	823.34	4	831.82	45.74	0.00	181.86	0.22
UNIFORM SIMPLE	866.13	1	868.17	82.09	0.00	217.54	0.10
UNIFORM	1350.51	0	1350.51	564.43	0.00	6.53	0.11
Model Average						**320.37**	**0.16**
Summer Season							
HAZARD	1009.57	2	1013.69	3.48	0.15	108.34	0.13
HALF COSINE	1001.81	4	1010.20	0.00	0.85	119.08	0.28
HALF	1038.38	1	1040.42	30.21	0.00	101.95	0.10
UNIFORM COSINE	1129.50	3	1135.74	125.53	0.00	40.09	0.13
UNIFORM SIMPLE	1200.42	2	1204.54	194.33	0.00	25.22	0.14
UNIFORM	1569.22	0	1569.22	559.02	0.00	3.96	0.08
Model Average						**117.48**	**0.26**
Fall Season							
HAZARD	538.45	2	542.70	0.00	0.87	81.73	0.31
HALF COSINE	542.41	2	546.66	3.96	0.12	56.20	0.20
HALF	562.92	1	565.00	22.29	0.00	36.23	0.19
UNIFORM COSINE	541.66	5	553.02	10.32	0.01	61.26	0.23
UNIFORM SIMPLE	636.46	1	638.55	95.84	0.00	9.17	0.16
UNIFORM	706.36	0	706.36	163.65	0.00	5.49	0.24
Model Average						**78.54**	**0.32**
Winter Season							
HAZARD	454.45	2	458.71	0.00	0.96	167.08	0.22
HALF COSINE	458.54	3	465.09	6.37	0.04	223.36	0.19
HALF	479.32	1	481.41	22.69	0.00	151.78	0.16
UNIFORM COSINE	517.11	3	523.66	64.94	0.00	46.07	0.22
UNIFORM SIMPLE	496.36	5	507.79	49.07	0.00	59.79	0.33
UNIFORM	714.70	0	714.70	255.98	0.00	4.85	0.14
Model Average						**78.54**	**0.32**
Spring 2 Season							
HAZARD	681.16	2	685.33	0.00	0.97	36.28	0.12
HALF COSINE	694.47	1	696.53	11.20	0.00	51.85	0.16
HALF HERMITE	688.91	2	693.08	7.75	0.02	42.10	0.38
HALF	694.47	1	696.53	11.20	0.00	51.85	0.16
UNIFORM COSINE	745.56	2	749.73	64.40	0.00	18.39	0.18
UNIFORM SIMPLE	738.55	1	740.61	55.27	0.00	28.67	0.09
UNIFORM	1072.99	0	1072.99	387.66	0.00	1.93	0.12
Model Average						**36.51**	**0.13**

B.3. Continued.

Summer 2 Season							
HAZARD	783.40	2	787.56	0.00	0.75	26.40	0.15
HALF COSINE	778.97	5	789.81	2.25	0.24	30.90	0.36
HALF	797.70	1	799.75	12.19	0.00	30.28	0.11
UNIFORM COSINE	893.88	2	898.04	110.48	0.00	16.36	0.11
UNIFORM SIMPLE	808.53	3	814.85	27.29	0.00	18.53	0.08
UNIFORM	1086.12	0	1086.12	298.56	0.00	1.61	0.07
Model Average						**27.51**	**0.22**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.4. Killdeer seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	299.69	2	304.19	2.33	0.21	10.11	0.26
HALF	299.70	1	301.86	0.00	0.69	12.34	0.21
UNIFORM COSINE	298.87	3	305.91	4.05	0.09	13.50	0.27
UNIFORM SIMPLE	304.41	3	311.45	9.59	0.01	7.29	0.16
UNIFORM	358.37	0	358.37	56.51	0.00	1.46	0.11
Model Average						**11.94**	**0.24**
Summer Season							
HALF COSINE	349.13	5	361.35	0.00	0.81	6.94	11.35
HAZARD	360.50	2	364.90	3.55	0.14	1.18	0.37
HALF	364.79	1	366.92	5.56	0.05	0.37	0.08
UNIFORM COSINE	367.70	2	372.10	10.74	0.00	0.02	0.01
UNIFORM SIMPLE	380.06	1	382.19	20.84	0.00	0.00	0.00
UNIFORM	440.10	0	440.10	78.75	0.00	0.00	0.00
Model Average						**8.50**	**1.39**
Fall Season							
HAZARD	94.40	2	100.40	3.84	0.09	7.33	0.60
HALF	96.10	1	98.67	2.11	0.21	8.56	0.89
UNIFORM COSINE	93.82	2	99.82	3.26	0.12	6.91	1.20
UNIFORM SIMPLE	93.99	1	96.57	0.00	0.59	7.85	0.62
UNIFORM	116.19	0	116.19	19.63	0.00	1.22	0.45
Model Average						**7.84**	**0.74**
Spring 2 Season							
HALF COSINE	949.36	3	955.65	0.92	0.39	26.10	0.14
HAZARD	950.59	2	954.73	0.00	0.61	20.42	0.16
HALF	965.99	1	968.04	13.31	0.00	16.82	0.09
UNIFORM COSINE	964.07	3	970.36	15.63	0.00	14.79	0.08
UNIFORM SIMPLE	999.25	4	1007.74	53.01	0.00	14.51	0.14
UNIFORM	1217.05	0	1217.05	262.31	0.00	1.47	0.08
Model Average						**7.84**	**0.74**
Summer 2 Season							
HAZARD SIMPLE	673.92	3	680.34	0.84	0.22	7.90	0.25
HAZARD	677.53	2	681.74	2.24	0.11	7.72	0.20
HALF	678.06	1	680.13	0.63	0.24	8.95	0.15
UNIFORM COSINE	673.08	3	679.50	0.00	0.33	12.00	0.18
UNIFORM SIMPLE	675.57	3	681.99	2.48	0.10	8.89	0.15
UNIFORM	805.41	0	805.41	125.90	0.00	1.22	0.12
Model Average						**9.60**	**0.25**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.5. Meadowlark spp. seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HALF COSINE	3558.52	5	3568.69	10.45	0.01	534.51	0.09
HAZARD	3554.21	2	3558.24	0.00	0.99	457.81	0.09
HALF	3670.21	1	3672.22	113.97	0.00	338.94	0.07
UNIFORM COSINE	3855.10	3	3861.16	302.92	0.00	144.60	0.08
UNIFORM	5271.95	0	5271.95	1713.70	0.00	14.00	0.06
Model Average						**458.22**	**0.10**
Summer Season							
HALF COSINE	3465.10	2	3469.14	6.81	0.03	117.46	0.08
HAZARD	3458.29	2	3462.32	0.00	0.97	88.27	0.09
HALF	3496.20	1	3498.22	35.89	0.00	91.68	0.08
UNIFORM SIMPLE	3594.27	3	3600.35	138.02	0.00	61.61	0.07
UNIFORM COSINE	3487.51	3	3493.59	31.26	0.00	79.25	0.07
UNIFORM	4500.73	0	4500.73	1038.40	0.00	7.67	0.07
Model Average						**89.20**	**0.10**
Fall Season							
HAZARD SIMPLE	1331.31	4	1339.67	0.00	0.65	99.33	0.42
HALF COSINE	1336.72	3	1342.93	3.26	0.13	84.79	0.19
HAZARD	1340.00	2	1344.11	4.44	0.07	97.32	0.32
HALF	1362.02	1	1364.05	24.38	0.00	43.38	0.15
UNIFORM SIMPLE	1349.16	3	1355.37	15.70	0.00	45.15	0.15
UNIFORM COSINE	1332.02	5	1342.57	2.90	0.15	91.02	0.20
UNIFORM	1517.84	0	1517.84	178.16	0.00	10.78	0.16
Model Average						**96.06**	**0.36**
Winter Season							
HALF COSINE	756.89	3	763.23	0.00	0.98	91.86	0.20
HAZARD	767.39	2	771.55	8.32	0.02	92.61	0.20
HALF	814.03	1	816.08	52.86	0.00	53.89	0.13
UNIFORM SIMPLE	820.06	4	828.62	65.39	0.00	33.91	0.16
UNIFORM COSINE	871.22	2	875.39	112.16	0.00	21.12	0.15
UNIFORM	1101.50	0	1101.50	338.27	0.00	4.57	0.21
Model Average						**91.87**	**0.20**
Spring 2 Season							
HAZARD SIMPLE	5351.17	3	5357.22	0.00	0.65	115.65	0.08
HALF COSINE	5352.59	3	5358.63	1.41	0.32	157.36	0.08
HAZARD	5359.35	2	5363.37	6.15	0.03	112.73	0.07
HALF	5399.45	1	5401.46	44.24	0.00	121.82	0.06
UNIFORM SIMPLE	5557.94	4	5566.02	208.80	0.00	69.64	0.07
UNIFORM COSINE	6247.17	1	6249.18	891.96	0.00	23.30	0.07
UNIFORM	7349.03	0	7349.03	1991.81	0.00	7.14	0.05
Model Average						**128.93**	**0.16**

Table B.5. Continued.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Summer 2 Season							
HAZARD SIMPLE	3919.01	3	3925.08	0.00	0.86	62.77	0.09
HALF COSINE	3920.55	4	3928.66	3.58	0.14	63.43	0.18
HAZARD	3933.69	2	3937.73	12.65	0.00	62.68	0.08
HALF	3962.83	1	3964.84	39.76	0.00	57.87	0.06
UNIFORM SIMPLE	3997.72	3	4003.79	78.71	0.00	42.52	0.05
UNIFORM COSINE	4350.82	1	4352.83	427.75	0.00	16.33	0.07
UNIFORM	5083.61	0	5083.61	1158.53	0.00	5.23	0.05
Model Average						**62.87**	**0.11**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.6. Mourning dove seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HALF COSINE	672.68	2	676.89	0.00	0.38	28.56	0.18
UNIFORM COSINE	671.92	3	678.34	1.45	0.18	25.00	0.15
HAZARD	672.89	2	677.10	0.21	0.34	23.27	0.23
HALF	677.88	1	679.95	3.06	0.08	19.85	0.13
UNIFORM SIMPLE	677.80	3	684.23	7.34	0.01	16.73	0.11
UNIFORM	793.78	0	793.78	116.88	0.00	3.04	0.10
Model Average						**113.18**	**0.08**
Summer Season							
HALF COSINE	1207.95	2	1212.07	0.00	0.45	42.55	0.15
HAZARD SIMPLE	1212.05	2	1216.17	4.10	0.06	31.55	0.18
UNIFORM COSINE	1206.83	3	1213.07	1.00	0.27	37.47	0.12
HAZARD COSINE	1208.06	3	1214.30	2.23	0.15	37.74	0.13
HAZARD	1212.05	2	1216.17	4.10	0.06	31.55	0.18
HALF	1218.54	1	1220.58	8.51	0.01	27.75	0.12
UNIFORM SIMPLE	1222.70	3	1228.94	16.87	0.00	22.31	0.12
UNIFORM	1405.53	0	1405.53	193.46	0.00	4.86	0.20
Model Average						**39.06**	**0.17**
Fall Season							
UNIFORM COSINE	339.43	2	343.89	1.00	0.25	4.81	0.29
HAZARD	339.60	2	344.07	1.18	0.23	4.38	0.35
HALF	340.74	1	342.89	0.00	0.41	4.32	0.26
UNIFORM SIMPLE	340.96	2	345.42	2.53	0.12	3.77	0.26
UNIFORM	365.32	0	365.32	22.43	0.00	1.72	0.24
Model Average						**4.39**	**0.29**
Spring 2 Season							
HALF COSINE	749.80	3	756.18	0.00	0.66	20.06	0.19
HAZARD SIMPLE	761.13	3	767.51	11.33	0.00	16.05	0.41
UNIFORM COSINE	746.50	5	757.48	1.30	0.34	20.36	0.25
HAZARD	765.67	2	769.86	13.68	0.00	13.64	0.28
HALF	778.29	1	780.35	24.17	0.00	7.95	0.13
UNIFORM SIMPLE	764.44	4	773.09	16.91	0.00	8.80	0.16
UNIFORM	892.30	0	892.30	136.12	0.00	1.39	0.09
Model Average						**20.15**	**0.21**

Table B.6. Continued.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Summer 2 Season							
HAZARD SIMPLE	1634.07	3	1640.24	0.00	0.77	16.47	0.19
UNIFORM COSINE	1657.12	1	1659.15	18.91	0.00	10.46	0.09
HAZARD COSINE	1643.80	2	1647.89	7.65	0.02	16.25	0.14
HAZARD	1645.58	2	1649.66	9.42	0.01	17.88	0.17
HALF	1640.85	1	1642.88	2.63	0.21	17.70	0.10
UNIFORM SIMPLE	1653.93	2	1658.02	17.78	0.00	10.86	0.08
UNIFORM	1858.07	0	1858.07	217.83	0.00	3.29	0.12
Model Average						**16.73**	**0.17**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.7. Red-winged blackbird seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HALF COSINE	1487.26	3	1493.43	6.68	0.03	146.56	0.15
HAZARD	1482.67	2	1486.75	0.00	0.97	116.14	0.17
HALF	1529.36	1	1531.39	44.63	0.00	92.45	0.13
UNIFORM SIMPLE	1554.93	3	1561.11	74.35	0.00	57.76	0.13
UNIFORM COSINE	1706.95	1	1708.98	222.23	0.00	24.90	0.15
UNIFORM	1995.45	0	1995.45	508.69	0.00	11.45	0.35
Model Average						**117.18**	**0.18**
Summer Season							
HALF COSINE	1087.50	3	1093.74	0.38	0.45	207.48	0.19
HAZARD	1089.24	2	1093.36	0.00	0.55	161.59	0.21
HALF	1114.43	1	1116.46	23.11	0.00	124.22	0.17
UNIFORM SIMPLE	1130.32	3	1136.56	43.20	0.00	78.92	0.17
UNIFORM COSINE	1233.66	1	1235.70	142.34	0.00	34.20	0.19
UNIFORM	1439.57	0	1439.57	346.21	0.00	11.45	0.16
Model Average						**182.35**	**0.24**
Fall Season							
HALF COSINE	547.86	2	552.14	1.84	0.24	46.45	0.33
HAZARD	546.03	2	550.30	0.00	0.60	61.32	0.50
HALF	564.77	1	566.86	16.56	0.00	20.00	0.25
UNIFORM SIMPLE	572.19	2	576.46	26.16	0.00	14.23	0.25
UNIFORM COSINE	546.43	3	552.99	2.69	0.16	39.23	0.31
UNIFORM	615.21	0	615.21	64.91	0.00	33.05	0.38
Model Average						**54.27**	**0.48**
Winter Season							
HAZARD SIMPLE	362.85	2	367.25	1.30	0.27	150.03	0.55
HALF COSINE	363.52	2	367.92	1.97	0.19	154.06	0.51
HAZARD	361.55	2	365.95	0.00	0.51	123.15	0.51
HALF	370.89	1	373.02	7.07	0.01	105.45	0.48
UNIFORM SIMPLE	372.64	3	379.47	13.52	0.00	81.39	0.46
UNIFORM COSINE	365.46	3	372.29	6.34	0.02	116.62	0.48
UNIFORM	444.27	0	444.27	78.32	0.00	23.48	0.36
Model Average						**135.72**	**0.53**
Spring 2 Season							
HAZARD SIMPLE	3655.77	3	3661.84	4.00	0.12	251.79	0.14
HALF COSINE	3651.77	3	3657.84	0.00	0.85	223.26	0.12
HAZARD	3660.28	2	3664.31	6.47	0.03	236.49	0.13
HALF	3746.17	1	3748.18	90.34	0.00	135.59	0.10
UNIFORM SIMPLE	3821.42	4	3829.54	171.70	0.00	106.44	0.11
UNIFORM COSINE	3717.44	3	3723.51	65.67	0.00	130.21	0.10
UNIFORM	4663.61	0	4663.61	1005.77	0.00	42.24	0.33
Model Average						**226.99**	**0.13**

Table B.7. Continued.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Summer 2 Season							
HAZARD SIMPLE	2683.45	3	2689.55	0.00	0.82	139.97	0.16
HALF COSINE	2684.53	4	2692.69	3.15	0.17	136.22	0.22
HAZARD	2696.64	2	2700.69	11.14	0.00	142.19	0.14
HALF	2716.44	1	2718.45	28.90	0.00	108.83	0.11
UNIFORM SIMPLE	2790.98	3	2797.08	107.53	0.00	67.63	0.12
UNIFORM COSINE	2693.55	4	2701.72	12.17	0.00	145.42	0.13
UNIFORM	3387.37	0	3387.37	697.83	0.00	49.46	0.39
Model Average						**139.35**	**0.17**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.8. Western meadowalrk seasonal detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring 2 Season							
HAZARD SIMPLE	2783.80	3	2789.89	0.00	0.69	73.02	0.09
HALF COSINE	2786.03	3	2792.12	2.23	0.23	99.45	0.09
HAZARD	2792.33	2	2796.37	6.48	0.03	70.22	0.08
HALF	2810.59	1	2812.61	22.72	0.00	75.60	0.06
UNIFORM SIMPLE	2816.35	4	2824.50	34.61	0.00	59.04	0.08
UNIFORM COSINE	2784.89	5	2795.11	5.22	0.05	86.73	0.10
UNIFORM	3934.53	0	3934.53	1144.64	0.00	3.53	0.03
Model Average						**79.65**	**0.09**
Summer 2 Season							
HAZARD SIMPLE	2457.73	3	2463.84	0.00	0.87	45.53	0.10
HALF COSINE	2461.10	4	2469.27	5.44	0.06	46.21	0.20
HAZARD	2464.81	2	2468.86	5.03	0.07	44.34	0.09
HALF	2486.76	1	2488.78	24.94	0.00	45.27	0.06
UNIFORM SIMPLE	2502.33	5	2512.59	48.75	0.00	33.97	0.07
UNIFORM COSINE	2637.30	2	2641.35	177.51	0.00	23.52	0.06
UNIFORM	3325.90	0	3325.90	862.06	0.00	2.91	0.04
Model Average						**45.49**	**0.09**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.9. American kestrel global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	400.21	2	404.60	0.00	0.40	4.39	0.45
UNIFORM COSINE	400.67	2	405.06	0.46	0.32	3.30	0.20
HALF COSINE	402.32	2	406.71	2.11	0.14	4.15	0.27
HALF	404.90	1	407.02	2.42	0.12	2.73	0.16
UNIFORM SIMPLE	405.19	2	409.57	4.98	0.03	2.12	0.18
UNIFORM	435.25	0	435.25	30.65	0.00	0.72	0.03
Model Average						**3.74**	**37.95%**

Summer		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
0.42	0.45	1.44	0.45	1.70	0.46	0.53	0.45	0.30	0.45
0.31	0.19	1.07	0.19	1.29	0.20	0.40	0.19	0.23	0.19
0.40	0.27	1.36	0.27	1.60	0.28	0.50	0.27	0.29	0.27
0.26	0.16	0.88	0.16	1.08	0.17	0.32	0.16	0.19	0.16
0.20	0.18	0.68	0.18	0.85	0.19	0.25	0.18	0.14	0.18
0.07	0.01	0.23	0.01	0.30	0.08	0.08	0.01	0.05	0.01
0.36	**38.20%**	**1.22**	**38.21%**	**1.46**	**37.98%**	**0.45**	**38.20%**	**0.26**	**38.19%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.10. Barn swallow global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	585.58	4	594.42	0.00	0.75	63.99	0.28
HAZARD	592.35	2	596.59	2.18	0.25	48.35	0.29
HALF	605.54	1	607.62	13.20	0.00	38.06	0.23
UNIFORM SIMPLE	606.81	3	613.29	18.88	0.00	29.65	0.24
UNIFORM COSINE	623.47	2	627.71	33.30	0.00	22.35	0.24
UNIFORM	754.46	0	754.46	160.05	0.00	4.71	0.27
Model Average						**60.02**	**30.16%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.88	0.19	7.44	0.28	6.79	0.35	6.41	0.39	41.47	0.35
1.06	0.20	5.01	0.30	4.22	0.36	3.42	0.31	34.64	0.35
0.83	0.09	3.99	0.24	3.41	0.32	2.14	0.23	27.70	0.30
0.58	0.10	3.02	0.25	2.56	0.33	1.48	0.20	22.01	0.30
0.44	0.11	2.27	0.26	1.85	0.32	1.12	0.21	16.67	0.30
0.08	0.01	0.40	0.22	0.47	0.28	0.30	0.18	3.47	0.37
1.67	**28.12%**	**6.82**	**32.48%**	**6.14**	**40.23%**	**5.65**	**45.32%**	**39.74**	**36.16%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.11. Blue-winged teal global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF	491.37	1	493.47	0.00	0.32	30.69	0.48
UNIFORM COSINE	489.59	2	493.89	0.42	0.26	25.34	0.46
UNIFORM SIMPLE	491.82	1	493.92	0.45	0.25	18.58	0.35
HAZARD SIMPLE	488.48	3	495.10	1.63	0.14	25.34	0.51
HAZARD	493.89	2	498.19	4.72	0.03	27.79	0.40
UNIFORM	547.06	0	547.06	53.60	0.00	11.71	0.28
Model Average						**25.40**	**49.38%**

Spring		**Summer**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
20.50	0.68	1.18	0.81	0.46	0.18	4.71	0.43	3.84	0.36
16.40	0.65	0.85	0.68	0.39	0.22	4.40	0.42	3.30	0.38
10.95	0.56	0.51	0.45	0.28	0.07	4.37	0.35	2.48	0.31
14.93	0.70	0.86	0.72	0.38	0.37	5.87	0.52	3.30	0.47
15.45	0.60	1.09	0.65	0.39	0.23	7.40	0.42	3.46	0.37
3.08	0.47	0.29	0.39	0.09	0.01	7.39	0.40	0.87	0.21
16.09	**69.59%**	**0.88**	**78.49%**	**0.38**	**28.21%**	**4.79**	**44.23%**	**3.27**	**40.74%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.12. Common grackle global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF	664.91	1	666.98	0.00	0.74	210.66	0.51
UNIFORM COSINE	664.02	3	670.44	3.46	0.13	196.68	0.50
HAZARD SIMPLE	665.31	3	671.73	4.76	0.07	149.87	0.48
HAZARD	667.63	2	671.84	4.86	0.06	116.90	0.44
UNIFORM SIMPLE	692.08	2	696.28	29.31	0.00	61.36	0.46
UNIFORM	817.10	0	817.10	150.12	0.00	15.41	0.27
Model Average						**198.62**	**52.42%**

Spring		**Summer**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
178.85	0.59	1.79	0.45	9.69	0.37	16.93	0.51
165.71	0.59	1.82	0.44	9.84	0.38	16.02	0.51
125.11	0.56	2.32	0.39	9.70	0.38	10.55	0.47
94.72	0.53	2.29	0.35	9.04	0.36	8.89	0.42
49.73	0.55	0.83	0.38	4.62	0.38	4.90	0.47
12.16	0.33	0.53	0.39	1.82	0.45	0.76	0.23
168.02	**60.68%**	**1.87**	**44.37%**	**9.67**	**37.19%**	**15.85**	**53.67%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.13. Common nighthawk global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM COSINE	737.02	2	741.22	0.00	0.41	8.21	0.12
HALF	739.77	1	741.84	0.62	0.30	7.76	0.12
HAZARD	738.31	2	742.51	1.29	0.22	7.98	0.21
UNIFORM SIMPLE	738.31	3	744.71	3.50	0.07	7.30	0.12
UNIFORM	821.01	0	821.01	79.79	0.00	1.49	0.04
Model Average						**7.96**	**14.49%**

