REDUCTION OF WILDLIFE ON AIRFIELDS THROUGH TURFGRASS SELECTION

BY

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THESIS

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Abstract

Aircraft collisions with wildlife are a major safety and economic concern for the aviation industry. Birdstrikes in particular are increasing due to rises in both the number of aircraft flights and the populations of several of the most hazardous bird species in North America. Traditional avian management practices at airports, including the use of pyrotechnics, sound, lights, and firearms, can be expensive and require continuous application. Therefore, manipulating the airport habitat in a way that repels birds is vital. A turfgrass species that reduces bird use will minimize the need for these less efficient management tactics. The purpose of this project was to identify a turfgrass species that birds find unattractive that can be used as a part of the management plan at airports to reduce collisions with birds.

Five turfgrass species, Kentucky bluegrass (*Poa pratensis* L.), endophytic tall fescue (*Schedonorus phoenix* [Scop.] Holub.), non-endophytic tall fescue, endophytic perennial ryegrass (*Lolium perenne* L.), and zoysia grass (*Zoysia japonica* Steud.), were established around a pond in Champaign, Illinois near the intersection of First street and Windsor Road. The endophytic grasses contain a fungus that produces alkaloids; compounds that are toxic to many species. Zoysia grass, a warm season turf, is dormant during prime bird migration periods. For these reasons, the endophytic grasses and zoysia grass have great potential in reducing bird visits. I recorded the species and number of birds on the plots between March and October of 2010 and 2011. Data on bird use were recorded every 5 minutes for 0.5-hr or 1-hr increments. I also sampled invertebrates and small mammals from each plot and surveyed Canada geese (*Branta canadensis* L.) using pellet counts. Results suggest that zoysia grass may be a successful means of reducing bird numbers at airports. Along with endophytic tall fescue and Kentucky bluegrass, zoysia had fewer bird observations than non-endophytic tall fescue and perennial ryegrass between July and October, the time period with the greatest number of birdstrike incidents ($p < 0.05$). Additionally, zoysia contained fewer invertebrates than all other turfgrass species ($p < 0.01$). These results offer insight into an alternative airport management technique that with further research may lead to a reduction in birdstrikes.

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Background

Air traffic worldwide has increased substantially since the post-World War II expansion of the civil aviation industry (Kelly and Allan, 2006). Commercial aircraft flights rose approximately 13% between 1990 and 2007 (Dolbeer, 2009). Through 2025, the U.S. civil fleet is predicted to expand by 2.5% annually due to greater demand (FAA, 2008b). Today, an estimated 28 million commercial jet takeoffs occur annually in the United States, compared to 18 million in 1980 (Sodhi, 2002). With the enormous and continuously growing industry, safety and economic efficiency are top concerns for airports and aviation companies alike.

Aircraft collisions with wildlife, particularly birds (hereafter birdstrikes) are of major safety and economic concern throughout the aviation world. The overall cost of birdstrikes is difficult to calculate because many collisions with wildlife are not reported. The Federal Aviation Administration (FAA) estimates that roughly 20% of all wildlife strikes annually in the United States are reported (Cleary et al., 2006). Additionally, commercial airlines often do not separate the costs of birdstrikes from other expenses (Allan, 2002). However, annual cost to commercial airlines including direct and indirect expenses is conservatively estimated at $1.2 billion worldwide (Allan, 2009). The Federal Aviation Administration reported 82,057 wildlife strikes, 97.5% of which were with birds, between 1990 and 2007 with an annual cost of at least $628 million (Dolbeer and Wright, 2008). Between 1988 and 2011, there were > 210 aircraft destroyed and ≥ 229 human deaths caused by birdstrikes (Richardson and West, 2000; Thorpe, 2003; Dolbeer and Wright, 2008).

The aircraft themselves have become more apt to collide with wildlife in recent years due to new designs and innovations. By the 1960s, turbine power began to replace piston-powered engines and the airplanes were becoming larger to accommodate an increase in passengers and cargo. Both the turbine engines and greater size are thought to have contributed to increased risk of wildlife strikes because the vacuum of the turbine and the greater surface area lead to a larger area for wildlife to avoid (Cleary and Dolbeer, 2005). The possibility of damage to the aircraft also is greater with a turbine engine than a piston-powered engine if an animal is ingested by the engine (Cleary and Dolbeer, 2005). Additionally, most modern airplanes have two efficient and quiet engines compared to aircraft of the past that had three or four very loud engines (Cleary et al. 2006). Because of the decrease in the number of engines, a collision with a flock of birds, impairing one or more engines, poses a threat to the safety of the aircraft and its passengers. Quieter engines may also decrease the ability of wildlife to detect approaching aircraft (International Civil Aviation Organization, 1994b).