Spring		**Summer**		**Fall**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.57	0.14	5.84	0.12	0.12	0.12	0.69	0.12
1.48	0.14	5.52	0.13	0.11	0.12	0.65	0.12
1.55	0.22	5.64	0.21	0.12	0.21	0.67	0.21
1.40	0.14	5.18	0.12	0.11	0.11	0.61	0.11
0.30	0.08	1.04	0.05	0.02	0.01	0.13	0.01
1.53	**16.43%**	**5.65**	**14.97%**	**0.11**	**14.03%**	**0.67**	**14.03%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.14. Dickcissel global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Glbal Detection Function							
HAZARD SIMPLE	1117.71	3	1123.93	0.00	0.61	67.70	0.13
HAZARD	1121.51	2	1125.62	1.69	0.26	62.65	0.11
HALF	1124.93	1	1126.96	3.04	0.13	69.62	0.08
UNIFORM SIMPLE	1198.52	4	1206.88	82.96	0.00	32.64	0.14
UNIFORM COSINE	1233.55	3	1239.76	115.84	0.00	21.39	0.13
UNIFORM	1717.26	0	1717.26	593.34	0.00	2.16	0.05
Model Average						**66.64**	**12.66%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
10.99	0.17	23.34	0.15	0.76	0.13	7.47	0.18	25.13	0.13
10.57	0.15	21.49	0.13	0.70	0.11	6.67	0.17	23.22	0.11
8.87	0.17	24.75	0.11	0.79	0.07	9.18	0.14	26.02	0.08
4.45	0.19	11.45	0.16	0.37	0.14	3.95	0.19	12.42	0.14
2.90	0.18	7.51	0.15	0.24	0.12	2.60	0.18	8.13	0.12
0.49	0.17	0.69	0.08	0.02	0.01	0.20	0.16	0.76	0.03
10.60	**17.49%**	**23.05**	**14.82%**	**0.75**	**12.24%**	**7.49**	**19.40%**	**24.75**	**12.38%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.15. Eastern meadowlark global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	702.93	2	707.12	0.00	0.55	14.53	0.20
HALF COSINE	701.22	3	707.60	0.48	0.44	18.55	0.18
HALF	713.83	1	715.89	8.77	0.01	12.11	0.13
UNIFORM SIMPLE	711.44	3	717.82	10.70	0.00	9.95	0.11
UNIFORM COSINE	768.69	2	772.88	65.76	0.00	7.11	0.15
UNIFORM	913.93	0	913.93	206.81	0.00	1.09	0.12
Model Average						**16.26**	**22.83%**

Fall		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**
4.73	0.34	4.50	0.19	5.29	0.18
5.90	0.34	5.65	0.16	7.01	0.15
3.88	0.31	3.66	0.10	4.57	0.09
3.25	0.30	2.99	0.07	3.72	0.06
2.28	0.31	2.15	0.13	2.68	0.12
0.38	0.35	0.33	0.05	0.37	0.01
5.23	**35.71%**	**4.99**	**20.62%**	**6.03**	**21.82%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.16. Great-tailed grackle detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM SIMPLE	593.78	3	600.27	0.00	0.26	64.46	0.29
HALF COSINE	596.40	2	600.64	0.37	0.22	87.92	0.34
UNIFORM COSINE	594.18	3	600.67	0.40	0.21	84.31	0.32
HAZARD	596.58	2	600.82	0.55	0.20	82.04	0.39
HALF	599.90	1	601.97	1.70	0.11	60.00	0.29
UNIFORM	694.63	0	694.63	94.35	0.00	23.24	0.43
Model Average						**76.77**	**36.29%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
9.36	0.48	11.50	0.32	4.54	0.09	4.54	0.09	4.68	0.36	31.46	0.54
10.30	0.57	19.32	0.42	6.34	0.19	6.34	0.19	7.51	0.41	40.39	0.61
10.75	0.55	17.11	0.39	5.99	0.15	5.99	0.15	6.80	0.39	39.83	0.58
12.40	0.55	12.26	0.39	5.34	0.24	5.34	0.24	5.01	0.42	43.61	0.59
8.50	0.48	11.52	0.33	4.46	0.12	4.46	0.12	4.69	0.37	27.96	0.54
2.97	0.32	1.08	0.24	0.68	0.01	0.68	0.01	0.49	0.27	17.60	0.56
10.37	**54.31%**	**14.55**	**44.01%**	**5.39**	**22.01%**	**3.45**	**34.43%**	**5.81**	**44.48%**	**37.20**	**59.70%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.17. Lark sparrow global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	1183.97	3	1190.18	0.00	0.92	117.54	0.11
HAZARD	1191.18	2	1195.29	5.11	0.07	75.11	0.11
HALF	1198.94	1	1200.97	10.79	0.00	98.65	0.09
UNIFORM COSINE	1241.03	3	1247.24	57.06	0.00	46.41	0.12
UNIFORM SIMPLE	1334.72	2	1338.83	148.65	0.00	28.36	0.13
UNIFORM	1688.65	0	1688.65	498.47	0.00	3.89	0.06
Model Average						**114.41**	**13.51%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
24.51	0.12	50.72	0.12	1.73	0.35	12.43	0.29	28.15	0.18
16.90	0.12	32.30	0.12	1.20	0.35	7.56	0.24	17.15	0.18
20.84	0.10	42.82	0.09	1.47	0.34	10.56	0.28	22.96	0.17
10.35	0.13	20.42	0.13	0.73	0.35	5.19	0.27	9.73	0.19
6.51	0.14	12.57	0.14	0.46	0.35	3.24	0.27	5.59	0.19
0.94	0.08	1.70	0.09	0.07	0.33	0.37	0.15	0.81	0.14
23.95	**13.97%**	**49.37**	**14.05%**	**1.96**	**35.73%**	**12.07**	**30.57%**	**27.34**	**20.61%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.18. Northern bobwhite global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM COSINE	1381.43	1	1383.46	0.00	0.41	7.35	0.06
HALF	1381.82	1	1383.86	0.39	0.34	8.35	0.11
UNIFORM SIMPLE	1381.60	2	1385.71	2.25	0.13	6.97	0.09
HAZARD SIMPLE	1380.30	3	1386.51	3.05	0.09	7.70	0.24
HAZARD	1384.58	2	1388.68	5.22	0.03	7.41	0.16
UNIFORM	1470.26	0	1470.26	86.79	0.00	2.31	0.07
Model Average						**7.67**	**12.17%**

Summer		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
3.11	0.08	0.78	0.05	0.14	0.05	0.62	0.09	2.70	0.06
3.55	0.13	0.87	0.11	0.16	0.11	0.71	0.14	3.05	0.11
2.95	0.11	0.74	0.08	0.14	0.08	0.58	0.12	2.57	0.09
3.26	0.24	0.81	0.23	0.15	0.23	0.64	0.25	2.85	0.24
3.13	0.17	0.79	0.16	0.15	0.16	0.60	0.18	2.76	0.16
0.95	0.16	0.25	0.01	0.05	0.01	0.18	0.09	0.88	0.07
3.25	**13.89%**	**0.81**	**11.40%**	**0.15**	**11.41%**	**0.65**	**14.88%**	**2.82**	**12.10%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.19. Northern harrier global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM COSINE	822.33	1	824.39	0.00	0.32	3.76	0.13
HALF COSINE	818.18	3	824.55	0.16	0.30	6.28	0.29
HALF	822.60	1	824.66	0.26	0.28	3.72	0.16
UNIFORM SIMPLE	822.45	2	826.63	2.24	0.10	3.72	0.16
UNIFORM	844.16	0	844.16	19.77	0.00	1.94	0.10
Model Average						**4.49**	**31.49%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
0.73	0.17	0.26	0.12	1.74	0.15	0.68	0.20	0.35	0.14
0.96	0.40	0.48	0.28	3.00	0.30	1.24	0.35	0.60	0.29
0.73	0.19	0.26	0.15	1.71	0.17	0.68	0.22	0.34	0.17
0.72	0.19	0.26	0.15	1.73	0.17	0.68	0.22	0.34	0.17
0.38	0.10	0.11	0.02	0.95	0.17	0.37	0.25	0.14	0.08
0.80	**28.33%**	**0.33**	**34.65%**	**2.10**	**33.55%**	**0.84**	**38.66%**	**0.42**	**33.36%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.20. Northern mockingbird global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	471.25	2	475.55	0.00	0.60	8.16	0.23
HALF COSINE	472.52	2	476.82	1.27	0.32	9.37	0.15
UNIFORM COSINE	473.72	3	480.34	4.79	0.05	6.98	0.11
HALF	479.76	1	481.86	6.31	0.03	6.45	0.11
UNIFORM SIMPLE	483.88	3	490.50	14.94	0.00	4.28	0.15
UNIFORM	583.06	0	583.06	107.51	0.00	0.77	0.04
Model Average						**8.43**	**21.68%**

Spring		**Summer**		**Spring2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.25	0.23	2.64	0.24	0.87	0.24	3.40	0.24
1.48	0.15	2.95	0.16	0.89	0.17	4.05	0.16
1.10	0.10	2.21	0.12	0.67	0.13	3.00	0.12
1.02	0.11	2.04	0.12	0.61	0.13	2.78	0.12
0.67	0.15	1.38	0.16	0.41	0.16	1.82	0.16
0.11	0.03	0.27	0.08	0.10	0.13	0.30	0.07
1.31	**21.99%**	**2.70**	**22.20%**	**0.86**	**22.40%**	**3.57**	**22.40%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.21. Ring-necked pheasant global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF	987.01	1	989.06	0.00	0.42	7.51	0.15
UNIFORM COSINE	986.13	2	990.28	1.22	0.23	8.24	0.18
HAZARD	986.26	2	990.41	1.34	0.22	7.29	0.22
UNIFORM SIMPLE	987.28	2	991.43	2.36	0.13	5.93	0.13
UNIFORM	1051.53	0	1051.53	62.47	0.00	1.49	0.07
Model Average						**7.43**	**19.15%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
2.50	0.21	1.68	0.33	0.08	0.12	0.16	0.12	1.74	0.12	1.36	0.12
2.87	0.24	1.82	0.33	0.09	0.15	0.17	0.15	1.85	0.15	1.44	0.15
2.48	0.26	1.54	0.37	0.08	0.20	0.16	0.20	1.69	0.20	1.34	0.20
1.82	0.18	1.27	0.37	0.07	0.10	0.14	0.10	1.47	0.11	1.16	0.10
0.38	0.13	0.20	0.44	0.02	0.01	0.05	0.01	0.46	0.05	0.38	0.01
2.49	**25.92%**	**1.63**	**35.63%**	**0.08**	**15.49%**	**0.16**	**15.48%**	**1.72**	**16.06%**	**1.35**	**15.52%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.22. Sandhill crane global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM COSINE	1011.40	1	1013.44	0.00	0.46	43.91	0.23
UNIFORM SIMPLE	1010.36	2	1014.50	1.06	0.27	44.64	0.26
HALF	1013.50	1	1015.54	2.10	0.16	43.06	0.23
HAZARD	1012.62	2	1016.77	3.32	0.09	43.27	0.54
UNIFORM	1020.64	0	1020.64	7.20	0.01	35.99	0.19
Model Average						**43.82**	**26.46%**

Spring		**Fall**		**Winter**		**Spring 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
0.62	0.15	22.61	0.25	18.39	0.36	2.30	0.93
0.63	0.19	22.74	0.27	18.90	0.37	2.37	0.93
0.54	0.15	23.07	0.24	17.45	0.35	2.01	0.93
0.62	0.51	22.74	0.55	17.58	0.60	2.32	1.05
0.34	0.02	22.20	0.28	12.19	0.24	1.26	0.92
0.60	**20.17%**	**22.73**	**27.95%**	**18.22**	**38.37%**	**2.26**	**94.37%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table B.23. Western kingbird global detection function models and density estimates from Distance 6.0 for model averaging for first 10 min of 20-min point-count surveys from Gray and Donley County Study Sites from April 2008–August 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	848.52	3	854.84	0.00	0.56	49.55	0.17
HAZARD SIMPLE	849.20	3	855.52	0.68	0.40	54.10	0.31
UNIFORM COSINE	850.11	5	860.94	6.09	0.03	41.13	0.20
HAZARD	858.84	2	863.00	8.16	0.01	39.58	0.19
HALF	865.97	1	868.02	13.18	0.00	28.22	0.11
UNIFORM SIMPLE	864.37	5	875.20	20.35	0.00	23.08	0.16
UNIFORM	1126.51	0	1126.51	271.67	0.00	2.08	0.07
Model Average						**51.03**	**23.73%**

Spring		**Summer**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
12.98	0.21	5.99	0.31	7.79	0.27	22.79	0.18
14.35	0.33	7.08	0.41	8.66	0.37	24.01	0.32
10.53	0.23	4.98	0.32	6.33	0.28	19.30	0.20
10.07	0.22	4.70	0.31	6.40	0.28	18.41	0.20
7.06	0.16	3.43	0.28	4.24	0.23	13.49	0.12
5.73	0.20	2.83	0.30	3.46	0.26	11.06	0.17
0.49	0.12	0.27	0.21	0.33	0.22	0.99	0.10
13.43	**27.10%**	**6.39**	**36.79%**	**8.08**	**31.73%**	**23.13**	**23.91%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

APPENDIX C

DISTANCE 6.0 MODELS FOR LINE-TRANSECT SURVEYS: MULTIMODLE INFERENCE

Table C.1. Cassin's sparrow seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	1153.58	2	1157.68	0.00	0.99	50.82	0.13
HALF	1164.95	1	1166.99	9.31	0.01	46.97	0.12
UNIFORM COSINE	1248.99	2	1253.08	95.41	0.00	23.06	0.14
UNIFORM	1533.81	0	1533.81	376.14	0.00	6.69	0.11
Model Average						**50.78**	**0.13**
Summer Season							
HAZARD SIMPLE	1261.59	3	1267.78	1.30	0.25	42.08	0.15
HAZARD	1264.10	2	1268.19	1.72	0.21	40.56	0.14
HALF	1264.44	1	1266.47	0.00	0.49	45.93	0.14
UNIFORM COSINE	1262.50	4	1270.80	4.33	0.06	44.04	0.18
UNIFORM	1629.68	0	1629.68	363.20	0.00	7.24	0.13
Model Average						**21.85**	**0.64**
Fall Season							
HAZARD	16.64	2	24.64	1.52	0.32	25.33	0.61
HALF	20.12	1	23.12	0.00	0.68	20.22	0.64
UNIFORM COSINE	53.58	2	61.58	38.46	0.00	1.17	1.46
UNIFORM	71.90	0	71.90	48.77	0.00	0.25	0.45
Model Average						**21.85**	**0.64**
Spring 2 Season							
HAZARD	419.14	2	423.42	0.00	0.92	13.02	0.23
HALF	426.41	1	428.50	5.08	0.07	18.86	0.25
UNIFORM COSINE	425.46	4	434.41	11.00	0.00	15.95	0.35
UNIFORM	563.20	0	563.20	139.78	0.00	2.27	0.22
Model Average						**13.46**	**0.24**
Summer 2 Season							
HAZARD SIMPLE	606.98	4	615.76	0.00	0.51	9.51	0.35
HAZARD	616.32	2	620.54	4.78	0.05	9.00	0.31
HALF	616.88	1	618.95	3.19	0.10	6.13	0.23
UNIFORM COSINE	610.05	3	616.52	0.76	0.35	7.20	0.25
UNIFORM	671.04	0	671.04 5	5.28	0.00	2.52	0.23
Model Average						**8.34**	**0.35**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.2. Grasshopper seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD SIMPLE	1775.25	4	1781.37	1.89	0.27	106.30	0.15
HALF	1777.46	1	1779.48	0.00	0.68	107.34	0.14
HAZARD COSINE	1779.51	3	1785.62	6.14	0.03	103.45	0.16
HAZARD	1782.79	2	1786.85	7.37	0.02	105.39	0.15
UNIFORM COSINE	1810.38	5	1820.67	41.18	0.00	78.36	0.14
UNIFORM	2552.36	0	2552.36	772.88	0.00	10.50	0.14
Model Average						**106.91**	**0.15**
Summer Season							
HAZARD SIMPLE	1222.82	3	1229.00	1.27	0.34	71.83	0.15
HALF	1225.69	1	1227.72	0.00	0.65	72.59	0.11
HAZARD	1232.84	2	1236.93	9.20	0.01	61.07	0.11
UNIFORM COSINE	1285.69	2	1289.78	62.06	0.00	39.24	0.13
UNIFORM	1701.58	0	1701.58	473.85	0.00	8.02	0.09
Model Average						**72.26**	**0.12**
Spring 2 Season							
HAZARD SIMPLE	1475.19	3.00	1481.34	4.17	0.11	56.25	0.13
HALF	1475.14	1.00	1477.17	0.00	0.85	65.36	0.12
HAZARD	1478.89	2.00	1482.96	5.79	0.05	52.28	0.12
UNIFORM COSINE	1482.85	5.00	1493.21	16.05	0.00	53.61	0.12
UNIFORM	2061.06	0.00	2061.06	583.90	0.00	6.92	0.11
Model Average						**63.78**	**0.13**
Summer 2 Season							
HALF COSINE	1401.34	2	1405.44	0.45	0.35	18.49	0.12
HAZARD SIMPLE	1398.79	3	1404.98	0.00	0.44	19.49	0.17
HALF	1410.96	1	1412.99	8.01	0.01	15.29	0.12
HAZARD	1402.37	2	1406.46	1.48	0.21	18.84	0.15
UNIFORM COSINE	1415.84	2	1419.94	14.95	0.00	13.84	0.11
UNIFORM	1557.78	0	1557.78	152.80	0.00	5.33	0.10
Model Average						**18.97**	**0.15**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.3. Horned lark seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	1832.05	2	1836.11	0.00	0.99	107.31	0.14
UNIFORM COSINE	1840.98	4	1849.18	13.07	0.00	111.21	0.16
HALF	1843.70	1	1845.72	9.61	0.01	126.26	0.14
UNIFORM	2444.52	0	2444.52	608.41	0.00	18.60	0.14
Model Average						**107.47**	**0.14**
Summer Season							
HAZARD	1940.68	2.00	1944.74	0.00	1.00	98.95	0.15
UNIFORM COSINE	1964.18	4.00	1972.37	27.63	0.00	122.77	0.19
HALF	1965.46	1.00	1967.47	22.74	0.00	130.32	0.15
UNIFORM	2576.33	0.00	2576.33	631.59	0.00	18.96	0.15
Model Average						**98.95**	**0.15**
Fall Season							
HAZARD SIMPLE	1997.84	3	2003.95	0.00	0.71	301.35	0.30
HAZARD	2002.82	2	2006.88	2.92	0.17	296.65	0.29
HALF COSINE	2001.59	3	2007.71	3.76	0.11	283.93	0.29
UNIFORM COSINE	2002.07	5	2012.37	8.41	0.01	244.64	0.29
HALF	2039.06	1	2041.08	37.13	0.00	197.77	0.28
UNIFORM	2492.45	0	2492.45	488.50	0.00	53.17	0.29
Model Average						**298.07**	**0.30**
Winter Season							
HAZARD	592.03	2	596.23	0.00	0.98	182.17	0.30
HALF COSINE	595.41	4	604.10	7.87	0.02	175.85	0.28
UNIFORM COSINE	611.05	4	619.74	23.51	0.00	90.85	0.27
HALF	624.10	1	626.17	29.94	0.00	95.97	0.27
UNIFORM	754.92	0	754.92	158.69	0.00	22.83	0.25
Model Average						**182.05**	**0.30**
Spring 2 Season							
HAZARD SIMPLE	1040.03	3	1046.24	1.68	0.16	40.95	0.23
HAZARD	1042.92	2	1047.03	2.46	0.11	34.50	0.21
HALF COSINE	1040.46	2	1044.56	0.00	0.38	43.33	0.23
UNIFORM COSINE	1040.69	4	1049.05	4.48	0.04	41.29	0.25
HALF	1043.00	1	1045.03	0.47	0.30	47.29	0.22
UNIFORM	1402.00	0	1402.00	357.44	0.00	6.36	0.21
Model Average						**43.07**	**0.24**
Summer 2 Season							
HAZARD	977.84	2	981.98	2.20	0.15	23.14	0.15
HALF COSINE	975.64	2	979.78	0.00	0.45	27.04	0.14
UNIFORM COSINE	976.63	3	982.89	3.12	0.10	24.95	0.14
HALF	978.56	1	980.61	0.83	0.30	24.37	0.14
UNIFORM	1126.40	0	1126.40	146.62	0.00	6.37 0.13	
Model Average						**25.45**	**0.15**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.4. Killdeer seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD	586.06	2	590.28	1.33	0.30	14.05	0.20
HALF COSINE	582.50	3	588.95	0.00	0.59	17.49	0.19
UNIFORM COSINE	583.87	4	592.63	3.68	0.09	14.52	0.21
HALF	596.76	1	598.83	9.88	0.00	11.93	0.17
UNIFORM SIMPLE	590.34	3	596.79	7.84	0.01	11.75	0.18
UNIFORM	683.03	0	683.03	94.08	0.00	3.61	0.16
Model Average						**16.08**	**0.22**
Summer Season							
HAZARD	952.54	2	956.68	0.89	0.29	17.62	0.16
HALF COSINE	951.65	2	955.79	0.00	0.45	18.49	0.14
UNIFORM COSINE	952.09	3	958.37	2.59	0.12	17.62	0.14
HALF	956.09	1	958.14	2.35	0.14	16.03	0.12
UNIFORM SIMPLE	974.68	2	978.82	23.03	0.00	11.20	0.14
UNIFORM	1054.50	0	1054.50	98.71	0.00	5.63	0.11
Model Average						**17.79**	**0.15**
Fall Season							
HAZARD	120.13	2	125.63	1.47	0.17	3.55	0.62
UNIFORM COSINE	122.59	1	125.04	0.88	0.23	1.94	0.49
HALF	121.71	1	124.16	0.00	0.36	2.51	0.45
UNIFORM SIMPLE	122.52	1	124.97	0.81	0.24	1.93	0.43
UNIFORM	131.81	0	131.81	7.65	0.01	0.93	0.39
Model Average						**2.41**	**0.54**
Spring 2 Season							
HAZARD	967.62	2	971.75	0.00	0.82	14.30	0.17
UNIFORM COSINE	971.69	3	977.95	6.20	0.04	17.50	0.19
HALF	973.56	1	975.60	3.85	0.12	17.26	0.18
UNIFORM SIMPLE	970.11	4	978.55	6.80	0.03	17.37	0.19
UNIFORM	1162.34	0	1162.34	190.60	0.00	3.91	0.16
Model Average						**14.85**	**0.19**
Summer 2 Season							
HAZARD	499.56	2	503.84	0.00	0.74	3.20	0.16
HALF COSINE	505.42	3	512.00	8.16	0.01	3.60	0.47
UNIFORM COSINE	511.67	1	513.76	9.92	0.01	3.81	0.26
HALF	515.37	1	517.46	13.62	0.00	3.91	0.24
UNIFORM SIMPLE	499.46	3	506.05	2.21	0.24	3.48	0.33
UNIFORM	539.23	0	539.23	35.39	0.00	1.96	0.16
Model Average						**3.28**	**0.21**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.5. Meadowlark spp. seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD SIMPLE	8055.13	3	8061.16	0.00	0.93	378.94	0.09
HAZARD COSINE	8062.80	3	8068.82	7.66	0.02	373.17	0.09
HALF COSINE	8062.45	3	8068.47	7.31	0.02	402.06	0.09
HAZARD	8063.96	2	8067.97	6.81	0.03	381.56	0.09
HALF	8166.13	1	8168.13	106.97	0.00	347.00	0.09
UNIFORM COSINE	8226.79	5	8236.86	175.70	0.00	277.13	0.09
UNIFORM	10856.53	0	10856.53	2795.37	0.00	48.49	0.09
Model Average						**379.46**	**0.09**
Summer Season							
HAZARD SIMPLE	5192.12	3	5198.17	2.39	0.22	150.81	0.08
HALF COSINE	5187.70	4	5195.78	0.00	0.74	165.77	0.10
HAZARD	5198.97	2	5202.99	7.21	0.02	144.09	0.08
HALF	5201.90	1	5203.91	8.13	0.01	161.58	0.08
UNIFORM COSINE	5203.05	3	5209.09	13.32	0.00	146.57	0.07
UNIFORM	6434.83	0	6434.83	1239.06	0.00	30.78	0.07
Model Average						**161.90**	**0.10**
Fall Season							
HAZARD SIMPLE	3563.62	5	3573.81	7.45	0.02	232.50	0.20
HAZARD COSINE	3558.24	4	3566.36	0.00	0.98	242.59	0.19
HALF COSINE	3583.61	4	3591.73	25.37	0.00	147.19	0.14
HAZARD	3584.63	2	3588.66	22.30	0.00	208.58	0.17
HALF	3630.13	1	3632.14	65.78	0.00	104.42	0.14
UNIFORM COSINE	3594.34	4	3602.46	36.10	0.00	142.08	0.14
UNIFORM	4014.28	0	4014.28	447.92	0.00	42.36	0.15
Model Average						**242.35**	**0.19**
Winter Season							
HALF COSINE	917.47	3	923.72	11.16	0.00	79.59	0.18
HAZARD	908.43	2	912.56	0.00	1.00	105.18	0.21
HALF	951.68	1	953.72	41.16	0.00	60.76	0.18
UNIFORM COSINE	981.78	3	988.03	75.48	0.00	38.75	0.21
UNIFORM	1198.29	0	1198.29	285.73	0.00	13.61	0.23
Model Average						**105.08**	**0.21**
Spring 2 Season							
HAZARD SIMPLE	4826.95	3	4833.00	0.44	0.39	95.62	0.08
HALF COSINE	4833.11	2	4837.13	4.57	0.05	105.58	0.08
HAZARD	4833.93	2	4837.95	5.39	0.03	92.31	0.08
HALF	4835.50	1	4837.51	4.95	0.04	104.45	0.08
UNIFORM COSINE	4824.48	4	4832.56	0.00	0.49	103.52	0.08
UNIFORM	6015.43	0	6015.43	1182.87	0.00	20.13	0.07
Model Average						**100.21**	**0.09**

Table C.5. Continued.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Summer 2 Season							
HAZARD SIMPLE	3496.93	3	3503.00	0.00	0.60	49.31	0.10
HALF COSINE	3498.97	3	3505.04	2.04	0.22	51.95	0.08
HAZARD	3512.16	2	3516.19	13.19	0.00	46.30	0.08
HALF	3517.58	1	3519.59	16.59	0.00	40.35	0.06
UNIFORM COSINE	3497.33	4	3505.46	2.45	0.18	50.04	0.07
UNIFORM	3870.49	0	3870.49	367.48	0.00	14.34	0.05
Model Average						**50.01**	**0.09**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.6. Mourning dove seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HAZARD SIMPLE	1984.39	3	1990.52	0.00	0.56	77.42	0.16
HALF COSINE	1985.58	3	1991.70	1.19	0.31	62.99	0.12
HAZARD	1992.84	2	1996.90	6.38	0.02	66.00	0.14
UNIFORM COSINE	1983.54	5	1993.85	3.33	0.11	62.80	0.13
HALF	2015.91	1	2017.93	27.42	0.00	48.02	0.11
UNIFORM SIMPLE	2028.23	3	2034.36	43.84	0.00	39.83	0.11
UNIFORM	2348.65	0	2348.65	358.14	0.00	12.60	0.11
Model Average						**71.13**	**0.18**
Summer Season							
HAZARD SIMPLE	2635.93	3	2642.03	0.00	0.50	87.34	0.14
HALF COSINE	2637.51	3	2643.61	1.58	0.23	88.64	0.11
HAZARD	2642.83	2	2646.88	4.85	0.04	85.17	0.13
UNIFORM COSINE	2633.39	5	2643.64	1.61	0.22	92.19	0.12
HALF	2663.01	1	2665.02	23.00	0.00	64.93	0.10
UNIFORM SIMPLE	2654.34	3	2660.44	18.41	0.00	63.59	0.10
UNIFORM	2947.80	0	2947.80	305.77	0.00	21.77	0.10
Model Average						**88.63**	**0.13**
Fall Season							
HALF COSINE	621.34	4	630.09	3.74	0.13	36.65	0.30
HAZARD	622.13	2	626.35	0.00	0.81	43.62	0.37
UNIFORM COSINE	620.38	5	631.53	5.18	0.06	36.68	0.30
HALF	643.65	1	645.72	19.37	0.00	23.31	0.28
UNIFORM SIMPLE	637.33	3	643.78	17.43	0.00	23.74	0.28
UNIFORM	695.01	0	695.01	68.66	0.00	10.73	0.28
Model Average						**42.32**	**0.37**
Winter Season							
HAZARD	205.22	2	209.92	1.86	0.26	7.42	0.42
UNIFORM COSINE	208.11	2	212.81	4.75	0.06	5.42	0.44
HALF	205.84	1	208.07	0.00	0.65	6.97	0.38
UNIFORM SIMPLE	211.58	1	213.80	5.74	0.04	4.53	0.36
UNIFORM	239.66	0	239.66	31.59	0.00	2.37	0.37
Model Average						**6.90**	**0.41**
Spring 2 Season							
HALF COSINE	1088.91	2	1093.02	1.68	0.28	20.73	0.14
HAZARD	1087.23	2	1091.35	0.00	0.64	18.59	0.16
UNIFORM COSINE	1088.24	4	1096.64	5.29	0.05	19.88	0.15
HALF	1094.87	1	1096.91	5.56	0.04	18.79	0.14
UNIFORM SIMPLE	1098.41	4	1106.80	15.45	0.00	15.70	0.15
UNIFORM	1282.17	0	1282.17	190.82	0.00	5.02	0.14
Model Average						**19.25**	**0.16**

Table C.6. Continued.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Summer 2 Season							
HAZARD SIMPLE	1600.60	3	1606.77	0.47	0.29	16.99	0.18
HAZARD	1608.61	2	1612.69	6.40	0.01	15.50	0.12
UNIFORM COSINE	1604.27	1	1606.30	0.00	0.36	15.63	0.10
HALF	1605.59	1	1607.62	1.32	0.19	16.71	0.11
UNIFORM SIMPLE	1606.06	1	1608.09	1.79	0.15	13.80	0.09
UNIFORM	1689.59	0	1689.59	83.30	0.00	8.13	0.09
Model Average						**15.95**	**0.14**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.7. Red-winged blackbird seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring Season							
HALF COSINE	3050.77	3	3056.86	0.00	0.92	139.24	0.26
UNIFORM COSINE	3051.50	5	3061.71	4.85	0.08	127.78	0.26
HAZARD SIMPLE	3060.55	4	3068.69	11.84	0.00	139.81	0.27
HAZARD	3091.05	2	3095.09	38.24	0.00	125.45	0.26
HALF	3115.31	1	3117.32	60.46	0.00	90.80	0.25
UNIFORM SIMPLE	3093.65	4	3101.79	44.93	0.00	94.40	0.25
UNIFORM	3487.03	0	3487.03	430.18	0.00	50.88	0.31
Model Average						**138.31**	**0.26**
Summer Season							
HALF COSINE	1964.13	3	1970.27	0.00	0.59	184.00	0.24
UNIFORM COSINE	1963.41	4	1971.64	1.37	0.30	171.31	0.24
HAZARD	1969.56	2	1973.63	3.36	0.11	164.78	0.25
HALF	2008.45	1	2010.47	40.20	0.00	133.70	0.23
UNIFORM SIMPLE	1994.84	3	2000.97	30.70	0.00	130.55	0.23
UNIFORM	2204.86	0	2204.86	234.59	0.00	57.55	0.23
Model Average						**178.10**	**0.25**
Fall Season							
HALF COSINE	949.72	2	953.87	6.43	0.04	375.69	0.33
UNIFORM COSINE	949.02	3	955.32	7.88	0.02	366.72	0.33
HAZARD	943.29	2	947.44	0.00	0.94	925.81	0.42
HALF	962.93	1	964.98	17.54	0.00	262.32	0.32
UNIFORM SIMPLE	947.40	5	958.16	10.72	0.00	375.72	0.33
UNIFORM	1018.55	0	1018.55	71.11	0.00	126.01	0.28
Model Average						**892.27**	**0.45**
Winter Season							
HALF COSINE	406.17	2	410.50	0.97	0.22	224.80	0.55
UNIFORM COSINE	406.73	3	413.41	3.88	0.05	176.24	0.58
HAZARD	405.19	2	409.53	0.00	0.36	194.05	0.54
HALF	409.26	1	411.37	1.84	0.14	168.99	0.54
UNIFORM SIMPLE	403.87	3	410.56	1.03	0.22	183.22	0.54
UNIFORM	467.33	0	467.33	57.81	0.00	62.05	0.39
Model Average						**194.02**	**0.55**
Spring 2 Season							
HALF COSINE	2667.65	4	2675.80	3.42	0.15	76.97	0.23
UNIFORM COSINE	2664.23	4	2672.38	0.00	0.81	82.90	0.21
HAZARD SIMPLE	2672.40	3	2678.49	6.11	0.04	76.05	0.22
HAZARD	2677.25	2	2681.29	8.91	0.01	75.01	0.21
HALF	2686.79	1	2688.81	16.43	0.00	72.76	0.21
UNIFORM SIMPLE	2717.31	3	2723.40	51.02	0.00	56.62	0.21
UNIFORM	3187.46	0	3187.46	515.08	0.00	24.18	0.23
Model Average						**81.70**	**0.22**

Table C.7. Continued.

Model[1]	-2LL	K	AICc	Delta	w	D	CV
Summer 2 Season							
UNIFORM COSINE	1881.94	3	1888.08	0.80	0.20	54.53	0.19
HAZARD SIMPLE	1881.13	3	1887.27	0.00	0.30	54.02	0.21
HAZARD	1887.83	2	1891.90	4.62	0.03	53.31	0.20
HALF	1885.56	1	1887.59	0.31	0.25	51.97	0.19
UNIFORM SIMPLE	1881.67	3	1887.81	0.54	0.23	52.50	0.19
UNIFORM	2085.03	0	2085.03	197.76	0.00	23.72	0.22
Model Average						**53.24**	**0.20**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.8. Sandhill crane seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Fall Season							
UNIFORM COSINE	1359.46	1	1361.49	0.00	0.34	261.18	0.48
HALF	1359.88	1	1361.92	0.42	0.27	260.43	0.48
UNIFORM SIMPLE	1360.31	1	1362.35	0.85	0.22	258.23	0.48
HAZARD	1359.28	2	1363.39	1.8 9	0.13	269.60	0.51
UNIFORM	1366.05	0	1366.05	4.56	0.03	257.31	0.46
Model Average						**261.30**	**0.48**
Winter Season							
UNIFORM COSINE	554.79	1	556.88	0.00	0.40	85.49	0.43
HALF	555.75	1	557.83	0.96	0.25	86.01	0.43
UNIFORM SIMPLE	554.57	2	558.85	1.97	0.15	87.58	0.44
HAZARD	554.13	2	558.40	1.52	0.19	70.22	0.52
UNIFORM	563.20	0	563.20	6.32	0.02	81.91	0.40
Model Average						**83.02**	**0.45**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation.

Table C.9. Western meadowlark seasonal detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Spring 2 Season							
HAZARD SIMP	3685.21	3	3691.28	0.00	0.81	78.49	0.08
UNIFORM COS	3690.22	4	3698.32	7.05	0.02	80.19	0.08
HAZARD	3693.60	2	3697.63	6.35	0.03	76.00	0.08
HALF	3692.84	1	3694.85	3.57	0.14	83.09	0.08
UNIFORM	4637.39	0	4637.39	946.12	0.00	14.88	0.07
Model Average						**79.07**	**0.08**
Summer 2 Season							
HAZARD SIMPLE	2123.10	3	2129.22	4.30	0.10	30.18	0.14
UNIFORM COSINE	2118.80	3	2124.93	0.00	0.82	27.94	0.08
HALF COSINE	2121.40	4	2129.60	4.68	0.08	28.67	0.12
HAZARD	2134.11	2	2138.18	13.25	0.00	27.16	0.10
HALF	2139.56	1	2141.58	16.65	0.00	23.53	0.08
UNIFORM	2372.62	0	2372.62	247.69	0.00	7.93	0.06
Model Average						**28.21**	**0.09**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.10. Barn swallow global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Density Function							
HALF COSINE	726.87	2	731.05	0.00	0.29	43.34	0.21
HAZARD COSINE	724.75	3	731.12	0.07	0.28	38.39	0.22
HAZARD	727.70	2	731.88	0.83	0.19	34.50	0.22
UNIFORM COSINE	726.35	3	732.72	1.66	0.13	39.48	0.22
HALF	731.05	1	733.11	2.06	0.10	36.90	0.20
UNIFORM SIMPLE	731.51	3	737.88	6.82	0.01	32.92	0.21
UNIFORM	826.82	0	826.82	95.77	0.00	12.44	0.20
Model Average						**39.01**	**23.01%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
2.22	0.50	15.73	0.35	11.30	0.44	3.05	0.36	11.06	0.38
1.98	0.50	12.78	0.35	11.28	0.44	2.77	0.36	9.57	0.38
1.65	0.50	10.07	0.34	11.97	0.44	2.88	0.36	7.93	0.37
2.02	0.50	13.67	0.35	11.02	0.44	2.82	0.37	9.95	0.38
1.88	0.49	12.49	0.34	10.72	0.43	2.62	0.36	9.19	0.37
1.67	0.49	10.59	0.34	10.28	0.44	2.36	0.36	8.02	0.37
0.54	0.52	3.39	0.33	4.86	0.41	1.34	0.38	2.32	0.33
1.98	**50.79%**	**13.18**	**37.79%**	**11.32**	**43.87%**	**2.86**	**36.74%**	**9.68**	**39.15%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.11. Brown-headed cowbird global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD SIMPLE	425.37	2	429.68	0.00	0.54	1164.02	3.40
HALF COSINE	426.56	3	433.19	3.51	0.09	1256.21	3.59
HALF	438.14	1	440.24	10.56	0.00	915.80	3.64
UNIFORM SIMPLE	433.46	4	442.54	12.86	0.00	893.43	3.65
UNIFROM COSINE	444.98	2	449.28	19.61	0.00	696.65	3.65
UNIFORM	503.28	0	503.28	73.60	0.00	22.62	0.42
Model Average						**751.36**	**356.99%**

Summer		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1093.50	3.62	22.75	0.51	31.69	1.22	6.32	0.59	9.79	0.53
1195.10	3.77	21.99	0.49	25.63	1.21	5.02	0.57	8.42	0.50
867.05	3.84	20.42	0.50	18.23	1.20	3.44	0.56	6.67	0.49
845.97	3.86	19.83	0.52	17.71	1.21	3.31	0.57	6.61	0.51
657.57	3.87	17.57	0.51	13.71	1.21	2.54	0.56	5.25	0.50
5.42	1.09	8.66	0.45	5.09	1.20	0.86	0.71	2.60	0.48
707.26	**377.81%**	**14.45**	**88.09%**	**19.63**	**157.25%**	**3.91**	**82.96%**	**6.12**	**77.61%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.12. Canada goose global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM COSINE	774.38	1	776.45	0.00	0.37	400.65	0.48
HALF	775.26	1	777.32	0.87	0.24	348.90	0.47
UNIFORM SIMPLE	775.82	1	777.89	1.44	0.18	319.36	0.46
UNIFORM	778.89	0	778.89	2.44	0.11	306.68	0.41
HAZARD	774.90	2	779.10	2.65	0.10	399.76	0.51
Model Average						**363.18**	**48.16%**

Fall		**Winter**	
D	**CV**	**D**	**CV**
18.80	0.79	381.85	0.50
20.06	0.79	328.84	0.49
21.92	0.79	297.44	0.49
84.76	0.84	221.93	0.46
20.56	0.83	379.20	0.54
27.06	**94.27%**	**336.12**	**52.34%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation.

Table C.13. Cliff swallow global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	583.97	2	588.20	0.00	0.89	87.14	0.31
HALF COSINE	581.19	5	592.37	4.17	0.11	75.06	0.25
UNIFORM COSINE	593.87	3	600.32	12.13	0.00	43.79	0.24
HALF	598.38	1	600.45	12.25	0.00	42.66	0.22
UNIFORM SIMPLE	597.60	3	604.06	15.86	0.00	37.61	0.23
UNIFORM	683.03	0	683.03	94.83	0.00	13.44	0.24
Model Average						**85.62**	**30.87%**

Spring		**Summer**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**
1.88	0.84	68.00	0.32	6.46	0.55
1.65	0.83	59.49	0.27	5.69	0.52
1.00	0.83	34.34	0.26	3.24	0.50
0.97	0.82	33.43	0.25	3.16	0.49
0.86	0.82	29.41	0.25	2.74	0.49
0.24	0.81	11.25	0.27	0.92	0.44
1.85	**84.49%**	**62.92**	**32.03%**	**6.36**	**54.52%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.14. Common grackle global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	750.95	2	755.14	0.00	0.47	78.93	0.29
HALF COSINE	752.17	2	756.36	1.22	0.25	91.08	0.28
UNIFORM COSINE	750.39	3	756.76	1.62	0.21	82.59	0.28
UNIFORM SIMPLE	750.70	4	759.33	4.20	0.06	77.47	0.27
HALF	760.22	1	762.28	7.15	0.01	64.48	0.26
UNIFORM	814.84	0	814.84	59.70	0.00	35.62	0.26
Model Average						**82.50**	**29.00%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
17.34	0.45	26.78	0.51	0.73	0.74	17.02	0.59	8.32	0.72	7.90	0.73
18.96	0.45	32.20	0.51	0.34	0.37	19.25	0.58	8.40	0.75	10.95	0.76
16.96	0.45	28.86	0.51	0.23	0.23	17.91	0.58	8.21	0.74	9.52	0.75
15.89	0.44	26.77	0.50	0.06	0.06	17.03	0.57	8.05	0.74	8.72	0.74
13.46	0.43	22.14	0.50	0.01	0.01	14.33	0.57	6.91	0.73	6.96	0.72
10.94	0.60	9.64	0.42	0.00	0.00	6.55	0.56	2.68	0.62	2.60	0.59
17.54	**45.34%**	**28.52**	**51.79%**	**1.37**	**102.3%2**	**17.74**	**58.31%**	**8.28**	**73.34%**	**9.05**	**75.81%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.15. Common nighthawk global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF	1102.07	1	1104.11	0.00	0.50	13.84	0.17
UNIFORM SIMPLE	1097.11	4	1105.53	1.42	0.24	14.45	0.18
HAZARD	1102.61	2	1106.73	2.62	0.13	12.48	0.18
UNIFORM COSINE	1100.63	3	1106.88	2.77	0.12	15.13	0.19
UNIFORM	1198.29	0	1198.29	94.18	0.00	5.09	0.15
Model Average						**13.97**	**18.31%**

Spring		**Summer**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.43	0.57	9.86	0.20	1.70	0.32	0.85	0.41
1.50	0.57	10.29	0.21	1.77	0.33	0.89	0.42
1.26	0.57	8.89	0.21	1.55	0.32	0.78	0.42
1.59	0.57	10.77	0.22	1.85	0.33	0.93	0.42
0.49	0.57	3.65	0.19	0.63	0.31	0.32	0.41
1.45	**57.32%**	**9.95**	**21.40%**	**1.72**	**32.78%**	**0.86**	**41.92%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.16. Dickcissel global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	1419.29	2	1423.37	0.00	0.99	44.47	0.16
HALF	1431.91	1	1433.94	10.57	0.01	44.05	0.15
UNIFORM SIMPLE	1435.40	4	1443.67	20.30	0.00	37.51	0.17
UNIFORM COSINE	1450.23	3	1456.39	33.02	0.00	34.23	0.17
UNIFORM	1833.39	0	1833.39	410.02	0.00	7.30	0.15
Model Average						**44.47**	**16.09%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
14.36	0.30	12.32	0.33	0.26	0.26	7.82	0.24	9.71	0.26
14.36	0.29	12.01	0.33	0.00	0.00	7.75	0.23	9.67	0.25
12.19	0.31	10.31	0.34	0.00	0.00	6.59	0.25	8.20	0.26
11.12	0.31	9.43	0.33	0.00	0.00	6.01	0.24	7.48	0.26
2.29	0.29	2.14	0.32	0.00	0.00	1.26	0.23	1.56	0.25
14.36	**29.92%**	**12.32**	**32.94%**	**0.26**	**100.23%**	**7.82**	**23.58%**	**9.71**	**25.56%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.17. Eastern meadowlark global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	748.81	2	752.98	0.00	0.28	13.37	0.17
HAZARD SIMPLE	746.79	3	753.13	0.15	0.26	13.93	0.19
HALF COSINE	746.99	3	753.33	0.35	0.23	15.13	0.18
HALF	752.40	1	754.45	1.47	0.13	12.52	0.15
UNIFORM COSINE	746.34	4	754.91	1.93	0.10	13.79	0.18
UNIFORM SIMPLE	783.83	1	785.89	32.91	0.00	7.12	0.14
UNIFORM	898.72	0	898.72	145.74	0.00	2.91	0.14
Model Average						**13.85**	**18.56%**