A dramatic increase in the populations of large birds may also be contributing to the rising rate of birdstrikes. The populations of 13 of the 14 largest bird species (>3.6 kg) of North America have significantly increased in the past 40 years (Dolbeer and Eschenfelder, 2003). Aggressive conservation management programs by natural resources agencies as well as habitat restoration and other land-use changes during the past 30 years have resulted in the immense increases in the populations of many North American wildlife species (Dolbeer, 2000). Of the 36 North American bird species with a mean body mass ≥ 1.81 kg, 24 (67%) display flocking behavior (Dolbeer and Eschenfelder, 2003). The risk of a damaging and potentially fatal strike increases as the size of the flock increases (DeVault et al. 2011). The Canada goose

(*Branta canadensis*), a particularly hazardous species, is one such large-bodied bird that also flocks. They have also adapted to urban environments and have found places like airports and golf courses, with expansive areas of grass and pavement, to be attractive sites for feeding and resting (Dolbeer and Wright, 2009).

The migratory and non-migratory population of Canada geese in North America more than quadrupled from 1.2 million to 5.5 million between 1970 and 2008 (Dolbeer and Seubert, 2009). Accessible waste grain and open water areas in the winter are partially to blame for the dramatic rate of increase in the geese (Ankney, 1996). Many Canada goose populations in urban areas are foregoing their traditional winter migration and instead remain in the same location year-round. In urban areas where predation is low and people commonly feed the geese, their survival rate is often much higher than in natural conditions (Washburn and Seamans, 2011).

The highly publicized 2009 crash landing of US Airways flight 1549 into the Hudson River in New York City brought attention to the hazards associated with birdstrikes. The airplane collided with numerous migratory Canada geese about 800m above ground and 8 km from La Guardia Airport, where the flight originated (Marra et al., 2009). Because of the dramatic landing in the river and heroic actions of the flight crew in keeping everyone onboard alive, the incident received a great deal of attention from the public and media. The crash landing of flight 1549 has led to concern in the public sector over the risks associated with strikes and a motivation to find ways of lessening the threats.

Fifty one percent of all birdstrikes occur between July and October, when the number of individual birds is highest and several species are migrating (Cleary et al., 2006). Additionally, most birdstrikes occur ≤ 150 m above ground, primarily at take-off or landing, with 60% of collisions with wildlife occurring within the airfield property itself (Cleary and Dolbeer, 2005; Dolbeer and Wright, 2008). Thus, keeping birds away from airports is vital to the safety of pilots and passengers of aircraft.

Current Airport Avian Management Techniques

Several techniques to reduce wildlife at airports currently exist. The most common management methods include modifications to bird behavior, airplane activities, and the airport habitat (Cleary and Dolbeer, 2005). Modifications to bird and airplane activities are often successful, but not completely reliable, and often expensive and time-consuming. Habitat management methods tend to be less expensive but often require time for successful establishment of the various treatments. Thus, airport managers need to assess the specific conditions of their airport to determine which method, or combination of methods might best suit the needs of their management area.

A simple and economically favorable avian diversion technique is to repel birds and other wildlife through habitat management. Common habitat modifications to reduce wildlife include removal or reduction of standing water and covering nearby ponds with netting to deter waterfowl from landing or loafing in and around the water. Other modifications include removing trees and shrubs from the airfield to discourage birds from nesting in the area (Cleary and Dolbeer, 2005). Treating the airfield with herbicides and pesticides to reduce seeds and insect food sources is another habitat modification option.

Along with the airfield itself, airports often include multiple buildings. Management practices pertaining to these structures can also help prevent bird use in the area. In north central Ohio, gulls (*Larus* spp.) prefer light-colored gravel surfaces to dark rubber or tar on building surfaces (Belant, 1997). Additionally, gulls prefer and have greater success in hatching when nesting near structures such as air conditioning units or air vents on roofs (Belant, 1997). Airport management can impede gulls and possibly other bird species from nesting on the airport property buildings by using dark rubber or tar and avoiding light-colored gravel on roofs as well as reducing the number of structures located on roofs. Although the dark roof surfaces increase the air conditioning load on the building, only structures on or directly adjacent to the airfield would maintain a black roof, so the increased safety measures may very well out-weigh any increase in energy expenditure for the building.