Spring 2		**Summer 2**	
D	**CV**	**D**	**CV**
7.78	0.20	5.59	0.25
8.10	0.22	5.83	0.26
8.77	0.20	6.36	0.25
7.26	0.18	5.26	0.23
8.00	0.20	5.79	0.25
4.15	0.17	2.98	0.22
1.71	0.17	1.20	0.22
8.04	**21.21%**	**5.81**	**25.53%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.18. Great-tailed grackle global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM SIMPLE	985.77	1	987.82	0.00	0.37	26.12	0.21
HALF	986.66	1	988.71	0.88	0.24	30.84	0.23
HAZARD SIMPLE	983.00	3	989.29	1.47	0.18	37.40	0.31
UNIFORM COSINE	987.30	1	989.35	1.53	0.17	30.41	0.22
HAZARD	987.59	2	991.74	3.92	0.05	47.34	0.33
UNIFORM	1018.55	0	1018.55	30.73	0.00	17.96	0.20
Model Average						**31.04**	**28.71%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
11.15	0.37	5.09	0.46	0.25	0.25	2.04	0.63	2.29	0.45	4.87	0.38
13.74	0.38	5.83	0.47	0.18	0.19	2.36	0.64	2.55	0.46	5.57	0.38
16.81	0.43	7.06	0.51	0.16	0.17	2.72	0.67	2.75	0.50	7.11	0.44
13.46	0.37	5.79	0.46	0.13	0.13	2.34	0.63	2.56	0.45	5.49	0.38
21.67	0.45	9.18	0.53	0.06	0.06	3.07	0.68	3.03	0.52	9.26	0.46
8.06	0.37	3.28	0.41	0.00	0.00	1.16	0.58	1.71	0.43	3.33	0.36
13.69	**42.73%**	**5.94**	**49.98%**	**0.79**	**101.90%**	**2.34**	**65.40%**	**2.52**	**47.29%**	**5.76**	**43.29%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.19. Lark sparrow global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD SIMPLE	1784.24	3	1790.36	0.00	0.63	174.93	0.13
HAZARD	1787.49	2	1791.55	1.19	0.35	158.94	0.13
HALF COSINE	1790.58	3	1796.70	6.34	0.03	150.28	0.11
HALF	1824.91	1	1826.93	36.57	0.00	120.80	0.11
UNIFORM COSINE	1865.68	4	1873.88	83.52	0.00	95.76	0.13
UNIFORM	2444.52	0	2444.52	654.16	0.00	15.62	0.11
Model Average						**168.74**	**13.77%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
33.08	0.18	96.79	0.17	3.89	0.63	9.38	0.30	31.79	0.26
30.50	0.18	88.30	0.17	3.54	0.62	9.01	0.30	27.59	0.26
28.77	0.17	83.18	0.16	3.36	0.62	8.46	0.30	26.51	0.25
23.40	0.17	66.57	0.15	2.72	0.62	7.11	0.30	21.00	0.25
18.83	0.18	52.59	0.17	2.17	0.63	5.84	0.31	16.33	0.26
3.13	0.17	9.06	0.16	0.34	0.62	0.97	0.30	2.12	0.24
32.07	**18.63%**	**93.49**	**17.77%**	**3.75**	**62.66%**	**9.23**	**30.44%**	**30.19**	**27.17%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.20. Mallard global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	838.67	2	842.85	0.00	0.42	30.16	0.38
HAZARD	840.28	2	844.45	1.60	0.19	29.84	0.44
UNIFORM COSINE	842.99	1	845.05	2.20	0.14	25.57	0.38
HALF	843.12	1	845.18	2.33	0.13	25.23	0.38
UNIFORM SIMPLE	843.58	1	845.64	2.79	0.11	24.14	0.37
UNIFORM	850.79	0	850.79	7.94	0.01	18.02	0.31
Model Average						**28.07**	**40.14%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
5.75	0.44	6.44	0.47	15.28	0.65	1.85	0.42	0.15	0.72
5.76	0.50	6.02	0.52	15.13	0.69	1.83	0.48	0.15	0.75
5.28	0.43	3.96	0.45	13.83	0.63	1.39	0.40	0.12	0.71
5.25	0.43	3.80	0.44	13.57	0.63	1.35	0.40	0.11	0.71
5.10	0.42	3.49	0.44	12.85	0.63	1.25	0.39	0.11	0.70
5.42	0.52	2.71	0.43	8.40	0.56	0.86	0.38	0.08	0.70
5.55	**45.10%**	**5.32**	**53.69%**	**14.51**	**65.29%**	**1.64**	**45.40%**	**0.13**	**73.35%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.21. Northern bobwhite global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM SIMPLE	2188.34	3	2194.47	0.00	0.45	20.29	0.12
HAZARD SIMPLE	2189.30	3	2195.43	0.95	0.28	18.52	0.15
UNIFORM COSINE	2194.76	1	2196.78	2.30	0.14	18.79	0.10
HALF	2195.34	1	2197.36	2.88	0.11	19.46	0.11
HAZARD	2197.25	2	2201.31	6.84	0.01	18.51	0.12
UNIFORM	2288.74	0	2288.74	94.27	0.00	9.50	0.11
Model Average						**19.46**	**13.02%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.12	0.35	10.79	0.17	0.08	0.08	0.21	0.70	3.99	0.18	4.01	0.16
1.04	0.36	9.76	0.19	0.05	0.05	0.19	0.71	3.68	0.20	3.69	0.18
1.05	0.34	9.89	0.15	0.02	0.02	0.20	0.70	3.74	0.17	3.74	0.14
1.08	0.34	10.29	0.16	0.02	0.02	0.20	0.70	3.85	0.17	3.87	0.15
1.04	0.35	9.72	0.17	0.00	0.00	0.20	0.70	3.69	0.18	3.70	0.16
0.54	0.34	5.00	0.18	0.00	0.00	0.10	0.70	1.90	0.16	1.88	0.14
1.08	**34.81%**	**10.30**	**17.47%**	**0.17**	**100.42%**	**0.20**	**70.13%**	**3.85**	**18.73%**	**3.86**	**16.75%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.22. Northern harrier global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	1495.09	2	1499.18	0.00	0.38	14.67	0.16
HAZARD COSINE	1493.79	3	1499.98	0.79	0.25	14.27	0.16
HAZARD	1496.62	2	1500.72	1.54	0.18	13.22	0.20
UNIFORM COSINE	1494.93	3	1501.12	1.94	0.14	14.85	0.17
UNIFORM SIMPLE	1495.00	4	1503.33	4.14	0.05	13.89	0.16
HALF	1506.91	1	1508.94	9.75	0.00	10.98	0.14
UNIFORM	1545.80	0	1545.80	46.61	0.00	6.4 9	0.12
Model Average						**14.29**	**17.25%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.91	0.29	0.87	0.41	6.63	0.24	4.40	0.22	0.87	0.40
1.87	0.29	0.84	0.41	6.42	0.24	4.28	0.23	0.87	0.40
1.73	0.31	0.78	0.42	5.88	0.27	4.02	0.25	0.81	0.41
1.93	0.29	0.88	0.41	6.72	0.24	4.44	0.23	0.88	0.40
1.82	0.29	0.82	0.41	6.24	0.24	4.17	0.22	0.84	0.40
1.46	0.28	0.64	0.40	4.80	0.23	3.40	0.21	0.68	0.39
0.88	0.28	0.36	0.39	2.79	0.22	2.02	0.20	0.45	0.39
1.86	**29.63%**	**0.84**	**41.26%**	**6.43**	**25.00%**	**4.29**	**23.24%**	**0.86**	**40.34%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.23. Northern mockingbird global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	-2LL	K	AICc	Delta	w	D	CV
Global Detection Function							
UNIFORM SIMPLE	882.13	3	888.42	0.00	0.54	16.14	0.15
HAZARD SIMPLE	884.34	3	890.63	2.20	0.18	16.14	0.19
HAZARD	886.69	2	890.83	2.41	0.16	15.75	0.17
HALF	889.47	1	891.52	3.09	0.12	15.54	0.16
UNIFORM COSINE	897.88	2	902.02	13.60	0.00	11.88	0.17
UNIFORM	1030.53	0	1030.53	142.11	0.00	4.26	0.14
Model Average						**16.00**	**16.39%**

Spring		Summer		Fall		Spring 2		Summer 2	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
2.85	0.34	6.50	0.27	0.09	0.09	2.50	0.28	4.12	0.24
2.84	0.35	6.33	0.30	0.03	0.03	2.64	0.30	4.17	0.27
2.77	0.35	6.12	0.29	0.03	0.03	2.62	0.29	4.07	0.25
2.74	0.34	6.24	0.28	0.02	0.02	2.41	0.28	3.99	0.24
2.11	0.34	4.70	0.28	0.00	0.00	1.85	0.28	3.10	0.25
0.73	0.33	1.61	0.28	0.00	0.00	0.74	0.27	1.12	0.24
2.82	**34.15%**	**6.38**	**28.06%**	**0.16**	**100.33%**	**2.53**	**28.43%**	**4.11**	**24.75%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.24. Ring-necked pheasant global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	1183.83	2	1187.95	0.00	0.36	22.00	0.49
HAZARD	1184.44	2	1188.56	0.62	0.26	20.61	0.54
UNIFORM COSINE	1182.42	3	1188.67	0.72	0.25	23.34	0.44
UNIFORM SIMPLE	1182.67	4	1191.08	3.13	0.07	20.76	0.51
HALF	1189.67	1	1191.71	3.76	0.05	13.96	0.54
UNIFORM	1222.26	0	1222.26	34.31	0.00	5.49	0.20
Model Average						**21.44**	**50.37%**

Spring		**Summer**		**Fall**		**Winter**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
1.48	0.34	2.41	0.35	12.05	0.87	0.46	0.49	2.93	0.27	2.67	0.23
1.44	0.37	2.29	0.37	11.11	0.96	0.44	0.51	2.79	0.30	2.54	0.27
1.54	0.35	2.55	0.35	12.83	0.77	0.49	0.49	3.11	0.27	2.83	0.23
1.41	0.34	2.30	0.35	11.26	0.91	0.44	0.49	2.79	0.27	2.55	0.23
1.24	0.33	1.84	0.34	6.21	1.19	0.36	0.48	2.26	0.25	2.06	0.22
0.73	0.34	0.99	0.33	1.10	0.88	0.20	0.47	1.30	0.24	1.16	0.20
1.47	**35.48%**	**2.37**	**36.08%**	**11.62**	**89.01%**	**0.46**	**49.74%**	**2.89**	**28.36%**	**2.63**	**25.04%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.25. Savannah sparrow global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD SIMPLE	385.21	3	391.77	0.00	1.00	259.52	0.53
HAZARD	402.15	2	406.42	14.66	0.00	189.76	0.46
HALF	405.61	1	407.70	15.94	0.00	64.21	0.40
UNIFORM SIMPLE	413.31	1	415.40	23.63	0.00	43.84	0.39
UNIFORM	563.20	0	563.20	171.43	0.00	7.30	0.37
Model Average						**259.40**	**52.81%**

Spring		**Fall**		**Winter**	
D	**CV**	**D**	**CV**	**D**	**CV**
4.17	0.81	239.52	0.55	15.82	0.72
3.22	0.77	172.00	0.50	14.54	0.66
1.29	0.74	56.96	0.45	5.95	0.57
0.90	0.74	38.30	0.44	4.64	0.58
0.15	0.74	5.74	0.44	1.41	0.64
4.17	**80.73%**	**239.41**	**55.34%**	**15.82**	**71.64%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.26. Scissor-tailed flycatcher global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF COSINE	398.34	2	402.67	0.00	0.56	11.04	0.26
HAZARD	400.25	2	404.58	1.91	0.21	11.69	0.29
UNIFORM SIMPLE	398.72	3	405.40	2.73	0.14	9.43	0.29
UNIFORM COSINE	397.61	4	406.79	4.12	0.07	10.91	0.31
HALF	407.78	1	409.89	7.21	0.02	9.07	0.24
UNIFORM	467.33	0	467.33	64.66	0.00	2.46	0.22
Model Averaging						**10.91**	**28.34%**

Spring		**Summer**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
2.10	0.40	4.74	0.45	2.21	0.39	1.99	0.46
2.25	0.42	4.96	0.47	2.40	0.41	2.08	0.48
1.86	0.42	3.99	0.47	1.89	0.41	1.69	0.48
2.09	0.44	4.67	0.48	2.19	0.43	1.97	0.49
1.79	0.39	3.84	0.44	1.81	0.38	1.63	0.45
0.59	0.39	0.99	0.43	0.48	0.36	0.40	0.43
2.09	**41.52%**	**4.66**	**46.58%**	**2.20**	**40.90%**	**1.96**	**47.29%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.27. Swainson's hawk global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HAZARD	438.26	2	442.59	0.00	0.33	5.92	0.33
UNIFORM COSINE	438.92	2	443.25	0.66	0.24	4.84	0.25
HALF COSINE	439.32	2	443.66	1.07	0.20	5.51	0.26
HALF	441.93	1	444.04	1.45	0.16	4.49	0.24
UNIFORM SIMPLE	438.96	3	445.65	3.05	0.07	4.76	0.24
UNIFORM	467.33	0	467.33	24.74	0.00	2.08	0.23
Model Average						**5.27**	**30.03%**

Spring		**Summer**		**Fall**		**Spring 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
0.44	0.61	3.27	0.40	0.95	0.68	1.13	0.40
0.35	0.57	2.72	0.34	0.76	0.64	0.92	0.34
0.41	0.58	3.07	0.35	0.87	0.65	1.05	0.35
0.33	0.57	2.52	0.33	0.70	0.63	0.85	0.33
0.35	0.57	2.67	0.34	0.75	0.64	0.90	0.33
0.15	0.56	1.15	0.34	0.38	0.63	0.37	0.32
0.39	**59.94%**	**2.94**	**37.86%**	**0.84**	**66.49%**	**1.00**	**37.70%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.28. Turkey vulture global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
UNIFORM	527.25	0	527.25	0.00	0.48	2.57	0.21
HALF	526.73	1	528.82	1.57	0.22	2.88	0.29
HALF COSINE	524.70	2	528.99	1.74	0.20	3.67	0.39
HAZARD	526.18	2	530.47	3.22	0.10	3.34	0.38
Model Averaging						**2.93**	**32.27%**

Spring		**Summer**		**Fall**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
0.98	0.32	1.04	0.37	0.13	0.56	0.22	0.45	0.10	0.12
1.15	0.34	0.87	0.38	0.14	0.58	0.25	0.47	0.10	0.12
1.38	0.40	1.05	0.43	0.19	0.61	0.33	0.51	0.15	0.21
1.34	0.42	1.00	0.45	0.17	0.63	0.30	0.53	0.05	0.06
1.13	**38.23%**	**1.00**	**39.72%**	**0.15**	**60.48%**	**0.26**	**50.38%**	**0.40**	**129.35%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

Table C.29. Western kingbird global detection function models and density estimates from Distance 6.0 for model averaging for line-transect surveys from Gray and Donley County Study Sites from April 2008–July 2009.

Model[1]	**-2LL**	**K**	**AICc**	**Delta**	**w**	**D**	**CV**
Global Detection Function							
HALF	1004.36	1	1006.41	0.00	0.57	26.31	0.13
UNIFORM COSINE	1002.42	3	1008.67	2.26	0.18	26.94	0.16
UNIFORM SIMPLE	1001.14	4	1009.56	3.15	0.12	26.17	0.14
HAZARD SIMPLE	1003.99	3	1010.24	3.84	0.08	25.39	0.16
HAZARD	1007.40	2	1011.52	5.12	0.04	24.20	0.14
UNIFORM	1198.29	0	1198.29	191.89	0.00	6.20	0.12
Model Average						**26.24**	**14.01%**

Spring		**Summer**		**Spring 2**		**Summer 2**	
D	**CV**	**D**	**CV**	**D**	**CV**	**D**	**CV**
3.31	0.29	5.26	0.25	11.69	0.19	6.05	0.22
3.39	0.30	5.37	0.27	11.99	0.21	6.19	0.24
3.29	0.29	5.14	0.26	11.76	0.20	5.99	0.22
3.15	0.30	4.90	0.27	11.59	0.21	5.74	0.24
2.98	0.29	4.51	0.26	11.28	0.20	5.43	0.22
0.78	0.28	1.12	0.24	3.02	0.19	1.28	0.21
3.29	**29.30%**	**5.20**	**26.12%**	**11.73**	**20.07%**	**6.01**	**22.74%**

[1]Models = key function + series expansion with size-bias regression of flock size against detection probability; -2LL = – 2*log-likelihood; K= number of parameters; AIC_C = second-order Akaike's information criterion; delta = difference in AIC_C compared to lowest AIC_C of the model set; w = AIC_C weight; D = density estimate; CV = coefficient of variation; Spring= spring 2008; summer = summer 2008; spring 2 = spring 2009; summer 2 = 2009.

APPENDIX D

DIVERSITY INDICES TABLES

Table D.1. Shannon and Simpson's diversity indices for Gray County study site from April 2008–August 2009.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	21	-0.0033	1.7501e-07
American coot	241	-0.0261	2.4101e-05
American crow	18	-0.0029	1.2751e-07
American kestrel	56	-0.0077	1.2834e-06
American pipit	60	-0.0082	1.4751e-06
American redstart	1	-0.0002	0.0000e+00
American robin	18	-0.0029	1.2751e-07
American wigeon	43	-0.0062	7.5254e-07
American white pelican	28	-0.0043	3.1502e-07
Baird's sandpiper	6	-0.0011	1.2501e-08
bald eagle	2	-0.0004	8.3338e-10
bank swallow	128	-0.0155	6.7737e-06
barn swallow	486	-0.0458	9.8218e-05
black-bellied plover	2	-0.0004	8.3338e-10
black-crowned night-heron	35	-0.0052	4.9586e-07
black-necked stilt	53	-0.0074	1.1484e-06
blue jay	6	-0.0011	1.2501e-08
blue-winged teal	1,038	-0.0817	4.4853e-04
bobolink	2	-0.0004	8.3338e-10
Brewer's blackbird	1,295	-0.0960	6.9826e-04
Brewer's sparrow	1	-0.0002	0.0000e+00
brown-headed cowbird	323	-0.0331	4.3338e-05
bufflehead	34	-0.0050	4.6752e-07
Bullock's oriole	2	-0.0004	8.3338e-10
burrowing owl	46	-0.0065	8.6255e-07
Canada goose	3,891	-0.2012	6.3070e-03
Cassin's sparrow	200	-0.0225	1.6584e-05
cattle egret	7	-0.0013	1.7501e-08
chestnut-collared longspur	70	-0.0094	2.0126e-06
Chihuahuan raven	1	-0.0002	0.0000e+00
chipping sparrow	3	-0.0006	2.5001e-09
chimney swift	4	-0.0008	5.0003e-09
cinnamon teal	14	-0.0023	7.5837e-08
clay-colored sparrow	31	-0.0047	3.8752e-07
cliff swallow	762	-0.0648	2.4163e-04
common goldeneye	27	-0.0041	2.9252e-07
common grackle	813	-0.0680	2.7508e-04
common nighthawk	54	-0.0075	1.1926e-06
common snipe	32	-0.0048	4.1336e-07
Cooper's hawk	2	-0.0004	8.3338e-10
curve-billed thrasher	2	-0.0004	8.3338e-10
dickcissel	134	-0.0161	7.4262e-06
double-crested cormorant	5	-0.0009	8.3338e-09
eastern kingbird	23	-0.0036	2.1084e-07
eastern phoebe	1	-0.0002	0.0000e+00
eastern screech-owl	1	-0.0002	0.0000e+00
Eurasian collared-dove	119	-0.0146	5.8511e-06
European starling	1,482	-0.1058	9.1457e-04
ferruginous hawk	2	-0.0004	8.3338e-10

Table D.1. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
field sparrow	14	-0.0023	7.5837e-08
gadwall	330	-0.0337	4.5240E-05
golden eagle	3	-0.0006	2.5001e-09
grasshopper sparrow	417	-0.0406	7.2284e-05
great blue heron	31	-0.0047	3.8752e-07
great crested flycatcher	3	-0.0006	2.5001e-09
great horned owl	1	-0.0002	0.0000e+00
greater scaup	1	-0.0002	0.0000e+00
greater white-fronted goose	36	-0.0053	5.2503e-07
greater yellowlegs	38	-0.0056	5.8586e-07
great-tailed grackle	1,870	-0.1247	1.4563e-03
green-winged teal	400	-0.0393	6.6504e-05
horned lark	1,358	-0.0994	7.6788e-04
house finch	18	-0.0029	1.2751e-07
house sparrow	246	-0.0266	2.5114e-05
killdeer	456	-0.0435	8.6455e-05
lark bunting	224	-0.0246	2.0814e-05
lark sparrow	237	-0.0258	2.3306e-05
long-billed curlew	17	-0.0028	1.1334e-07
long-billed dowitcher	87	-0.0112	3.1177e-06
least flycatcher	1	-0.0002	0.0000e+00
least sandpiper	121	-0.0148	6.0503e-06
lesser scaup	26	-0.0040	2.7085e-07
lesser yellowlegs	15	-0.0025	8.7505e-08
Lincoln's sparrow	2	-0.0004	8.3338e-10
loggerhead shrike	10	-0.0017	3.7502e-08
mallard	795	-0.0669	2.6303e-04
marbled godwit	1	-0.0002	0.0000e+00
McCown's longspur	160	-0.0187	1.0601e-05
meadowlark spp.	3,607	-0.1921	5.4198e-03
merlin	2	-0.0004	8.3338e-10
Mississippi kite	11	-0.0019	4.5836e-08
mourning dove	1,168	-0.0891	5.6797e-04
northern bobwhite	167	-0.0194	1.1551e-05
northern cardinal	18	-0.0029	1.2751e-07
northern flicker	3	-0.0006	2.5001e-09
northern harrier	163	-0.0190	1.1003e-05
northern mockingbird	52	-0.0073	1.1051e-06
northern pintail	377	-0.0375	5.9066e-05
northern rough-winged swallow	27	-0.0041	2.9252e-07
northern shoveler	1,030	-0.0812	4.4164e-04
pectoral sandpiper	1	-0.0002	0.0000e+00
pied-billed grebe	16	-0.0026	1.0001e-07
pine siskin	26	-0.0040	2.7085e-07
prairie falcon	5	-0.0009	8.3338e-09
purple martin	3	-0.0006	2.5001e-09
red-bellied woodpecker	2	-0.0004	8.3338e-10
redhead	148	-0.0175	9.0655e-06
red-necked phalarope	14	-0.0023	7.5837e-08
red phalarope	39	-0.0057	6.1753e-07

Table D.1. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
red-headed woodpecker	5	-0.0009	8.3338e-09
red-winged blackbird	14,512	-0.3604	8.7748e-02
red-tailed hawk	23	-0.0036	2.1084e-07
ring-necked duck	12	-0.0020	5.5003E-08
ring-necked pheasant	123	-0.0150	6.2528e-06
rock pigeon	23	-0.0036	2.1084e-07
rock wren	1	-0.0002	0.0000e+00
Ross's goose	6	-0.0011	1.2501e-08
rough-legged hawk	4	-0.0008	5.0003e-09
rudy duck	57	-0.0079	1.3301e-06
rufous-crowned sparrow	3	-0.0006	2.5001e-09
sandhill crane	6,607	-0.2702	1.8187e-02
savannah sparrow	65	-0.0088	1.7334e-06
Say's phoebe	10	-0.0017	3.7502e-08
scaled quail	56	-0.0077	1.2834e-06
scissor-tailed flycatcher	36	-0.0053	5.2503e-07
short-billed dowitcher	30	-0.0045	3.6252e-07
snow goose	1,065	-0.0832	4.7217e-04
solitary sandpiper	2	-0.0004	8.3338e-10
song sparrow	55	-0.0076	1.2376e-06
stilt sandpiper	2	-0.0004	8.3338e-10
Swainson's hawk	53	-0.0074	1.1484e-06
tree swallow	41	-0.0059	6.8337e-07
turkey vulture	61	-0.0083	1.5251e-06
upland sandpiper	13	-0.0022	6.5003e-08
vesper sparrow	8	-0.0014	2.3335e-08
western kingbird	161	-0.0188	1.0734e-05
white crowned sparrow	64	-0.0087	1.6801e-06
white-faced ibis	231	-0.0253	2.2139e-05
white-throated sparrow	4	-0.0008	5.0003e-09
wild turkey	46	-0.0065	8.6255e-07
willet	43	-0.0062	7.5254e-07
Wilson's phalarope	43	-0.0062	7.5254e-07
yellow-headed blackbird	101	-0.0127	4.2086e-06
yellow warbler	1	-0.0002	0.0000E+00
∑134	**48,989**	**-2.8875**	**0.1249**

Shannon diversity index (H') = 2.8875 — **1 -Simpson's diversity index (D_S) = 0.8751**

Variance H' = 5.3099E-05 — **Variance D_S = 1.1364E-06**

Evenness H' (E) = 0.5896

Table D.2. Shannon and Simpson's diversity indices of spring Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	6	-0.0032	1.3708e-07
American coot	148	-0.0461	9.9412e-05
American crow	4	-0.0022	5.4833e-08
American kestrel	15	-0.0070	9.5957e-07
American robin	10	-0.0049	4.1125e-07
American white pelican	28	-0.0119	3.4545e-06
American wigeon	43	-0.0170	8.2523e-06
Baird's sandpiper	4	-0.0022	5.4833e-08
bank swallow	42	-0.0166	7.8685e-06
barn swallow	40	-0.0160	7.1282e-06
black-crowned night-heron	11	-0.0054	5.0263e-07
black-necked stilt	13	-0.0062	7.1282e-07
blue jay	1	-0.0006	0.0000e+00
blue-winged teal	859	-0.1653	3.3677e-03
bobolink	2	-0.0012	9.1388e-09
Brewer's blackbird	35	-0.0143	5.4376e-06
Brewer's sparrow	1	-0.0006	0.0000e+00
brown headed cowbird	21	-0.0093	1.9191e-06
bufflehead	32	-0.0133	4.5328e-06
burrowing owl	26	-0.0111	2.9701e-06
Cassin's sparrow	60	-0.0223	1.6176e-05
cattle egret	3	-0.0017	2.7416e-08
chestnut-collarded longspur	20	-0.0089	1.7364e-06
Chihuahuan raven	1	-0.0006	0.0000e+00
chimney swift	4	-0.0022	5.4833e-08
chipping sparrow	1	-0.0006	0.0000e+00
cinnamon teal	1	-0.0006	0.0000e+00
clay-colored sparrow	29	-0.0122	3.7103e-06
cliff swallow	345	-0.0876	5.4230e-04
common goldeneye	27	-0.0115	3.2077e-06
common grackle	583	-0.1274	1.5504e-03
common nighthawk	4	-0.0022	5.4833e-08
common snipe	1	-0.0006	0.0000e+00
dickcissel	32	-0.0133	4.5328e-06
double-crested cormorant	5	-0.0027	9.1388e-08
eastern kingbird	6	-0.0032	1.3708e-07
eastern phoebe	1	-0.0006	0.0000e+00
Eurasian collarded-dove	50	-0.0192	1.1195e-05
European starling	69	-0.0250	2.1440e-05
ferruginous hawk	1	-0.0006	0.0000e+00
field sparrow	10	-0.0049	4.1125e-07
gadwall	289	-0.0769	3.8032e-04
golden eagle	3	-0.0017	2.7416e-08
grasshopper sparrow	184	-0.0546	1.5386e-04
great blue heron	17	-0.0078	1.2429e-06
greater scaup	1	-0.0006	0.0000e+00
greater yellowlegs	18	-0.0082	1.3982e-06
great-tailed grackle	205	-0.0593	1.9109e-04
green-winged teal	379	-0.0939	6.5462e-04

Table D.2. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
horned lark	439	-0.1044	8.7861e-04
house finch	4	-0.0022	5.4833e-08
house sparrow	21	-0.0093	1.9191e-06
killdeer	236	-0.0660	2.5342e-04
lark bunting	218	-0.0621	2.1616e-04
lark sparrow	53	-0.0202	1.2593e-05
least sandpiper	111	-0.0367	5.5792e-05
leaster scaup	23	-0.0101	2.3121e-06
lesser yellowlegs	7	-0.0036	1.9191e-07
Lincoln's sparrow	2	-0.0012	9.1388e-09
loggerhead shrike	7	-0.0036	1.9191e-07
long-billed curlew	13	-0.0062	7.1282e-07
long-billed dowitcher	87	-0.0302	3.4188e-05
mallard	378	-0.0937	6.5117e-04
marbled godwit	1	-0.0006	0.0000e+00
McCown's longspur	3	-0.0017	2.7416e-08
meadowlark spp.	1,329	-0.2165	8.0646e-03
Mississippi kite	1	-0.0006	0.0000e+00
mourning dove	337	-0.0861	5.1740e-04
northern bobwhite	24	-0.0104	2.5223e-06
northern cardinal	4	-0.0022	5.4833e-08
northern flicker	2	-0.0012	9.1388e-09
northern harrier	43	-0.0170	8.2523e-06
northern mockingbird	11	-0.0054	5.0263e-07
northern pintail	285	-0.0761	3.6985e-04
northern rough-winged swallow	10	-0.0049	4.1125e-07
northern shoveler	1,010	-0.1833	4.6566e-03
pectoral sandpiper	1	-0.0006	0.0000e+00
pied-billed grebe	4	-0.0022	5.4833e-08
pine siskin	26	-0.0111	2.9701e-06
prairie falcon	2	-0.0012	9.1388e-09
purple martin	3	-0.0017	2.7416e-08
red-bellied woodpecker	2	-0.0012	9.1388e-09
redhead	134	-0.0426	8.1436e-05
red-necked phalarope	8	-0.0041	2.5589e-07
red phalarope	39	-0.0157	6.7718e-06
red-tailed hawk	3	-0.0017	2.7416e-08
red-winged blackbird	5,361	-0.3678	1.3130e-01
ring-necked duck	12	-0.0058	6.0316e-07
ring-necked pheasant	63	-0.0232	1.7848e-05
rough-legged hawk	1	-0.0006	0.0000e+00
ruddy duck	40	-0.0160	7.1282e-06
rufous-crowned sparrow	1	-0.0006	0.0000e+00
sandhill crane	240	-0.0669	2.6210e-04
savannah sparrow	5	-0.0027	9.1388e-08
Say's phoebe	3	-0.0017	2.7416e-08
scaled quail	29	-0.0122	3.7103e-06
scissor-tailed flycatcher	11	-0.0054	5.0263e-07
short-billed dowitcher	30	-0.0126	3.9754e-06

Table D.2. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
song sparrow	29	-0.0122	3.7103e-06
stilt sandpiper	2	-0.0012	9.1388e-09
Swainson's hawk	17	-0.0078	1.2429e-06
tree swallow	22	-0.0097	2.1111e-06
turkey vulture	27	-0.0115	3.2077e-06
upland sandpiper	10	-0.0049	4.1125e-07
western kingbird	51	-0.0195	1.1652e-05
white-crowned sparrow	53	-0.0202	1.2593e-05
white-faced ibis	23	-0.0101	2.3121e-06
white-throated sparrow	4	-0.0022	5.4833e-08
wild turkey	26	-0.0111	2.9701e-06
willet	43	-0.0170	8.2523e-06
Wilson's phoebe	30	-0.0126	3.9754e-06
yellow-headed blackbird	89	-0.0308	3.5787e-05
yellow warbler	1	-0.0006	0.0000e+00
∑113	**14,794**	**-2.8307**	**0.1546**

Shannon diversity index (H') = 2.8307
Variance H' = 1.9999E-04
Evenness H' (E) = 0.5988

1 -Simpson's diversity index (D_S) = 0.8454
Variance D_S = 7.2406E-06

Table D.3. Shannon and Simpson's diversity indices of summer Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	15	-0.0082	1.3936e-06
American coot	87	-0.0351	4.9652e-05
American crow	1	-0.0008	0.0000e+00
American kestrel	7	-0.0043	2.7872e-07
American redstart	1	-0.0008	0.0000e+00
American robin	7	-0.0043	2.7872E-07
bank swallow	82	-0.0335	4.4078e-05
barn swallow	372	-0.1060	9.1588e-04
black-bellied plover	2	-0.0014	1.3272e-08
black-crowned night-heron	23	-0.0118	3.3579e-06
black-necked stilt	40	-0.0187	1.0353e-05
blue jay	5	-0.0032	1.3272e-07
blue-winged teal	93	-0.0370	5.6780e-05
brown headed cowbird	52	-0.0231	1.7599e-05
Bullock's oriole	1	-0.0008	0.0000e+00
burrowing owl	20	-0.0105	2.5218e-06
Cassin's sparrow	140	-0.0510	1.2914e-04
cattle egret	4	-0.0026	7.9635e-08
cinnamon teal	13	-0.0073	1.0353e-06
cliff swallow	244	-0.0779	3.9348e-04
common grackle	175	-0.0606	2.0207e-04
common nighthawk	49	-0.0220	1.5608e-05
curve-billed thrasher	2	-0.0014	1.3272e-08
dickcissel	101	-0.0395	6.7026e-05
eastern kingbird	17	-0.0091	1.8051e-06
eastern screech-owl	1	-0.0008	0.0000e+00
Eurasian collarded-dove	46	-0.0209	1.3737e-05
European starling	119	-0.0449	9.3186e-05
gadwall	24	-0.0122	3.6632e-06
grasshopper sparrow	228	-0.0740	3.4346e-04
great blue heron	12	-0.0068	8.7598e-07
great crested flycatcher	3	-0.0020	3.9817e-08
greater yellowlegs	17	-0.0091	1.8051e-06
great horned owl	1	-0.0008	0.0000e+00
great-tailed grackle	1,601	-0.2657	1.6999e-02
green-winged teal	2	-0.0014	1.3272e-08
horned lark	300	-0.0907	5.9527e-04
house finch	13	-0.0073	1.0353e-06
house sparrow	173	-0.0601	1.9747e-04
killdeer	165	-0.0579	1.7958e-04
lark bunting	6	-0.0037	1.9909e-07
lark sparrow	153	-0.0547	1.5433e-04
least flycatcher	1	-0.0008	0.0000e+00
lesser yellowlegs	8	-0.0048	3.7163e-07
loggerhead shrike	2	-0.0014	1.3272e-08
long-billed curlew	4	-0.0026	7.9635e-08
mallard	246	-0.0784	3.9997e-04
meadowlark spp.	1,163	-0.2233	8.9682E-03
Mississippi kite	10	-0.0058	5.9726e-07

Table D.3. Continued.

Species	n	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
mourning dove	693	-0.1623	3.1824e-03
northern bobwhite	131	-0.0484	1.1302e-04
northern cardinal	13	-0.0073	1.0353e-06
northern harrier	7	-0.0043	2.7872e-07
northern mockingbird	41	-0.0190	1.0883e-05
northern rough-winged swallow	17	-0.0091	1.8051e-06
northern shoveler	1	-0.0008	0.0000e+00
pied-billed grebe	12	-0.0068	8.7598e-07
redhead	6	-0.0037	1.9909e-07
red-headed woodpecker	5	-0.0032	1.3272e-07
red-necked phalarope	6	-0.0037	1.9909e-07
red-winged blackbird	4,961	-0.3662	1.6329e-01
ring-necked pheasant	55	-0.0242	1.9710e-05
rock pigeon	9	-0.0053	4.7781e-07
ruddy duck	13	-0.0073	1.0353e-06
Say's phoebe	3	-0.0020	3.9817e-08
scaled quail	10	-0.0058	5.9726e-07
scissor-tailed flycatcher	25	-0.0126	3.9817e-06
solitary sandpiper	2	-0.0014	1.3272e-08
Swainson's hawk	27	-0.0135	4.6586e-06
tree swallow	18	-0.0096	2.0307e-06
turkey vulture	13	-0.0073	1.0353e-06
upland sandpiper	2	-0.0014	1.3272e-08
western kingbird	110	-0.0422	7.9568e-05
white-faced ibis	208	-0.0691	2.8573e-04
wild turkey	20	-0.0105	2.5218e-06
Wilson's phoebe	5	-0.0032	1.3272e-07
yellow-headed blackbird	12	-0.0068	8.7598e-07
∑77	**12,276**	**-2.4573**	**0.1969**

Shannon diversity index (H') = 2.4573 **1 -Simpson's diversity index (D_S) = 0.8031**

Variance H' = 2.2366E-04 **Variance D_S = 9.9538E-06**

Evenness H' (E) = 0.5657

Table D.4. Shannon and Simpson's diversity indices of fall Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American coot	6	-0.0044	2.9429e-07
American crow	11	-0.0074	1.0791e-06
American kestrel	19	-0.0118	3.3549e-06
American pipit	59	-0.0300	3.3569e-05
Baird's sandpiper	2	-0.0017	1.9620e-08
bank swallow	4	-0.0031	1.1772e-07
barn swallow	74	-0.0360	5.2992e-05
black-crowned night-heron	1	-0.0009	0.0000e+00
blue-winged teal	75	-0.0364	5.4444e-05
Brewer's blackbird	879	-0.2125	7.5708e-03
brown headed cowbird	188	-0.0742	3.4487e-04
Bullock's oriole	1	-0.0009	0.0000e+00
Canada goose	183	-0.0727	3.2672e-04
chestnut-collarded longspur	39	-0.0215	1.4538e-05
chipping sparrow	2	-0.0017	1.9620e-08
clay-colored sparrow	2	-0.0017	1.9620e-08
cliff swallow	173	-0.0697	2.9190e-04
common grackle	47	-0.0250	2.1209e-05
common nighthawk	1	-0.0009	0.0000e+00
common snipe	31	-0.0178	9.1231e-06
Cooper's hawk	2	-0.0017	1.9620e-08
dickcissel	1	-0.0009	0.0000e+00
Eurasian collarded-dove	19	-0.0118	3.3549e-06
European starling	805	-0.2016	6.3491e-03
field sparrow	4	-0.0031	1.1772e-07
gadwall	7	-0.0050	4.1201e-07
grasshopper sparrow	1	-0.0009	0.0000e+00
great blue heron	2	-0.0017	1.9620e-08
greater white-fronted goose	36	-0.0201	1.2360e-05
greater yellowlegs	3	-0.0024	5.8859e-08
great-tailed grackle	31	-0.0178	9.1231e-06
horned lark	406	-0.1292	1.6130e-03
house finch	1	-0.0009	0.0000e+00
house sparrow	37	-0.0206	1.3067e-05
killdeer	53	-0.0276	2.7036e-05
lark sparrow	31	-0.0178	9.1231e-06
least sandpiper	10	-0.0069	8.8288e-07
loggerhead shrike	1	-0.0009	0.0000e+00
mallard	74	-0.0360	5.2992e-05
meadowlark spp.	791	-0.1995	6.1300e-03
mourning dove	108	-0.0485	1.1336e-04
northern bobwhite	11	-0.0074	1.0791e-06
northern cardinal	1	-0.0009	0.0000e+00
northern flicker	1	-0.0009	0.0000e+00
northern harrier	88	-0.0413	7.5104e-05
northern pintail	58	-0.0296	3.2431e-05
northern shoveler	16	-0.0102	2.3543e-06
red-tailed hawk	15	-0.0097	2.0600e-06
red-winged blackbird	2,250	-0.3345	4.9640e-02

Table D.4. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index** **N (N- 1)**
ring-necked pheasant	1	-0.0009	0.0000e+00
rock pigeon	9	-0.0063	7.0630e-07
rock wren	1	-0.0009	0.0000e+00
rufous-crowned sparrow	2	-0.0017	1.9620e-08
sandhill crane	3,268	-0.3651	1.0473e-01
savannah sparrow	39	-0.0215	1.4538e-05
Say's phoebe	4	-0.0031	1.1772e-07
scaled quail	13	-0.0086	1.5303e-06
snow goose	44	-0.0237	1.8560e-05
song sparrow	8	-0.0057	5.4935e-07
Swainson's hawk	9	-0.0063	7.0630e-07
turkey vulture	21	-0.0128	4.1201e-06
upland sandpiper	1	-0.0009	0.0000e+00
vesper sparrow	8	-0.0057	5.4935e-07
white-crowned sparrow	1	-0.0009	0.0000e+00
Wilson's phoebe	8	-0.0057	5.4935e-07
∑65	**10,097**	**-2.2895**	**0.1776**

Shannon diversity index (H') = 2.2895 **1 -Simpson's diversity index (D_S) = 0.8224**
Variance H' = 2.0420E-04 **Variance D_S = 5.9971E-06**
Evenness H' (E) = 0.5485

Table D.5. Shannon and Simpson's diversity indices of winter Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American crow	2	-0.0015	1.4311e-08
American kestrel	15	-0.0085	1.5027e-06
American pipit	1	-0.0008	0.0000e+00
American robin	1	-0.0008	0.0000e+00
bald eagle	2	-0.0015	1.4311E-08
blue-winged teal	11	-0.0065	7.8713e-07
Brewer's blackbird	381	-0.1107	1.0360e-03
brown headed cowbird	62	-0.0275	2.7063e-05
bufflehead	2	-0.0015	1.4311e-08
Canada goose	3,708	-0.3637	9.8360e-02
chestnut-collarded longspur	11	-0.0065	7.8713e-07
common grackle	8	-0.0049	4.0072e-07
Eurasian collarded-dove	4	-0.0027	8.5869e-08
European starling	489	-0.1318	1.7076e-03
ferruginous hawk	1	-0.0008	0.0000e+00
gadwall	10	-0.0060	6.4402e-07
grasshopper sparrow	4	-0.0027	8.5869e-08
great-tailed grackle	33	-0.0164	7.5565e-06
green-winged teal	19	-0.0103	2.4473e-06
horned lark	213	-0.0724	3.2312e-04
house sparrow	15	-0.0085	1.5027e-06
killdeer	2	-0.0015	1.4311e-08
leaster scaup	3	-0.0021	4.2934e-08
mallard	97	-0.0394	6.6634e-05
McCown's longspur	157	-0.0574	1.7526e-04
meadowlark spp.	324	-0.0986	7.4886E-04
merlin	2	-0.0015	1.4311e-08
mourning dove	30	-0.0152	6.2255e-06
northern bobwhite	1	-0.0008	0.0000e+00
northern harrier	25	-0.0130	4.2934e-06
northern pintail	34	-0.0168	8.0287e-06
northern shoveler	3	-0.0021	4.2934e-08
prairie falcon	3	-0.0021	4.2934e-08
redhead	8	-0.0049	4.0072e-07
red-tailed hawk	5	-0.0033	1.4311e-07
ring-necked pheasant	4	-0.0027	8.5869E-08
Ross's goose	6	-0.0039	2.1467E-07
rock pigeon	5	-0.0033	1.4311e-07
rough-legged hawk	3	-0.0021	4.2934e-08
ruddy duck	4	-0.0027	8.5869e-08
red-winged blackbird	1,940	-0.2966	2.6917e-02
sandhill crane	3,099	-0.3510	6.8700e-02
savannah sparrow	21	-0.0112	3.0054e-06
scaled quail	4	-0.0027	8.5869e-08
snow goose	1,021	-0.2115	7.4521e-03
song sparrow	18	-0.0099	2.1897e-06
tree swallow	1	-0.0008	0.0000e+00

Table D.5. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
white-crowned sparrow	10	-0.0060	6.4402e-07
∑48	**11,822**	**-1.9488**	**0.2056**

Shannon diversity index (H') = 1.9488 **1 -Simpson's diversity index (D_S) = 0.7944**
Variance H' = 1.2356E-04 **Variance D_S = 3.9878E-06**
Evenness H' (E) = 0.5034

Table D.6. Shannon diversity and Simpson's indices Donley County study site from May 2008–February 2009.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American crow	2	-0.0160	3.6572e-06
American goldfinch	1	-0.0089	0.0000e+00
American kestrel	10	-0.0582	1.6458e-04
American pipit	7	-0.0441	7.6802e-05
American robin	4	-0.0282	2.1943e-05
bank swallow	13	-0.0710	2.8526e-04
blue jay	5	-0.0338	3.6572e-05
brown-headed cowbird	66	-0.2156	7.8448e-03
Cassin's sparrow	48	-0.1774	4.1254e-03
chestnut-collared longspur	22	-0.1045	8.4482e-04
cliff swallow	2	-0.0160	3.6572e-06
common nighthawk	29	-0.1269	1.4848e-03
common snipe	1	-0.0089	0.0000e+00
eastern bluebird	5	-0.0338	3.6572e-05
eastern phoebe	1	-0.0089	0.0000e+00
grasshopper sparrow	46	-0.1727	3.7852e-03
horned lark	113	-0.2870	2.3143e-02
killdeer	12	-0.0668	2.4138e-04
ladder-backed woodpecker	1	-0.0089	0.0000e+00
lapland longspur	2	-0.0160	3.6572e-06
lark sparrow	52	-0.1866	4.8495e-03
mallard	2	-0.0160	3.6572e-06
McCown's longspur	2	-0.0160	3.6572e-06
meadowlark spp.	177	-0.3422	5.6965e-02
mourning dove	60	-0.2037	6.4733e-03
northern bobwhite	8	-0.0489	1.0240e-04
northern cardinal	1	-0.0089	0.0000e+00
northern flicker	7	-0.0441	7.6802e-05
northern harrier	3	-0.0223	1.0972e-05
northern mockingbird	9	-0.0536	1.3166e-04
red-headed woodpecker	3	-0.0223	1.0972e-05
red-winged blackbird	8	-0.0489	1.0240e-04
ring-necked pheasant	2	-0.0160	3.6572e-06
sandhill crane	6	-0.0390	5.4859e-05
song sparrow	2	-0.0160	3.6572e-06
Swainson's hawk	2	-0.0160	3.6572e-06
turkey vulture	2	-0.0160	3.6572e-06
western kingbird	2	-0.0160	3.6572E-06
white crowned sparrow	2	-0.0160	3.6572e-06
∑39	**740**	**-2.6522**	**0.1109**

Shannon diversity index (H') = 2.6522
Variance H' = 1.9062E-03
Evenness H' (E) = 0.7239

1 -Simpson's diversity index (D_S) = 0.8891
Variance D_S = 3.7217E-05

Table D.7. Shannon and Simpson's diversity indices of spring Donley County study site.

		Shannon Index	Simpson's Index
Species	***n***	**p_i Ln p_i**	**N (N- 1)**
bank swallow	13	-0.1811	4.1664e-03
Cassin's sparrow	24	-0.2585	1.4743e-02
cliff swallow	2	-0.0472	5.3416e-05
common nighthawk	6	-0.1075	8.0124e-04
grasshopper sparrow	28	-0.2794	2.0191e-02
horned lark	16	-0.2058	6.4099e-03
lark sparrow	19	-0.2276	9.1341e-03
mourning dove	19	-0.2276	9.1341e-03
meadowlark spp.	62	-0.3646	1.0101E-01
northern flicker	1	-0.0272	0.0000e+00
northern mockingbird	1	-0.0272	0.0000e+00
red-headed woodpecker	1	-0.0272	0.0000e+00
red-winged blackbird	1	-0.0272	0.0000e+00
western kingbird	1	-0.0272	0.0000e+00
∑14	**194**	**-2.0349**	**0.1656**

Shannon diversity index (H') = 2.0349 **1 -Simpson's diversity index (D_S) = 0.8344**

Variance H' = 3.6308E-03 **Variance D_S = 2.3572E-04**

Evenness H' (E) = 0.7711

Table D.8. Shannon and Simpson's diversity indices of summer Donley County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American kestrel	3	-0.0469	7.0130e-05
Cassin's sparrow	24	-0.2050	6.4519E-03
common nighthawk	23	-0.1998	5.9143e-03
common snipe	1	-0.0194	0.0000e+00
eastern bluebird	1	-0.0194	0.0000e+00
grasshopper sparrow	16	-0.1588	2.8052e-03
horned lark	36	-0.2576	1.4727e-02
killdeer	10	-0.1153	1.0519e-03
lark sparrow	33	-0.2459	1.2343e-02
mallard	2	-0.0340	2.3377e-05
meadowlark spp.	87	-0.3605	8.7451E-02
mourning dove	28	-0.2244	8.8363e-03
northern bobwhite	7	-0.0892	4.9091e-04
northern flicker	4	-0.0586	1.4026e-04
northern mockingbird	8	-0.0983	6.5454e-04
red-headed woodpecker	1	-0.0194	0.0000e+00
red-winged blackbird	4	-0.0586	1.4026e-04
ring-necked pheasant	2	-0.0340	2.3377e-05
Swainson's hawk	2	-0.0340	2.3377e-05
western kingbird	1	-0.0194	0.0000e+00
∑20	**293**	**-2.2986**	**0.1411**

Shannon diversity index (H') = 2.2986 **1 -Simpson's diversity index (D_S) = 0.8589**
Variance H' = 3.3088E-03 **Variance D_S = 1.4818E-04**
Evenness H' (E) = 0.7673

Table D.9. Shannon and Simpson's diversity indices of fall Donley County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American crow	2	-0.0604	1.0132e-04
American kestrel	5	-0.1184	1.0132e-03
American pipit	3	-0.0819	3.0395e-04
American robin	3	-0.0819	3.0395E-04
brown headed cowbird	66	-0.3553	2.1733e-01
chestnut-collarded longspur	1	-0.0351	0.0000e+00
eastern phoebe	1	-0.0351	0.0000e+00
grasshopper sparrow	2	-0.0604	1.0132e-04
horned lark	16	-0.2469	1.2158e-02
ladder-backed woodpecker	1	-0.0351	0.0000e+00
McCown's longspur	2	-0.0604	1.0132e-04
meadowlark spp.	18	-0.2628	1.5502E-02
mourning dove	8	-0.1628	2.8369e-03
northern harrier	1	-0.0351	0.0000e+00
red-winged blackbird	3	-0.0819	3.0395e-04
sandhill crane	6	-0.1343	1.5198e-03
turkey vulture	2	-0.0604	1.0132e-04
white-crowned sparrow	1	-0.0351	0.0000e+00
∑18	**141**	**-1.9433**	**0.2517**

Shannon diversity index (H') = 1.9433 | **1 -Simpson's diversity index (D_S) = 0.7483**
Variance H' = 1.1846E-02 | **Variance D_S = 1.1464E-03**
Evenness H' (E) = 0.6723

Table D.10. Shannon and Simpson's diversity indices of winter Donley County study site.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index** **N (N- 1)**
American golden finch	1	-0.0421	0.0000E+00
American kestrel	2	-0.0719	1.6088e-04
American pipit	4	-0.1190	9.6525e-04
American robin	1	-0.0421	0.0000E+00
blue jay	5	-0.1388	1.6088e-03
chestnut-collarded longspur	21	-0.3139	3.3784e-02
eastern bluebird	4	-0.1190	9.6525e-04
horned lark	45	-0.3664	1.5927e-01
killdeer	2	-0.0719	1.6088e-04
lapland longspur	2	-0.0719	1.6088e-04
meadowlark spp.	10	-0.2157	7.2394E-03
mourning dove	5	-0.1388	1.6088e-03
northern bobwhite	1	-0.0421	0.0000e+00
northern cardinal	1	-0.0421	0.0000e+00
northern flicker	2	-0.0719	1.6088e-04
northern harrier	2	-0.0719	1.6088e-04
red-headed woodpecker	1	-0.0421	0.0000e+00
song sparrow	2	-0.0719	1.6088e-04
white-crowned sparrow	1	-0.0421	0.0000e+00
∑19	**112**	**-2.0956**	**0.2064**

Shannon diversity index (H') = 2.0956 1 -Simpson's diversity index (D_S) = 0.7936**

Variance H' = 1.3695E-02 **Variance D_S = 9.6052E-04**

Evenness H' (E) = 0.7117

Table D.11. Shannon diversity and Simpson's indices for breaks cover type for both Gray County and Donley County study sites from April 2008–August 2009.