Given that most airports use turfgrass near their runways and often most airport property is turfgrass, identifying a species of turfgrass that repels wildlife and is relatively low maintenance may be a worthwhile solution to reducing birdstrikes with aircraft. In several studies, intermediate or tall grass height was found to reduce the number of birds compared to shorter grass heights (Barras and Seamans, 2002). The taller grass limited the loafing space for several bird species such as gulls, which prefer very short or paved areas for loafing.

Modifications to bird behaviors present another method of avian deterrence at airports. The means of influencing bird behavior can fall into two categories: non-lethal and lethal interference. A number of non-lethal avian management techniques have been employed at a numerous airports to reduce birdstrikes with aircraft. Pyrotechnics along with sound, light, and decoy treatments are commonly used to detract birds from the airfield. However, birds can habituate to the sound, light, and decoy treatments in a short amount of time and so may not be a successful long-term solution (Harris and Davis, 1998). Aerosols and chemical treatments are another non-lethal method of bird deterrence. Dimethyl and methyl anthranilate, non-toxic taste aversion chemicals, were strongly avoided by captive mallards (*Anas platyrhynchos*) and Canada geese when the birds were offered both treated and untreated grain and so may be a successful means of detracting hazardous birds from airfields (Cummings et al., 1992).

Furthermore, non-lethal interference management was employed at Elmendorf Air Force Base (EAFB) in Anchorage, Alaska. The airport was experiencing large numbers of lesser Canada geese (*Branta hutchinsii*) (York et al., 2000). The birds in the airport and several in locations adjacent to the airport were captured; neck banded, and relocated 32 km outside Anchorage. Ninety six percent of the translocated geese returned to either the airport itself or Anchorage. EAFB employed other non-lethal hazing techniques on the geese, including sirens, crackers and screamer shells, and horns. Twenty percent of all geese hazed at least one time at EAFB returned at a later date.   These examples demonstrate some of the shortcomings of non-lethal interference. All the tactics used were costly to implement and did not provide effective, long-term management of geese populations.

Lethal interference is another option airport managers may choose to employ based on their particular avian situation. Several lethal control methods exist, including sharp shooting, hunter harvest and egg oiling (York et al., 2000). Biologists began shooting laughing gulls

(*Leucophaeus atricilla*) flying over John F. Kennedy International Airport in New York in 1991 and 1992. After the sharp shooting had begun, the number of strikes involving laughing gulls was reduced by 66% between May 20 and August 15 and by 68% between May 20 and December 31 compared with the same time periods from 1988 through 1990 (Dolbeer et al., 1993). However, shooting was ineffective in dispersing cattle egrets (*Bubulcus ibis*) from an airport in Hilo, Hawaii. Most egrets returned soon after shooting, even if some birds had been killed (Burger, 1983; Fellows and Paton, 1988).

Modifications to airplane activities are another technique that may be used to reduce birdstrikes. Spotters can be used on the airfield to identify potentially hazardous birds with spotting scopes and radar equipment can be used to track the movements of large flocks of birds. Airports can then adjust flight schedules to avoid peak bird movement times. If a hazardous bird or flock has been spotted in the path of an aircraft, the pilot can then take measures to safely avoid a collision.

Though modifying bird and airplane activities can affect the number of birds in an airfield, the birds tend to habituate to the deterrence treatments quickly. The bird behavior and plane modifications that are relatively successful tend to be expensive and require continuous application by one or more technicians. Habitat modifications require minimal maintenance after the initial establishment and several of the techniques have significantly decreased bird use in airfields. Thus, a turfgrass that deters bird species, particularly hazardous species in terms of bird strike risks, would have a number of economic and safety benefits. Selecting a grass that is hardy, low maintenance, and reasonably inhospitable to wildlife is essential in reducing avian abundance on airport grounds (Austin-Smith and Lewis 1969, Linnell et al. 1995).

Endophyte-Infected Grasses

Many plants produce compounds such as alkaloids, caffeine, and tannins that provide them with protection from grazing or foraging animals (Alcock 1979). The compounds often prove toxic when consumed by animals and so are undesirable for forage (Alcock 1979). Plants using these natural defenses might be suitable airfield vegetation.