Species	n	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0040	1.4173e-07
American crow	13	-0.0196	1.1055e-05
American goldfinch	1	-0.0022	0.0000e+00
American kestrel	29	-0.0375	5.7543e-05
American pipit	14	-0.0208	1.2897e-05
American robin	13	-0.0196	1.1055e-05
bank swallow	26	-0.0344	4.6062e-05
barn swallow	19	-0.0267	2.4236e-05
blue jay	11	-0.0171	7.7952e-06
Brewer's blackbird	20	-0.0279	2.6929e-05
brown-headed cowbird	84	-0.0850	4.9407e-04
Canada goose	82	-0.0835	4.7069e-04
Cassin's sparrow	180	-0.1456	2.2833e-03
chestnut-collared longspur	25	-0.0334	4.2519e-05
Chihuahuan raven	1	-0.0022	0.0000e+00
chipping sparrow	1	-0.0022	0.0000e+00
chimney swift	4	-0.0073	8.5038e-07
clay-colored sparrow	1	-0.0022	0.0000e+00
cliff swallow	22	-0.0301	3.2740e-05
common grackle	71	-0.0750	3.5220e-04
common nighthawk	68	-0.0726	3.2286e-04
common snipe	1	-0.0022	0.0000e+00
curve-billed thrasher	2	-0.0040	1.4173e-07
dickcissel	17	-0.0244	1.9275e-05
eastern bluebird	5	-0.0088	1.4173e-06
eastern phoebe	1	-0.0022	0.0000e+00
Eurasian collared-dove	3	-0.0057	4.2519e-07
European starling	1	-0.0022	0.0000e+00
ferruginous hawk	1	-0.0022	0.0000e+00
field sparrow	4	-0.0073	8.5038e-07
golden eagle	3	-0.0057	4.2519e-07
grasshopper sparrow	177	-0.1439	2.2076e-03
great crested flycatcher	2	-0.0040	1.4173e-07
great-tailed grackle	45	-0.0530	1.4031e-04
horned lark	361	-0.2251	9.2096e-03
house finch	4	-0.0073	8.5038e-07
house sparrow	3	-0.0057	4.2519e-07
killdeer	86	-0.0865	5.1802e-04
ladder-backed woodpecker	1	-0.0022	0.0000e+00
lapland longspur	2	-0.0040	1.4173e-07
lark bunting	104	-0.0993	7.5911e-04
lark sparrow	155	-0.1315	1.6916e-03
loggerhead shrike	3	-0.0057	4.2519e-07
long-billed curlew	6	-0.0103	2.1260e-06
mallard	6	-0.0103	2.1260e-06
McCown's longspur	2	-0.0040	1.4173e-07
meadowlark spp.	1,051	-0.3564	7.8203e-02
merlin	1	-0.0022	0.0000e+00
Mississippi kite	7	-0.0117	2.9763e-06

Table D.11. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
mourning dove	359	-0.2244	9.1077E-03
northern bobwhite	73	-0.0766	3.7247E-04
northern cardinal	17	-0.0244	1.9275e-05
northern flicker	7	-0.0117	2.9763e-06
northern harrier	16	-0.0232	1.7008e-05
northern mockingbird	50	-0.0575	1.7362e-04
northern rough-winged swallow	4	-0.0073	8.5038e-07
northern shoveler	1	-0.0022	0.0000e+00
pine siskin	25	-0.0334	4.2519e-05
red-bellied woodpecker	2	-0.0040	1.4173e-07
red-headed woodpecker	8	-0.0131	3.9685e-06
red-tailed hawk	1	-0.0022	0.0000e+00
red-winged blackbird	109	-0.1027	8.3423e-04
ring-necked pheasant	3	-0.0057	4.2519e-07
rock pigeon	11	-0.0171	7.7952e-06
rock wren	1	-0.0022	0.0000e+00
rufous-crowned sparrow	2	-0.0040	1.4173e-07
sandhill crane	137	-0.1208	1.3204e-03
savannah sparrow	1	-0.0022	0.0000e+00
Say's phoebe	4	-0.0073	8.5038e-07
scaled quail	46	-0.0539	1.4669e-04
scissor-tailed flycatcher	8	-0.0131	3.9685e-06
song sparrow	10	-0.0158	6.3779e-06
Swainson's hawk	8	-0.0131	3.9685e-06
turkey vulture	45	-0.0530	1.4031e-04
vesper sparrow	1	-0.0022	0.0000e+00
western kingbird	26	-0.0344	4.6062e-05
white crowned sparrow	16	-0.0232	1.7008e-05
wild turkey	4	-0.0073	8.5038e-07
yellow-headed blackbird	21	-0.0290	2.9763E-05
∑79	**3,757**	**-2.9635**	**0.1093**

Shannon diversity index (H') = 2.9635
Variance H' = 5.6458E-04
Evenness H' (E) = 0.6782

1 -Simpson's diversity index (D_S) = 0.8907
Variance D_S = 1.2889

Table D.12. Shannon and Simpson's diversity indices of spring for breaks cover type for both Gray County and Donley County study sites.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0097	1.1097E-06
American kestrel	6	-0.0242	1.6645E-05
American robin	7	-0.0274	2.3303E-05
bank swallow	24	-0.0719	3.0627E-04
barn swallow	1	-0.0054	0.0000E+00
blue jay	1	-0.0054	0.0000E+00
brown-headed cowbird	2	-0.0097	1.1097E-06
Cassin's sparrow	55	-0.1309	1.6479E-03
chestnut-collarded longspur	2	-0.0097	1.1097E-06
Chihuahan raven	1	-0.0054	0.0000E+00
chipping sparrow	1	-0.0054	0.0000E+00
chimney swift	4	-0.0173	6.6581E-06
clay-colored sarrow	1	-0.0054	0.0000E+00
cliff sparrow	6	-0.0242	1.6645E-05
coomon grackle	61	-0.1404	2.0307E-03
common nighthawk	7	-0.0274	2.3303E-05
dickcissel	15	-0.0502	1.1652E-04
Eurasian collarded-dove	1	-0.0054	0.0000E+00
ferruginous hawk	1	-0.0054	0.0000E+00
field sparrow	2	-0.0097	1.1097E-06
golden eagle	3	-0.0136	3.3291E-06
grasshopper sparrow	88	-0.1786	4.2479E-03
great-tailed grackle	18	-0.0578	1.6978E-04
horned lark	94	-0.1861	4.8505E-03
house finch	3	-0.0136	3.3291E-06
killdeer	40	-0.1047	8.6556E-04
lark bunting	102	-0.1958	5.7160E-03
lark sparrow	36	-0.0970	6.9910E-04
loggerhead shrike	2	-0.0097	1.1097E-06
long-billed curlew	6	-0.0242	1.6645E-05
mallard	3	-0.0136	3.3291E-06
meadowlark spp.	469	-0.3674	1.2178E-01
mourning dove	96	-0.1886	5.0602E-03
northern bobwhite	2	-0.0097	1.1097E-06
northern cardinal	3	-0.0136	3.3291E-06
northern flicker	1	-0.0054	0.0000E+00
northern harrier	4	-0.0173	6.6581E-06
northern mockingbird	10	-0.0365	4.9936E-05
northern rough-winged swallow	3	-0.0136	3.3291E-06
pine siskin	25	-0.0742	3.3291E-04
red-bellied woodpecker	2	-0.0097	1.1097E-06
red-headed woodpecker	1	-0.0054	0.0000E+00
red-winged blackbird	35	-0.0951	6.6027E-04
scaled quail	29	-0.0828	4.5053E-04
scissor-tailed flycatcher	1	-0.0054	0.0000E+00
song sparrow	3	-0.0136	3.3291E-06
Swainson's hawk	3	-0.0136	3.3291E-06
turkey vulture	20	-0.0626	2.1084E-04

Table D.12. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
western kingbird	8	-0.0305	3.1071E-05
white-crowned sparrow	12	-0.0422	7.3240E-05
yellow-headed blackbird	21	-0.0650	2.3303E-04
∑51	**1,343**	**-2.6371**	**0.1497**

Shannon diversity index (H') = 2.6371
Variance H' = 1.5355E-03
Evenness (E) = 0.7076

1 -Simpson's diversity index (D_S) = 0.8503
Variance D_S = 6.4583E-05

Table D.13. Shannon and Simpson's diversity indices of summer for breaks cover type for both Gray County and Donley County study sites.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American kestrel	6	-0.0233	1.5165E-05
American robin	2	-0.0093	1.0110E-06
bank swallow	2	-0.0093	1.0110E-06
barn swallow	12	-0.0406	6.6726E-05
blue jay	5	-0.0200	1.0110E-05
brown-headed cowbird	8	-0.0294	2.8308E-05
Cassin's sparroe	125	-0.2151	7.8352E-03
cliff swallow	9	-0.0323	3.6396E-05
common grackle	10	-0.0352	4.5495E-05
common nighthawk	61	-0.1361	1.8501E-03
common snipe	1	-0.0052	0.0000E+00
curve-billed thrasher	2	-0.0093	1.0110E-06
dickcissel	2	-0.0093	1.0110E-06
eastern bluebird	1	-0.0052	0.0000E+00
grasshopper sparrow	86	-0.1708	3.6952E-03
great crested flycatcher	2	-0.0093	1.0110E-06
great-tailed grackle	27	-0.0759	3.5486E-04
horned lark	121	-0.2110	7.3399E-03
house finch	1	-0.0052	0.0000E+00
house sparrow	3	-0.0131	3.0330E-06
killdeer	40	-0.1012	7.8858E-04
lark bunting	2	-0.0093	1.0110E-06
lark sparrow	90	-0.1759	4.0490E-03
loggerhead shrike	1	-0.0052	0.0000E+00
mallard	3	-0.0131	3.0330E-06
meadowlark spp.	340	-0.3432	5.8264E-02
Mississippi kite	7	-0.0264	2.1231E-05
mourning dove	219	-0.2895	2.4134E-02
northern bobwhite	58	-0.1314	1.6712E-03
northern cardinal	13	-0.0433	7.8858E-05
northern flicker	4	-0.0167	6.0660E-06
northern harrier	1	-0.0052	0.0000E+00
northern mockingbird	40	-0.1012	7.8858E-04
northern rough-winged swallow	1	-0.0052	0.0000E+00
northern shoveler	1	-0.0052	0.0000E+00
red-headed woodpecker	6	-0.0233	1.5165E-05
red-winged blackbird	43	-0.1066	9.1293E-04
ring-necked pheasant	3	-0.0131	3.0330E-06
rock pigeon	7	-0.0264	2.1231E-05
Say's phoebe	3	-0.0131	3.0330E-06
scissor-tailed flycatcher	7	-0.0264	2.1231E-05
Swainson's hawk	4	-0.0167	6.0660E-06
turkey vulture	6	-0.0233	1.5165E-05
western kingbird	18	-0.0558	1.5468E-04

Table D.13. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
wild turkey	4	-0.0167	6.0660E-06
∑45	**1,407**	**-2.6579**	**0.1122**

Shannon diversity index (H') = 2.6579
Variance H' = 1.0504E-03
Evenness (E) = 0.6982

1 -Simpson's diversity index (D_S) = 0.8845
Variance D_S = 2.0484E-05

Table D.14. Shannon diversity index of fall for breaks cover type for both Gray County and Donley County study sites.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index** **N (N- 1)**
American crow	13	-0.0785	3.7324e-04
American kestrel	12	-0.0740	3.1582e-04
American pipit	10	-0.0644	2.1533e-04
American robin	3	-0.0249	1.4355e-05
barn swallow	6	-0.0434	7.1777e-05
Brewer's blackbird	1	-0.0100	0.0000e+00
brown-headed cowbird	74	-0.2480	1.2925e-02
chestnut-collared longspur	1	-0.0100	0.0000e+00
cliff swallow	7	-0.0490	1.0049e-04
eastern phoebe	1	-0.0100	0.0000e+00
Eurasian collared-dove	2	-0.0179	4.7851e-06
European starling	1	-0.0100	0.0000e+00
field sparrow	2	-0.0179	4.7851e-06
grasshopper sparrow	2	-0.0179	4.7851e-06
horned lark	77	-0.2533	1.4001e-02
killdeer	4	-0.0314	2.8711e-05
ladder-backed woodpecker	1	-0.0100	0.0000e+00
lark sparrow	29	-0.1392	1.9428e-03
McCown's longspur	2	-0.0179	4.7851e-06
meadowlark spp.	221	-0.3669	1.1633e-01
mourning dove	25	-0.1257	1.4355e-03
northern bobwhite	11	-0.0693	2.6318e-04
northern harrier	5	-0.0376	4.7851e-05
red-tailed hawk	1	-0.0100	0.0000e+00
red-winged blackbird	23	-0.1186	1.2106e-03
rock pigeon	4	-0.0314	2.8711e-05
rock wren	1	-0.0100	0.0000e+00
rufous-crowned sparrow	2	-0.0179	4.7851e-06
sandhill crane	69	-0.2387	1.1226e-02
Say's phoebe	1	-0.0100	0.0000e+00
scaled quail	13	-0.0785	3.7324e-04
song sparrow	1	-0.0100	0.0000e+00
Swainson's hawk	1	-0.0100	0.0000e+00
turkey vulture	19	-0.1036	8.1826e-04
vesper sparrow	1	-0.0100	0.0000e+00
white crowned sparrow	1	-0.0100	0.0000E+00
∑36	**647**	**-2.3859**	**0.1617**

Shannon diversity index (H') = 2.3859
Variance H' = 2.6520E-03
Evenness (E) = 0.6658

1 -Simpson's diversity index (D_S) = 0.8383
Variance D_S = 1.1078E-04

Table D.15. Shannon and Simpson's diversity indices of winter for breaks cover type for both Gray County and Donley County study sites.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American goldfinch	1	-0.0164	0.0000e+00
American kestrel	5	-0.0594	1.5475e-04
American pipit	4	-0.0500	9.2851e-05
American robin	1	-0.0164	0.0000e+00
blue jay	5	-0.0594	1.5475e-04
Brewer's blackbird	19	-0.1553	2.6462e-03
Canada goose	82	-0.3370	5.1393e-02
chestnut-collared longspur	22	-0.1708	3.5747e-03
eastern bluebird	4	-0.0500	9.2851e-05
grasshopper sparrow	1	-0.0164	0.0000e+00
horned lark	69	-0.3166	3.6305e-02
killdeer	2	-0.0288	1.5475e-05
lapland longspur	2	-0.0288	1.5475e-05
meadowlark spp.	21	-0.1658	3.2498E-03
merlin	1	-0.0164	0.0000e+00
mourning dove	19	-0.1553	2.6462e-03
northern bobwhite	2	-0.0288	1.5475e-05
northern cardinal	1	-0.0164	0.0000e+00
northern flicker	2	-0.0288	1.5475e-05
northern harrier	6	-0.0682	2.3213e-04
red-headed woodpecker	1	-0.0164	0.0000e+00
red-winged blackbird	8	-0.0846	4.3330e-04
sandhill crane	68	-0.3148	3.5252e-02
savannah sparrow	1	-0.0164	0.0000e+00
scaled quail	4	-0.0500	9.2851e-05
song sparrow	6	-0.0682	2.3213e-04
white crowned sparrow	3	-0.0399	4.6425e-05
∑27	**360**	**-2.3751**	**0.1367**

Shannon diversity index (H') = 2.3751 **1 -Simpson's diversity index (D_S) = 0.8633**
Variance H' = 3.5464E-03 **Variance D_S = 7.7919E-05**
Evenness (E) = 0.7206

Table D.16. Shannon and Simpson's diversity indices for agriculture cover type for Gray County study site from April 2008–August 2009.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	6	-0.0025	7.9371e-08
American crow	5	-0.0021	5.2914e-08
American kestrel	20	-0.0071	1.0054e-06
American pipit	51	-0.0156	6.7465e-06
American redstart	1	-0.0005	0.0000e+00
American robin	8	-0.0032	1.4816e-07
American white pelican	16	-0.0058	6.3497e-07
Baird's sandpiper	2	-0.0009	5.2914e-09
bank swallow	32	-0.0105	2.6245e-06
barn swallow	165	-0.0405	7.1593e-05
black-bellied plover	2	-0.0009	5.2914e-09
black-crowned night-heron	1	-0.0005	0.0000e+00
black-necked stilt	6	-0.0025	7.9371e-08
blue-winged teal	30	-0.0100	2.3018e-06
Brewer's blackbird	884	-0.1405	2.0652e-03
brown-headed cowbird	199	-0.0469	1.0425e-04
bufflehead	2	-0.0009	5.2914e-09
Bullock's oriole	1	-0.0005	0.0000e+00
Canada goose	3,108	-0.2931	2.5548e-02
Cassin's sparrow	49	-0.0151	6.2227e-06
cattle egret	2	-0.0009	5.2914e-09
chestnut-collared longspur	51	-0.0156	6.7465e-06
chipping sparrow	2	-0.0009	5.2914e-09
cinnamon teal	3	-0.0014	1.5874e-08
clay-colored sparrow	12	-0.0046	3.4923e-07
cliff swallow	241	-0.0544	1.5303e-04
common grackle	593	-0.1064	9.2879e-04
common nighthawk	9	-0.0036	1.9049e-07
common snipe	31	-0.0103	2.4605e-06
Cooper's hawk	2	-0.0009	5.2914e-09
dickcissel	54	-0.0163	7.5720e-06
eastern kingbird	7	-0.0029	1.1112e-07
eastern phoebe	1	-0.0005	0.0000e+00
Eurasian collared-dove	87	-0.0242	1.9795e-05
European starling	797	-0.1309	1.6785e-03
ferruginous hawk	1	-0.0005	0.0000e+00
field sparrow	6	-0.0025	7.9371e-08
gadwall	20	-0.0071	1.0054e-06
grasshopper sparrow	67	-0.0195	1.1699e-05
great blue heron	4	-0.0017	3.1748e-08
greater yellowlegs	10	-0.0039	2.3811e-07
greater white-fronted goose	36	-0.0117	3.3336e-06
great-tailed grackle	304	-0.0650	2.4370e-04
green-winged teal	11	-0.0042	2.9103e-07
horned lark	862	-0.1382	1.9636e-03
house finch	2	-0.0009	5.2914e-09
house sparrow	200	-0.0471	1.0530e-04
killdeer	127	-0.0329	4.2336e-05
lark bunting	95	-0.0260	2.3626e-05

Table D.16. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
lark sparrow	58	-0.0173	8.7467e-06
least sandpiper	92	-0.0253	2.2150e-05
lesser scaup	3	-0.0014	1.5874e-08
loggerhead shrike	3	-0.0014	1.5874e-08
long-billed curlew	8	-0.0032	1.4816E-07
long-billed dowitcher	12	-0.0046	3.4923e-07
mallard	162	-0.0399	6.9005e-05
McCown's longspur	158	-0.0391	6.5629e-05
meadowlark spp.	1,634	-0.2081	7.0596e-03
Mississippi kite	1	-0.0005	0.0000e+00
mourning dove	485	-0.0921	6.2105e-04
northern bobwhite	42	-0.0133	4.5559e-06
northern cardinal	1	-0.0005	0.0000e+00
northern flicker	2	-0.0009	5.2914e-09
northern harrier	70	-0.0203	1.2779e-05
northern mockingbird	5	-0.0021	5.2914e-08
northern pintail	114	-0.0301	3.4082e-05
northern rough-winged swallow	6	-0.0025	7.9371e-08
northern shoveler	19	-0.0068	9.0483e-07
prairie falcon	1	-0.0005	0.0000e+00
purple martin	2	-0.0009	5.2914e-09
redhead	2	-0.0009	5.2914e-09
red-tailed hawk	8	-0.0032	1.4816e-07
red-winged blackbird	2,787	-0.2785	2.0543e-02
ring-necked pheasant	41	-0.0130	4.3389e-06
rock pigeon	7	-0.0029	1.1112e-07
Ross's goose	6	-0.0025	7.9371e-08
rough-legged hawk	1	-0.0005	0.0000e+00
rudy duck	4	-0.0017	3.1748e-08
sandhill crane	4,318	-0.3342	4.9318e-02
savannah sparrow	26	-0.0088	1.7197e-06
Say's phoebe	6	-0.0025	7.9371e-08
scissor-tailed flycatcher	9	-0.0036	1.9049e-07
snow goose	890	-0.1412	2.0933e-03
song sparrow	11	-0.0042	2.9103e-07
Swainson's hawk	23	-0.0080	1.3387e-06
tree swallow	5	-0.0021	5.2914e-08
turkey vulture	11	-0.0042	2.9103e-07
upland sandpiper	3	-0.0014	1.5874e-08
western kingbird	36	-0.0117	3.3336e-06
white crowned sparrow	30	-0.0100	2.3018e-06
white-faced ibis	44	-0.0138	5.0057e-06
white-throated sparrow	4	-0.0017	3.1748e-08
wild turkey	21	-0.0074	1.1112e-06
Wilson's phalarope	8	-0.0032	1.4816e-07

Table D.16. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
yellow-headed blackbird	38	-0.0122	3.7199E-06
∑95	**19,442**	**-2.7191**	**0.1129**

Shannon diversity index (H') = 2.7191
Variance H' = 9.9543E-05
Evenness (E) = 0.5971

1 -Simpson's diversity index (D_S) = 0.8871
Variance D_S = 1.2814E-06

Table D.17. Shannon and Simpson's diversity indices of spring for agriculture cover type for Gray Count study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0045	1.8859E-07
American crow	2	-0.0045	1.8859E-07
American kestrel	1	-0.0025	0.0000E+00
American robin	3	-0.0064	5.6578E-07
American white pelican	16	-0.0261	2.2631E-05
bank swallow	6	-0.0116	2.8289E-06
barn swallow	13	-0.0220	1.4710E-05
blue-winged teal	16	-0.0261	2.2631E-05
Brewer's blackbird	12	-0.0206	1.2447E-05
brown-headed cowbird	11	-0.0192	1.0373E-05
Cassin's sparrow	25	-0.0374	5.6578E-05
chestnut-collarded longspur	7	-0.0132	3.9605E-06
clay-colored sparrow	10	-0.0178	8.4867E-06
cliff swallow	20	-0.0313	3.5833E-05
common grackle	434	-0.2686	1.7720E-02
common nighthawk	2	-0.0045	1.8859E-07
common snipe	1	-0.0025	0.0000E+00
dickcissel	11	-0.0192	1.0373E-05
eastern kingbird	1	-0.0025	0.0000E+00
eastern phoebe	1	-0.0025	0.0000E+00
Eurasian collarded-dove	32	-0.0454	9.3543E-05
European starling	8	-0.0148	5.2806E-06
field sparrow	6	-0.0116	2.8289E-06
gadwall	3	-0.0064	5.6578E-07
grasshopper sparrow	28	-0.0409	7.1289E-05
great-tailed grackle	129	-0.1279	1.5570E-03
horned lark	246	-0.1951	5.6833E-03
house finch	1	-0.0025	0.0000E+00
house sparrow	9	-0.0163	6.7894E-06
killdeer	50	-0.0641	2.3103E-04
lark bunting	95	-0.1031	8.4207E-04
lark sparrow	14	-0.0234	1.7162E-05
least sandpiper	82	-0.0927	6.2632E-04
long-billed curlew	7	-0.0132	3.9605E-06
long-billed dowitcher	12	-0.0206	1.2447E-05
loggerhead shrike	2	-0.0045	1.8859E-07
mallard	52	-0.0661	2.5008E-04
McCown's longspur	3	-0.0064	5.6578E-07
meadowlark spp.	329	-0.2316	1.0176E-02
Mississippi kite	1	-0.0025	0.0000E+00
mourning dove	135	-0.1319	1.7058E-03
northern bobwhite	7	-0.0132	3.9605E-06
northern flicker	1	-0.0025	0.0000E+00
northern harrier	8	-0.0148	5.2806E-06
northern pintail	35	-0.0487	1.1221E-04
northern rough-winged swallow	1	-0.0025	0.0000E+00
northern shoveler	2	-0.0045	1.8859E-07
purple martin	2	-0.0045	1.8859E-07
red-tailed hawk	2	-0.0045	1.8859E-07

Table D.17. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
red-winged blackbird	1,111	-0.3669	1.1629E-01
ring-necked pheasant	20	-0.0313	3.5833E-05
rough-legged hawk	1	-0.0025	0.0000E+00
sandhill crane	95	-0.1031	8.4207E-04
savannah sparrow	4	-0.0082	1.1316E-06
Say's phoebe	3	-0.0064	5.6578E-07
scissor-tailed flycatcher	3	-0.0064	5.6578E-07
song sparrow	2	-0.0045	1.8859E-07
Swainson's hawk	10	-0.0178	8.4867E-06
tree swallow	4	-0.0082	1.1316E-06
turkey vulture	4	-0.0082	1.1316E-06
upland sandpiper	2	-0.0045	1.8859E-07
western kingbird	12	-0.0206	1.2447E-05
wild turkey	21	-0.0325	3.9605E-05
white-crowned sparrow	25	-0.0374	5.6578E-05
white-faced ibis	2	-0.0045	1.8859E-07
white-throated sparrow	4	-0.0082	1.1316E-06
yellow-headed blackbird	38	-0.0519	1.3258E-04
∑67	**3,257**	**-2.5829**	**0.1568**

Shannon diversity index (H') = 2.5829
Variance H' = 7.2616E-04
Evenness (E) = 0.6143

1 -Simpson's diversity index (D_S) = 0.8432
Variance D_S = 2.3432E-05

Table D.18. Shannon and Simpson's diversity indices of summer for agriculture cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	4	-0.0095	1.5759E-06
American crow	1	-0.0029	0.0000E+00
American kestrel	3	-0.0074	7.8794E-07
American redstart	1	-0.0029	0.0000E+00
American robin	4	-0.0095	1.5759E-06
bank swallow	22	-0.0385	6.0671E-05
barn swallow	86	-0.1081	9.5997E-04
black-bellied plover	2	-0.0052	2.6265E-07
black-crowned night-heron	1	-0.0029	0.0000E+00
black-necked stilt	6	-0.0133	3.9397E-06
blue-winged teal	7	-0.0152	5.5155E-06
brown-headed cowbird	28	-0.0466	9.9280E-05
Cassin's sparrow	24	-0.0413	7.2490E-05
cattle egret	2	-0.0052	2.6265E-07
cinnamon teal	3	-0.0074	7.8794E-07
cliff swallow	55	-0.0780	3.9003E-04
common grackle	106	-0.1252	1.4616E-03
common nighthawk	6	-0.0133	3.9397E-06
dickcissel	42	-0.0637	2.2614E-04
eastern kingbird	6	-0.0133	3.9397E-06
Eurasian collarded-dove	34	-0.0542	1.4734E-04
European starling	90	-0.1116	1.0519E-03
grasshopper sparrow	37	-0.0578	1.7492E-04
great blue heron	2	-0.0052	2.6265E-07
greater yellowlegs	7	-0.0152	5.5155E-06
great-tailed grackle	111	-0.1292	1.6034E-03
horned lark	142	-0.1527	2.6293E-03
house sparrow	139	-0.1505	2.5190E-03
killdeer	35	-0.0554	1.5627E-04
lark sparrow	43	-0.0648	2.3717E-04
long-billed curlew	1	-0.0029	0.0000E+00
mallard	18	-0.0328	4.0185E-05
meadowlark spp.	604	-0.3325	4.7829E-02
mourning dove	254	-0.2195	8.4390E-03
northern bobwhite	35	-0.0554	1.5627E-04
northern harrier	4	-0.0095	1.5759E-06
northern mockingbird	5	-0.0114	2.6265E-06
northern rough-winged swallow	5	-0.0114	2.6265E-06
red-winged blackbird	680	-0.3451	6.0634E-02
ring-necked pheasant	19	-0.0343	4.4912E-05
rock pigeon	2	-0.0052	2.6265E-07
scissor-tailed flycatcher	6	-0.0133	3.9397E-06
Swainson's hawk	8	-0.0169	7.3541E-06
turkey vulture	3	-0.0074	7.8794E-07
upland sandpiper	1	-0.0029	0.0000E+00
western kingbird	24	-0.0413	7.2490E-05

Table D.18. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
white-faced ibis	42	-0.0637	2.2614E-04
∑47	**2,760**	**-2.6116**	**0.1293**

Shannon diversity index (H') = 2.6116
Variance H' = 6.2762E-04
Evenness (E) = 0.6783

1 -Simpson's diversity index (D_S) = 0.8707
Variance D_S = 1.4350E-05

Table D.19. Shannon and Simpson's diversity indices of fall for agriculture cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American kestrel	9	-0.0111	2.7173e-06
American pipit	50	-0.0450	9.2464e-05
Baird's sandpiper	2	-0.0031	7.5481e-08
bank swallow	4	-0.0056	4.5289e-07
barn swallow	66	-0.0559	1.6191e-04
Brewer's blackbird	660	-0.2633	1.6415e-02
brown-headed cowbird	98	-0.0754	3.5876e-04
Bullock's oriole	1	-0.0017	0.0000e+00
Canada goose	183	-0.1186	1.2570e-03
chestnut-collared longspur	35	-0.0339	4.4911e-05
chipping sparrow	2	-0.0031	7.5481e-08
clay-colored sparrow	2	-0.0031	7.5481e-08
cliff swallow	166	-0.1107	1.0337e-03
common grackle	45	-0.0414	7.4726e-05
common nighthawk	1	-0.0017	0.0000e+00
common snipe	30	-0.0300	3.2834e-05
Cooper's hawk	2	-0.0031	7.5481e-08
dickcissel	1	-0.0017	0.0000e+00
Eurasian collared-dove	17	-0.0189	1.0265e-05
European starling	295	-0.1639	3.2732e-03
gadwall	7	-0.0090	1.5851e-06
great blue heron	2	-0.0031	7.5481e-08
greater white-fronted goose	36	-0.0347	4.7553e-05
greater yellowlegs	3	-0.0043	2.2644e-07
great-tailed grackle	31	-0.0308	3.5099e-05
horned lark	324	-0.1741	3.9496e-03
house finch	1	-0.0017	0.0000e+00
house sparrow	37	-0.0355	5.0270e-05
killdeer	42	-0.0392	6.4989e-05
lark sparrow	1	-0.0017	0.0000e+00
least sandpiper	10	-0.0121	3.3966e-06
loggerhead shrike	1	-0.0017	0.0000e+00
meadowlark spp.	474	-0.2196	8.4615e-03
mourning dove	80	-0.0647	2.3852e-04
northern cardinal	1	-0.0017	0.0000e+00
northern flicker	1	-0.0017	0.0000e+00
northern harrier	50	-0.0450	9.2464e-05
northern pintail	45	-0.0414	7.4726e-05
northern shoveler	16	-0.0179	9.0577e-06
red-tailed hawk	5	-0.0067	7.5481e-07
red-winged blackbird	134	-0.0950	6.7261e-04
rock pigeon	5	-0.0067	7.5481e-07
sandhill crane	2,090	-0.3660	1.6478e-01
savannah sparrow	19	-0.0207	1.2907e-05
Say's phoebe	3	-0.0043	2.2644e-07
snow goose	44	-0.0407	7.1405e-05
Swainson's hawk	5	-0.0067	7.5481e-07
turkey vulture	4	-0.0056	4.5289e-07

Table D.19. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
Wilson's phalarope	8	-0.0100	2.1135E-06
∑49	**5,148**	**-2.2932**	**0.2013**

Shannon diversity index (H') = 2.2932 **1 -Simpson's diversity index (D_S) = 0.7987**
Variance H' = 4.1844E-04 **Variance D_S = 2.3124E-05**
Evenness (E) = 0.5892

Table D.20. Shannon and Simpson's diversity indices of winter for agriculture cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American crow	2	-0.0020	2.9197e-08
American kestrel	7	-0.0060	6.1313e-07
American pipit	1	-0.0011	0.0000e+00
American robin	1	-0.0011	0.0000e+00
blue-winged teal	7	-0.0060	6.1313e-07
Brewer's blackbird	212	-0.0939	6.5302e-04
brown-headed cowbird	62	-0.0367	5.5211e-05
bufflehead	2	-0.0020	2.9197e-08
Canada goose	2,925	-0.3676	1.2486e-01
chestnut-collared longspur	9	-0.0074	1.0511e-06
common grackle	8	-0.0067	8.1751e-07
Eurasian collared-dove	4	-0.0037	1.7518e-07
European starling	404	-0.1474	2.3768e-03
ferruginous hawk	1	-0.0011	0.0000e+00
gadwall	10	-0.0081	1.3139e-06
grasshopper sparrow	2	-0.0020	2.9197e-08
great-tailed grackle	33	-0.0220	1.5416e-05
green-winged teal	11	-0.0088	1.6058e-06
horned lark	150	-0.0727	3.2628e-04
house sparrow	15	-0.0114	3.0657e-06
lesser scaup	3	-0.0029	8.7591e-08
mallard	92	-0.0500	1.2222e-04
McCown's longspur	155	-0.0745	3.4846e-04
meadowlark spp.	227	-0.0986	7.4893e-04
mourning dove	16	-0.0121	3.5036e-06
northern harrier	8	-0.0067	8.1751e-07
northern pintail	34	-0.0226	1.6379e-05
northern shoveler	1	-0.0011	0.0000e+00
prairie falcon	1	-0.0011	0.0000e+00
redhead	2	-0.0020	2.9197e-08
red-tailed hawk	1	-0.0011	0.0000e+00
red-winged blackbird	862	-0.2356	1.0835e-02
ring-necked pheasant	2	-0.0020	2.9197e-08
Ross's goose	6	-0.0052	4.3795e-07
rudy duck	4	-0.0037	1.7518e-07
sandhill crane	2,133	-0.3494	6.6387e-02
savannah sparrow	3	-0.0029	8.7591e-08
snow goose	846	-0.2331	1.0436e-02
song sparrow	9	-0.0074	1.0511e-06
tree swallow	1	-0.0011	0.0000e+00
white crowned sparrow	5	-0.0045	2.9197E-07
∑41	**8,277**	**-1.9252**	**0.2172**

Shannon diversity index (H') = 1.9252
Variance H' = 1.7638E-04
Evenness (E) = 0.5184

1 -Simpson's diversity index (D_S) = 0.7828
Variance D_S = 7.9248E-06

Table D.21. Shannon and Simpson's diversity indices for plateau grassland cover type for Gray County study site from April 2008–August 2009.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0013	1.0485e-08
American coot	17	-0.0082	1.4259e-06
American kestrel	15	-0.0074	1.1009e-06
American pipit	2	-0.0013	1.0485e-08
American white pelican	12	-0.0061	6.9198e-07
bald eagle	2	-0.0013	1.0485e-08
bank swallow	62	-0.0243	1.9826e-05
barn swallow	94	-0.0340	4.5828e-05
black-crowned night-heron	17	-0.0082	1.4259e-06
blue-winged teal	318	-0.0868	5.2845e-04
bobolink	1	-0.0007	0.0000e+00
Brewer's blackbird	368	-0.0966	7.0800e-04
Brewer's sparrow	1	-0.0007	0.0000e+00
brown-headed cowbird	101	-0.0360	5.2947e-05
Canada goose	701	-0.1513	2.5724e-03
Cassin's sparrow	15	-0.0074	1.1009e-06
chestnut-collared longspur	5	-0.0029	1.0485e-07
cinnamon teal	2	-0.0013	1.0485e-08
clay-colored sparrow	7	-0.0038	2.2017e-07
cliff swallow	147	-0.0483	1.1251e-04
common grackle	109	-0.0382	6.1712e-05
common nighthawk	3	-0.0018	3.1454e-08
common snipe	1	-0.0007	0.0000e+00
dickcissel	40	-0.0169	8.1779e-06
double-crested cormorant	5	-0.0029	1.0485e-07
eastern kingbird	4	-0.0024	6.2907e-08
eastern screech-owl	1	-0.0007	0.0000e+00
Eurasian collared-dove	19	-0.0091	1.7929e-06
European starling	602	-0.1366	1.8967e-03
field sparrow	4	-0.0024	6.2907e-08
gadwall	75	-0.0283	2.9095e-05
grasshopper sparrow	144	-0.0476	1.0795e-04
great blue heron	7	-0.0038	2.2017e-07
great horned owl	1	-0.0007	0.0000e+00
greater yellowlegs	5	-0.0029	1.0485e-07
great-tailed grackle	43	-0.0180	9.4675e-06
green-winged teal	10	-0.0052	4.7180e-07
horned lark	192	-0.0594	1.9224e-04
house finch	4	-0.0024	6.2907e-08
house sparrow	3	-0.0018	3.1454e-08
killdeer	79	-0.0295	3.2303e-05
lark bunting	16	-0.0078	1.2581e-06
lark sparrow	32	-0.0141	5.2003e-06
Lincoln's sparrow	2	-0.0013	1.0485e-08
loggerhead shrike	3	-0.0018	3.1454e-08
long-billed curlew	3	-0.0018	3.1454e-08
mallard	209	-0.0634	2.2789e-04
McCown's longspur	2	-0.0013	1.0485e-08
meadowlark spp.	685	-0.1490	2.4562e-03

Table D.21. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
merlin	1	-0.0007	0.0000e+00
Mississippi kite	3	-0.0018	3.1454E-08
mourning dove	236	-0.0695	2.9074e-04
northern bobwhite	36	-0.0155	6.6052e-06
northern cardinal	1	-0.0007	0.0000e+00
northern flicker	1	-0.0007	0.0000e+00
northern harrier	72	-0.0274	2.6798e-05
northern mockingbird	1	-0.0007	0.0000e+00
northern pintail	13	-0.0066	8.1779e-07
northern rough-winged swallow	13	-0.0066	8.1779e-07
northern shoveler	26	-0.0118	3.4075e-06
pied-billed grebe	2	-0.0013	1.0485e-08
prairie falcon	4	-0.0024	6.2907e-08
purple martin	1	-0.0007	0.0000e+00
redhead	14	-0.0070	9.5409e-07
red-tailed hawk	14	-0.0070	9.5409e-07
red-winged blackbird	6,604	-0.3528	2.2859e-01
ring-necked pheasant	60	-0.0236	1.8558e-05
rock pigeon	5	-0.0029	1.0485e-07
rough-legged hawk	3	-0.0018	3.1454e-08
rufous-crowned sparrow	1	-0.0007	0.0000e+00
sandhill crane	2,016	-0.2809	2.1295e-02
savannah sparrow	38	-0.0162	7.3706e-06
scaled quail	6	-0.0034	1.5727e-07
scissor-tailed flycatcher	12	-0.0061	6.9198e-07
snow goose	175	-0.0553	1.5963e-04
song sparrow	24	-0.0110	2.8937e-06
Swainson's hawk	20	-0.0095	1.9921e-06
tree swallow	17	-0.0082	1.4259e-06
turkey vulture	2	-0.0013	1.0485e-08
upland sandpiper	4	-0.0024	6.2907e-08
vesper sparrow	7	-0.0038	2.2017e-07
western kingbird	48	-0.0197	1.1827e-05
white crowned sparrow	5	-0.0029	1.0485e-07
white-faced ibis	129	-0.0436	8.6560e-05
wild turkey	5	-0.0029	1.0485e-07
yellow warbler	1	-0.0007	0.0000E+00
∑86	**13,812**	**-2.1897**	**0.2596**

Shannon diversity index (H') = 2.1897
Variance H' = 2.1884E-04
Evenness (E) = 0.4916

1 -Simpson's diversity index (D_S) = 0.7404
Variance D_S = 1.3144E-05

Table D.22. Shannon and Simpson's diversity indices of spring for plateau grassland cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American kestrel	6	-0.0098	1.9078E-06
American white pelican	12	-0.0176	8.3942E-06
bank swallow	14	-0.0199	1.1574E-05
barn swallow	10	-0.0151	5.7233E-06
black-crowned night-heron	3	-0.0054	3.8155E-07
blue-winged teal	226	-0.1633	3.2337E-03
bobolink	1	-0.0021	0.0000E+00
Brewer's sparrow	1	-0.0021	0.0000E+00
brown-headed cowbird	3	-0.0054	3.8155E-07
Cassin's sparrow	3	-0.0054	3.8155E-07
clay-colored sparrow	7	-0.0112	2.6709E-06
cliff swallow	27	-0.0340	4.4642E-05
common grackle	55	-0.0593	1.8887E-04
dickcissel	1	-0.0021	0.0000E+00
double-crested cormorant	5	-0.0084	1.2718E-06
eastern kingbird	4	-0.0070	7.6311E-07
Eurasian collarded-dove	12	-0.0176	8.3942E-06
field sparrow	2	-0.0038	1.2718E-07
gadwall	68	-0.0697	2.8973E-04
grasshopper sparrow	58	-0.0618	2.1024E-04
great blue heron	3	-0.0054	3.8155E-07
greater yellowlegs	5	-0.0084	1.2718E-06
great-tailed grackle	16	-0.0222	1.5262E-05
horned lark	77	-0.0765	3.7214E-04
killdeer	40	-0.0464	9.9204E-05
lark bunting	13	-0.0188	9.9204E-06
lark sparrow	7	-0.0112	2.6709E-06
Lincoln's sparrow	2	-0.0038	1.2718E-07
loggerhead shrike	2	-0.0038	1.2718E-07
mallard	25	-0.0319	3.8155E-05
meadowlark spp.	309	-0.1988	6.0522E-03
mourning dove	85	-0.0824	4.5405E-04
northern bobwhite	8	-0.0125	3.5612E-06
northern cardinal	1	-0.0021	0.0000E+00
northern flicker	1	-0.0021	0.0000E+00
northern harrier	23	-0.0299	3.2178E-05
northern rough-winged swallow	4	-0.0070	7.6311E-07
northern shoveler	24	-0.0309	3.5103E-05
prairie falcon	2	-0.0038	1.2718E-07
purple martin	1	-0.0021	0.0000E+00
redhead	2	-0.0038	1.2718E-07
red-tailed hawk	1	-0.0021	0.0000E+00
red-winged blackbird	2,691	-0.2632	4.6033E-01
ring-necked pheasant	33	-0.0398	6.7153E-05
rufous-crowned sparrow	1	-0.0021	0.0000E+00
sandhill crane	3	-0.0054	3.8155E-07
savannah sparrow	1	-0.0021	0.0000E+00
scissor-tailed flycatcher	5	-0.0084	1.2718E-06
song sparrow	12	-0.0176	8.3942E-06

Table D.22. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index** N (N- 1)
Swainson's hawk	2	-0.0038	1.2718E-07
tree swallow	5	-0.0084	1.2718E-06
upland sandpiper	2	-0.0038	1.2718E-07
western kingbird	22	-0.0288	2.9380E-05
wild turkey	5	-0.0084	1.2718E-06
white-crowned sparrow	1	-0.0021	0.0000E+00
white-faced ibis	13	-0.0188	9.9204E-06
yellow warbler	1	-0.0021	0.0000E+00
∑57	**3,966**	**-1.5418**	**0.4716**

Shannon diversity index (H') = 1.5418
Variance H' = 8.58466E-04
Evenness (E) = 0.3813

1 -Simpson's diversity index (D_S) = 0.5284
Variance D_S = 3.8835E-04

Table D.23. Shannon and Simpson's diversity indices of summer for plateau grassland cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0066	4.2142E-07
American coot	11	-0.0274	2.3178E-05
American kestrel	1	-0.0036	0.0000E+00
bank swallow	48	-0.0862	4.7536E-04
barn swallows	82	-0.1264	1.3995E-03
black-crowned night-heron	13	-0.0314	3.2871E-05
blue-winged teal	13	-0.0314	3.2871E-05
brown-headed cowbird	16	-0.0371	5.0570E-05
Cassin's sparrow	12	-0.0294	2.7814E-05
cinnamon teal	2	-0.0066	4.2142E-07
cliff swallow	120	-0.1633	3.0089E-03
common grackle	52	-0.0914	5.5880E-04
common nighthawk	3	-0.0093	1.2643E-06
dickcissel	39	-0.0739	3.1227E-04
eastern screech-owl	1	-0.0036	0.0000E+00
Eurasian collarded-dove	7	-0.0190	8.8498E-06
European starling	8	-0.0212	1.1800E-05
gadwall	7	-0.0190	8.8498E-06
grasshopper sparrow	84	-0.1285	1.4691E-03
great blue heron	4	-0.0119	2.5285E-06
great horned owl	1	-0.0036	0.0000E+00
great-tailed grackle	27	-0.0559	1.4792E-04
green-winged teal	2	-0.0066	4.2142E-07
horned lark	55	-0.0952	6.2581E-04
house finch	4	-0.0119	2.5285E-06
house sparrow	3	-0.0093	1.2643E-06
killdeer	30	-0.0606	1.8332E-04
lark bunting	3	-0.0093	1.2643E-06
lark sparrow	24	-0.0510	1.1631E-04
loggerhead shrike	1	-0.0036	0.0000E+00
long-billed curlew	3	-0.0093	1.2643E-06
mallard	105	-0.1495	2.3010E-03
meadowlark spp.	176	-0.2074	6.4899E-03
Mississippi kite	3	-0.0093	1.2643E-06
mourning dove	140	-0.1802	4.1004E-03
northern bobwhite	28	-0.0574	1.5930E-04
northern harrier	2	-0.0066	4.2142E-07
northern mockingbird	1	-0.0036	0.0000E+00
northern rough-winged swallow	9	-0.0233	1.5171E-05
pied-billed grebe	2	-0.0066	4.2142E-07
redhead	6	-0.0167	6.3213E-06
red-winged blackbird	747	-0.3676	1.1742E-01
ring-necked pheasant	24	-0.0510	1.1631E-04
scaled quail	6	-0.0167	6.3213E-06
scissor-tailed flycatcher	7	-0.0190	8.8498E-06
Swainson's hawk	15	-0.0352	4.4249E-05
tree swallow	12	-0.0294	2.7814E-05
turkey vulture	2	-0.0066	4.2142E-07
upland sandpiper	1	-0.0036	0.0000E+00

Table D.23. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
western kingbird	26	-0.0543	1.3696E-04
white-faced ibis	116	-0.1597	2.8109E-03
∑51	**2,106**	**-2.6475**	**0.1422**

Shannon diversity index (H') = 2.6475
Variance H' = 1.0012E-03
Evenness (E) = 0.6733

1 -Simpson's diversity index (D_S) = 0.8578
Variance D_S = 3.5989E-05

Table D.24. Shannon and Simpson's diversity indices of fall for plateau grassland cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American coot	6	-0.0089	1.5201e-06
American kestrel	3	-0.0049	3.0402e-07
American pipit	2	-0.0035	1.0134e-07
barn swallow	2	-0.0035	1.0134e-07
black-crowned night-heron	1	-0.0019	0.0000e+00
blue-winged teal	75	-0.0689	2.8121e-04
Brewer's blackbird	218	-0.1479	2.3970e-03
brown-headed cowbird	82	-0.0737	3.3655e-04
chestnut-collared longspur	4	-0.0063	6.0803e-07
common grackle	2	-0.0035	1.0134e-07
common snipe	1	-0.0019	0.0000e+00
European starling	509	-0.2482	1.3102e-02
field sparrow	2	-0.0035	1.0134e-07
grasshopper sparrow	1	-0.0019	0.0000e+00
horned lark	21	-0.0253	2.1281e-05
killdeer	7	-0.0102	2.1281e-06
lark sparrow	1	-0.0019	0.0000e+00
mallard	74	-0.0682	2.7372e-04
meadowlark spp.	114	-0.0940	6.5272e-04
mourning dove	11	-0.0149	5.5736e-06
northern harrier	34	-0.0373	5.6851e-05
northern pintail	13	-0.0171	7.9044e-06
red-tailed hawk	9	-0.0126	3.6482e-06
red-winged blackbird	2,096	-0.3544	2.2250e-01
ring-necked pheasant	1	-0.0019	0.0000e+00
sandhill crane	1,115	-0.3469	6.2937e-02
savannah sparrow	20	-0.0243	1.9254e-05
song sparrow	7	-0.0102	2.1281e-06
Swainson's hawk	3	-0.0049	3.0402e-07
upland sandpiper	1	-0.0019	0.0000e+00
vesper sparrow	7	-0.0102	2.1281e-06
white crowned sparrow	1	-0.0019	0.0000E+00
∑32	**4,443**	**-1.6164**	**0.3026**

Shannon diversity index (H') = 1.6164
Variance H' = 3.6451E-04
Evenness (E) = 0.4664

1 -Simpson's diversity index (D_S) = 0.6974
Variance D_S = 2.7718E-05

Table D.25. Shannon and Simpson's diversity indices of winter for plateau grassland cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American kestrel	5	-0.0098	1.8404E-06
bald eagle	2	-0.0045	1.8404E-07
blue-winged teal	4	-0.0081	1.1043E-06
Brewer's blackbird	150	-0.1406	2.0567E-03
Canada goose	701	-0.3292	4.5155E-02
chestnut-collared longspur	1	-0.0025	0.0000E+00
European starling	85	-0.0943	6.5704E-04
grasshopper sparrow	1	-0.0025	0.0000E+00
green-winged teal	8	-0.0146	5.1533E-06
horned lark	39	-0.0525	1.3638E-04
killdeer	2	-0.0045	1.8404E-07
mallard	5	-0.0098	1.8404E-06
McCown's longspur	2	-0.0045	1.8404E-07
meadowlark spp.	86	-0.0951	6.7268E-04
merlin	1	-0.0025	0.0000E+00
northern harrier	13	-0.0218	1.4356E-05
northern shoveler	2	-0.0045	1.8404E-07
prairie falcon	2	-0.0045	1.8404E-07
redhead	6	-0.0115	2.7607E-06
red-tailed hawk	4	-0.0081	1.1043E-06
red-winged blackbird	1,070	-0.3652	1.0526E-01
ring-necked pheasant	2	-0.0045	1.8404E-07
rock pigeon	5	-0.0098	1.8404E-06
rough-legged hawk	3	-0.0064	5.5213E-07
sandhill crane	898	-0.3542	7.4125E-02
savannah sparrow	17	-0.0272	2.5030E-05
snow goose	175	-0.1558	2.8021E-03
song sparrow	5	-0.0098	1.8404E-06
white-crowned sparrow	3	-0.0064	5.5213E-07
∑29	**3,297**	**-1.7649**	**0.2309**

Shannon diversity index (H') = 1.7649
Variance H' = 3.6985E-04
Evenness (E) = 0.5241

1 -Simpson's diversity index (D_S) = 0.7691
Variance D_S = 1.3159E-05

Table D.26. Shannon and Simpson's diversity indices for playa wetland cover type for Gray County study site from March 2009–August 2009.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	11	-0.0069	9.0031e-07
American coot	224	-0.0790	4.0884e-04
American crow	2	-0.0016	1.6369e-08
American kestrel	2	-0.0016	1.6369e-08
American wigeon	43	-0.0216	1.4781e-05
Baird's sandpiper	4	-0.0029	9.8216e-08
bank swallow	19	-0.0109	2.7992e-06
barn swallow	192	-0.0704	3.0015e-04
black-crowned night-heron	17	-0.0100	2.2262e-06
black-necked stilt	47	-0.0232	1.7695e-05
blue-winged teal	690	-0.1731	3.8911e-03
bobolink	1	-0.0008	0.0000e+00
Brewer's blackbird	23	-0.0128	4.1414e-06
bufflehead	32	-0.0169	8.1192e-06
Bullock's oriole	1	-0.0008	0.0000e+00
Cassin's sparrow	2	-0.0016	1.6369e-08
cattle egret	1	-0.0008	0.0000e+00
clay-colored sparrow	10	-0.0063	7.3662e-07
cinnamon teal	9	-0.0058	5.8930e-07
cliff swallow	344	-0.1080	9.6572e-04
common goldeneye	27	-0.0147	5.7456e-06
common grackle	7	-0.0047	3.4376e-07
common nighthawk	2	-0.0016	1.6369e-08
dickcissel	7	-0.0047	3.4376e-07
eastern kingbird	12	-0.0074	1.0804e-06
Eurasian collared-dove	3	-0.0022	4.9108e-08
gadwall	235	-0.0819	4.5007e-04
grasshopper sparrow	17	-0.0100	2.2262e-06
great blue heron	20	-0.0114	3.1102e-06
great crested flycatcher	1	-0.0008	0.0000e+00
greater scaup	1	-0.0008	0.0000e+00
greater yellowlegs	23	-0.0128	4.1414e-06
great-tailed grackle	1,439	-0.2654	1.6936e-02
green-winged teal	379	-0.1156	1.1726e-03
horned lark	17	-0.0100	2.2262e-06
killdeer	134	-0.0535	1.4587e-04
lark bunting	3	-0.0022	4.9108e-08
lark sparrow	20	-0.0114	3.1102e-06
least flycatcher	1	-0.0008	0.0000e+00
least sandpiper	29	-0.0156	6.6459e-06
lesser scaup	23	-0.0128	4.1414e-06
lesser yellowlegs	15	-0.0090	1.7188e-06
loggerhead shrike	1	-0.0008	0.0000e+00
long-billed dowitcher	75	-0.0339	4.5425e-05
mallard	410	-0.1222	1.3725e-03
marbled godwit	1	-0.0008	0.0000e+00
meadowlark spp.	92	-0.0399	6.8522e-05
mourning dove	55	-0.0264	2.4308e-05
northern bobwhite	8	-0.0052	4.5834e-07

Table D.26. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
northern harrier	2	-0.0016	1.6369e-08
northern mockingbird	1	-0.0008	0.0000E+00
northern pintail	230	-0.0806	4.3109e-04
northern rough-winged swallow	2	-0.0016	1.6369e-08
northern shoveler	984	-0.2153	7.9168e-03
pectoral sandpiper	1	-0.0008	0.0000e+00
pied-billed grebe	14	-0.0084	1.4896e-06
pine siskin	1	-0.0008	0.0000e+00
redhead	132	-0.0529	1.4153e-04
red-necked phalarope	14	-0.0084	1.4896e-06
red phalarope	39	-0.0199	1.2130e-05
red-winged blackbird	4,390	-0.3667	1.5770e-01
ring-necked duck	12	-0.0074	1.0804e-06
ring-necked pheasant	8	-0.0052	4.5834e-07
rudy duck	53	-0.0256	2.2557e-05
sandhill crane	138	-0.0547	1.5474e-04
scissor-tailed flycatcher	3	-0.0022	4.9108e-08
short-billed dowitcher	30	-0.0160	7.1206e-06
solitary sandpiper	2	-0.0016	1.6369e-08
song sparrow	3	-0.0022	4.9108e-08
stilt sandpiper	2	-0.0016	1.6369e-08
Swainson's hawk	4	-0.0029	9.8216e-08
tree swallow	19	-0.0109	2.7992e-06
turkey vulture	3	-0.0022	4.9108e-08
upland sandpiper	5	-0.0035	1.6369e-07
western kingbird	31	-0.0165	7.6117e-06
white crowned sparrow	12	-0.0074	1.0804e-06
white-faced ibis	58	-0.0275	2.7058e-05
wild turkey	16	-0.0095	1.9643e-06
willet	43	-0.0216	1.4781e-05
Wilson's phalarope	35	-0.0182	9.7397e-06
yellow-headed blackbird	36	-0.0187	1.0313E-05
∑81	**11,054**	**-2.4472**	**0.1923**

Shannon diversity index (H') = 2.4472
Variance H' = 2.4132E-04
Evenness (E) = 0.5569

1 -Simpson's diversity index (D_S) = 0.8077
Variance D_S = 1.0469E-05

Table D.27. Shannon and Simpson's diversity indices of spring for playa wetland cover type for Gray County study site from.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	2	-0.0030	7.1106e-08
American coot	148	-0.0999	7.7349e-04
American crow	2	-0.0030	7.1106e-08
American kestrel	2	-0.0030	7.1106e-08
American wigeon	43	-0.0390	6.4209e-05
Baird's sandpiper	4	-0.0054	4.2663e-07
bank swallow	11	-0.0128	3.9108e-06
barn swallow	16	-0.0175	8.5327e-06
black-crowned night-heron	8	-0.0098	1.9910e-06
black-necked stilt	13	-0.0147	5.5463e-06
blue-winged teal	617	-0.2503	1.3513e-02
bobolink	1	-0.0016	0.0000e+00
Brewer's blackbird	23	-0.0236	1.7990e-05
bufflehead	32	-0.0308	3.5268e-05
Cassin's sparrow	1	-0.0016	0.0000e+00
clay-colored sparrow	10	-0.0118	3.1998e-06
cinnamon teal	1	-0.0016	0.0000e+00
cliff swallow	294	-0.1603	3.0626e-03
common goldeneye	27	-0.0269	2.4958e-05
common grackle	1	-0.0016	0.0000e+00
common nighthawk	1	-0.0016	0.0000e+00
dickcissel	1	-0.0016	0.0000e+00
eastern kingbird	1	-0.0016	0.0000e+00
Eurasian collared-dove	1	-0.0016	0.0000e+00
gadwall	218	-0.1312	1.6819e-03
grasshopper sparrow	6	-0.0077	1.0666e-06
great blue heron	14	-0.0157	6.4706e-06
greater scaup	1	-0.0016	0.0000e+00
greater yellowlegs	13	-0.0147	5.5463e-06
great-tailed grackle	35	-0.0331	4.2308e-05
green-winged teal	379	-0.1885	5.0934e-03
horned lark	6	-0.0077	1.0666e-06
killdeer	81	-0.0639	2.3038e-04
lark bunting	3	-0.0042	2.1332e-07
lark sparrow	2	-0.0030	7.1106e-08
least sandpiper	29	-0.0285	2.8869e-05
lesser scaup	23	-0.0236	1.7990e-05
lesser yellowlegs	7	-0.0088	1.4932e-06
loggerhead shrike	1	-0.0016	0.0000e+00
long-billed dowitcher	75	-0.0602	1.9732e-04
mallard	292	-0.1596	3.0210e-03
marbled godwit	1	-0.0016	0.0000e+00
meadowlark spp.	45	-0.0405	7.0395e-05
mourning dove	15	-0.0166	7.4661e-06
northern harrier	2	-0.0030	7.1106e-08
northern pintail	230	-0.1361	1.8726e-03
northern shoveler	984	-0.3125	3.4389e-02
pectoral sandpiper	1	-0.0016	0.0000e+00
pied-billed grebe	4	-0.0054	4.2663e-07

Table D.27. Continued.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
pine siskin	1	-0.0016	0.0000E+00
redhead	132	-0.0919	6.1478e-04
red-necked phalarope	8	-0.0098	1.9910e-06
red phalarope	39	-0.0361	5.2689e-05
red-winged blackbird	1,015	-0.3164	3.6591e-02
ring-necked duck	12	-0.0138	4.6930e-06
ring-necked pheasant	3	-0.0042	2.1332e-07
rudy duck	40	-0.0369	5.5463e-05
sandhill crane	138	-0.0949	6.7216e-04
scissor-tailed flycatcher	2	-0.0030	7.1106e-08
short-billed dowitcher	30	-0.0293	3.0931e-05
song sparrow	3	-0.0042	2.1332e-07
stilt sandpiper	2	-0.0030	7.1106e-08
Swainson's hawk	2	-0.0030	7.1106e-08
tree swallow	13	-0.0147	5.5463e-06
turkey vulture	3	-0.0042	2.1332e-07
upland sandpiper	5	-0.0066	7.1106e-07
western kingbird	6	-0.0077	1.0666e-06
white crowned sparrow	12	-0.0138	4.6930e-06
white-faced ibis	8	-0.0098	1.9910e-06
willet	43	-0.0390	6.4209e-05
Wilson's phalarope	30	-0.0293	3.0931e-05
yellow-headed blackbird	30	-0.0293	3.0931E-05
∑72	**5,304**	**-2.7981**	**0.1023**

Shannon diversity index (H') = 2.7981
Variance H' = 3.2920E-04
Evenness (E) = 0.6543

1 -Simpson's diversity index (D_S) = 0.8977
Variance D_S = 4.0539E-06

Table D.28. Shannon and Simpson's diversity indices of summer for playa wetland cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
American avocet	9	-0.0101	2.1781e-06
American coot	76	-0.0572	1.7243e-04
bank swallow	8	-0.0092	1.6941e-06
barn swallow	176	-0.1067	9.3173e-04
black-crowned night-heron	9	-0.0101	2.1781e-06
black-necked stilt	34	-0.0303	3.3942e-05
blue-winged teal	73	-0.0554	1.5900e-04
Bullock's oriole	1	-0.0015	0.0000e+00
Cassin's sparrow	1	-0.0015	0.0000e+00
cattle egret	1	-0.0015	0.0000e+00
cinnamon teal	8	-0.0092	1.6941e-06
cliff swallow	50	-0.0413	7.4115e-05
common grackle	6	-0.0072	9.0753e-07
common nighthawk	1	-0.0015	0.0000e+00
dickcissel	6	-0.0072	9.0753e-07
eastern kingbird	11	-0.0120	3.3276e-06
Eurasian collared-dove	2	-0.0028	6.0502e-08
gadwall	17	-0.0172	8.2283e-06
grasshopper sparrow	11	-0.0120	3.3276e-06
great blue heron	6	-0.0072	9.0753e-07
great crested flycatcher	1	-0.0015	0.0000e+00
greater yellowlegs	10	-0.0111	2.7226e-06
great-tailed grackle	1,404	-0.3443	5.9589e-02
horned lark	11	-0.0120	3.3276e-06
killdeer	53	-0.0432	8.3372e-05
lark sparrow	18	-0.0181	9.2568e-06
least flycatcher	1	-0.0015	0.0000e+00
lesser yellowlegs	8	-0.0092	1.6941e-06
mallard	118	-0.0798	4.1765e-04
meadowlark spp.	47	-0.0393	6.5403e-05
mourning dove	40	-0.0346	4.7192e-05
northern bobwhite	8	-0.0092	1.6941e-06
northern mockingbird	1	-0.0015	0.0000e+00
northern rough-winged	2	-0.0028	6.0502e-08
pied-billed grebe	10	-0.0111	2.7226e-06
red-necked phalarope	6	-0.0072	9.0753e-07
red-winged blackbird	3,375	-0.3127	3.4448e-01
ring-necked pheasant	5	-0.0061	6.0502e-07
rudy duck	13	-0.0138	4.7192e-06
scissor-tailed flycatcher	1	-0.0015	0.0000e+00
solitary sandpiper	2	-0.0028	6.0502e-08
Swainson's hawk	2	-0.0028	6.0502e-08
tree swallow	6	-0.0072	9.0753e-07
western kingbird	25	-0.0236	1.8151e-05
white-faced ibis	50	-0.0413	7.4115e-05
wild turkey	16	-0.0164	7.2602e-06
Wilson's phalarope	5	-0.0061	6.0502e-07

Table D.28. Continued.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
yellow-headed blackbird	6	-0.0072	9.0753E-07
∑48	**5,750**	**-1.4683**	**0.4062**

Shannon diversity index (H') = 1.4683
Variance H' = 4.5212E-04
Evenness (E) = 0.3793

1 -Simpson's diversity index (D_S) = 0.5983
Variance D_S = 3.5989E-05

Table D.29. Shannon and Simpson's diversity indices for prairie dog (*Cynomys ludovicianus*) town cover type for Gray County study site from March 2009–August 2009.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index N (N- 1)**
American robin	1	-0.0045	0.0000e+00
bank swallow	2	-0.0081	7.2274e-07
barn swallow	16	-0.0447	8.6729e-05
brown-headed cowbird	5	-0.0175	7.2274e-06
burrowing owl	46	-0.0992	7.4804e-04
Cassin's sparrow	2	-0.0081	7.2274e-07
cattle egret	4	-0.0145	4.3365e-06
chestnut-collared longspur	11	-0.0332	3.9751e-05
clay-colored sparrow	1	-0.0045	0.0000e+00
cliff swallow	10	-0.0307	3.2523e-05
common grackle	33	-0.0777	3.8161e-04
common nighthawk	1	-0.0045	0.0000e+00
dickcissel	16	-0.0447	8.6729e-05
Eurasian collared-dove	7	-0.0230	1.5178e-05
European starling	82	-0.1483	2.4002e-03
grasshopper sparrow	58	-0.1170	1.1947e-03
great-tailed grackle	39	-0.0880	5.3555e-04
horned lark	39	-0.0880	5.3555e-04
house finch	8	-0.0257	2.0237e-05
house sparrow	40	-0.0896	5.6374e-04
killdeer	42	-0.0929	6.2228e-04
lark bunting	6	-0.0203	1.0841e-05
lark sparrow	24	-0.0611	1.9948e-04
mallard	10	-0.0307	3.2523e-05
meadowlark spp.	322	-0.3178	3.7352e-02
mourning dove	93	-0.1612	3.0919e-03
northern bobwhite	16	-0.0447	8.6729e-05
northern harrier	6	-0.0203	1.0841e-05
northern mockingbird	4	-0.0145	4.3365e-06
northern pintail	20	-0.0531	1.3732e-04
northern rough-winged swallow	2	-0.0081	7.2274e-07
red-winged blackbird	630	-0.3677	1.4320e-01
ring-necked pheasant	13	-0.0379	5.6374e-05
sandhill crane	4	-0.0145	4.3365e-06
scaled quail	4	-0.0145	4.3365e-06
scissor-tailed flycatcher	4	-0.0145	4.3365e-06
song sparrow	9	-0.0282	2.6019e-05
turkey vulture	2	-0.0081	7.2274e-07
upland sandpiper	1	-0.0045	0.0000e+00
western kingbird	22	-0.0572	1.6695e-04
white crowned sparrow	3	-0.0114	2.1682e-06
yellow-headed blackbird	6	-0.0203	1.0841E-05
∑43	**1,664**	**-2.3747**	**0.1917**

Shannon diversity index (H') = 2.3747
Variance H' = 1.3678E-03
Evenness (E) = 0.6314

1 -Simpson's diversity index (D_S) = 0.8083
Variance D_S =6.0148E-05

Table D.30. Shannon and Simpson's diversity indices of spring for prairie dog town cover type for Gray County study site.

Species	*n*	Shannon Index p_i Ln p_i	Simpson's Index N (N- 1)
brown-headed cowbird	5	-0.0242	1.6015e-05
burrowing owl	26	-0.0875	5.2050e-04
cattle egret	3	-0.0159	4.8046e-06
chestnut-collared longspur	11	-0.0455	8.8084e-05
clay-colored sparrow	1	-0.0063	0.0000e+00
common grackle	32	-0.1017	7.9436e-04
dickcissel	4	-0.0202	9.6092e-06
Eurasian collared-dove	4	-0.0202	9.6092e-06
European starling	61	-0.1587	2.9308e-03
grasshopper sparrow	32	-0.1017	7.9436e-04
great-tailed grackle	7	-0.0318	3.3632e-05
horned lark	32	-0.1017	7.9436e-04
house sparrow	12	-0.0487	1.0570e-04
killdeer	25	-0.0850	4.8046e-04
lark bunting	5	-0.0242	1.6015e-05
lark sparrow	13	-0.0518	1.2492e-04
mallard	6	-0.0281	2.4023e-05
meadowlark spp.	239	-0.3298	4.5549e-02
mourning dove	25	-0.0850	4.8046e-04
northern bobwhite	7	-0.0318	3.3632e-05
northern harrier	6	-0.0281	2.4023e-05
northern mockingbird	2	-0.0113	1.6015e-06
northern pintail	20	-0.0720	3.0429e-04
northern rough-winged swallow	2	-0.0113	1.6015e-06
red-winged blackbird	510	-0.3580	2.0787e-01
ring-necked pheasant	7	-0.0318	3.3632e-05
sandhill crane	4	-0.0202	9.6092e-06
song sparrow	9	-0.0388	5.7655e-05
upland sandpiper	1	-0.0063	0.0000e+00
western kingbird	4	-0.0202	9.6092E-06
white crowned sparrow	3	-0.0159	4.8046e-06
∑31	**1,118**	**-2.0132**	**0.2611**

Shannon diversity index (H') = 2.0132 **1 -Simpson's diversity index (D_S) = 0.7389**
Variance H' = 2.0584E-03 **Variance D_S = 1.3038E-04**
Evenness (E) = 0.5863

Table D.31. Shannon and Simpson's diversity indices of summer for prairie dog town cover type for Gray County study site.

Species	***n***	**Shannon Index** p_i **Ln** p_i	**Simpson's Index** **N (N- 1)**
American robin	1	-0.0115	0.0000e+00
bank swallow	2	-0.0205	6.7211e-06
barn swallow	16	-0.1034	8.0653e-04
burrowing owl	20	-0.1211	1.2770e-03
Cassin's sparrow	2	-0.0205	6.7211e-06
cattle egret	1	-0.0115	0.0000e+00
cliff swallow	10	-0.0733	3.0245e-04
common grackle	1	-0.0115	0.0000e+00
common nighthawk	1	-0.0115	0.0000e+00
dickcissel	12	-0.0839	4.4359e-04
Eurasian collared-dove	3	-0.0286	2.0163e-05
European starling	21	-0.1253	1.4114e-03
grasshopper sparrow	26	-0.1450	2.1844e-03
great-tailed grackle	32	-0.1663	3.3337e-03
horned lark	7	-0.0559	1.4114e-04
house finch	8	-0.0619	1.8819e-04
house sparrow	28	-0.1523	2.5406e-03
killdeer	17	-0.1080	9.1407e-04
lark bunting	1	-0.0115	0.0000e+00
lark sparrow	11	-0.0787	3.6966e-04
mallard	4	-0.0360	4.0327e-05
meadowlark spp.	83	-0.2864	2.2872e-02
mourning dove	68	-0.2594	1.5311e-02
northern bobwhite	9	-0.0677	2.4196e-04
northern mockingbird	2	-0.0205	6.7211e-06
red-winged blackbird	120	-0.3330	4.7989e-02
ring-necked pheasant	6	-0.0496	1.0082e-04
scaled quail	4	-0.0360	4.0327e-05
scissor-tailed flycatcher	4	-0.0360	4.0327e-05
turkey vulture	2	-0.0205	6.7211e-06
western kingbird	18	-0.1125	1.0283e-03
yellow-headed blackbird	6	-0.0496	1.0082E-04
∑32	**546**	**-2.7097**	**0.1017**

Shannon diversity index (H') = 2.7097
Variance H' = 2.1630E-03
Evenness (E) = 0.7819

1 -Simpson's diversity index (D_S) = 0.8983
Variance D_S = 4.4365E-05