Tall fescue (*Schedonorous phoenix* [Scop.] Holub) and perennial ryegrass (*Lolium perenne* L.) are cool-season perennial sod-forming grasses that may be unattractive to wildlife due to toxic alkaloids often present in the plant material(Clay 1993). Tall fescue grows well in the U.S. with over 14 million ha in the eastern U.S. alone (Mead and Carter 1973, Barnes et al. 1995, Shelby and Dalrymple 1987). Tall fescue develops into solid stands and crowds out other grasses (Barnes et al. 1995, Washburn et al. 2007). As a cool-season grass, tall fescue grows predominately in the cooler months of spring and fall and is relatively cold tolerant.

Fescues and perennial ryegrass are substandard forage for livestock due to the fungal endophyte *Neotyphodium coenophialu*m and *Acremonium lolii* with which they often form mutualistic symbiotic relationships (Washburn and Seamans 2004). Alkaloids created by the endophyte cause reproductive problems, weight loss, and several diseases in livestock and small mammals, suggesting that animals may deliberately avoid consuming endophyte-infected grasses (Schmidt and Osborn 1993, Bacon and Hill 1997). Several studies regarding animal use of endophyte-infected grasses have been conducted (Godfrey et al. 1994, Fortier et al. 2000, Coley et al. 1995, Settivari et al. 2008). However, no published studies have examined the preference for E+ or E- turf by multiple species in a free-ranging area.

The tall fescue cultivar Kentucky-31 was released in the 1940's. Because of its hardiness and ease of establishment, it quickly became a widespread forage grass in the U.S. (Stuedemann and Hoveland 1988). However, farmers soon noticed their cattle lost weight, had reduced reproductive performance, and demonstrated several other toxicosis symptoms. Soon after, numerous studies reported that the fescue toxicosis seen in livestock was caused by tall fescue infected with the fungus *Neotyphodium coenophialum* (Bacon et al. 1997). The discovery of the toxicosis-causing fungus launched several research projects on the effects of *N. coenophialum* and other endophytes on livestock as well as wild animals.

Canada geese prefer to forage and loaf in endophyte-free ryegrass over endophyte-infected tall fescue (Washburn et al. 2007). In a similar study, results revealed that Canada geese fed E+ tall fescue lost weight while those fed E- tall fescue gained weight (Conover and Messmer, 1996). Both studies were carried out in controlled environments in which the geese were penned. However, some factors may be present in natural conditions that are not present in the controlled environment. In natural conditions, birds are often able to move among cover types and consume a variety of plant species. Both studies supplemented the diets with wheat grain and calcium (Conover and Messmer, 1996) or corn and poultry pellets (Washburn et al. 2007).

Other studies have been performed in laboratory settings, with many finding that animals avoid or have adverse reactions to E+ tall fescue. Madej and Clay (1991) found that 4 of 5 species of song birds ate significantly more E- than E+ fescue seed. The birds were also able to distinguish between two types of seeds and preferred E- seeds in choice tests.

Endophytes may have an impact on wild rodent populations. In one study comparing species richness of small mammals between E+ and E- plots, no differences in species richness between the two treatments were found (Coley et al., 1995). However, more individuals of four different species were captured in the E- plots than the E+ plots, which may indicate a trend toward small mammals inhabiting E- turf areas over E+ areas. In lab settings, E+ tall fescue reduces daily weight gain and lowers feed intake in rats (Settivari et al. 2008).

Lab mice experience chronic and acute negative effects from consuming endophyte-rich food (Godfrey et al. 1994). Hawks are ranked eighth in the list of the most hazardous wildlife groups to aviation based on frequency of strikes, damage caused, and cost of damage (Dolbeer et al. 2000). Raptor populations can follow the population trends of small mammals (Baker and Brooks 1981). Therefore, a reduced abundance of small mammals at airports can potentially reduce raptor numbers at and near the airport. Although negative effects are recorded in lab mice, the study was not administered in a natural habitat. Unlike laboratory mice, many small mammals are well adapted to low quality diets (Batzli, 1985; Cole and Batzli, 1979). Thus, results of one study on laboratory mice may not be indicative of field results for all small mammals.

Although most of the research regarding E+ and E- tall fescue took place in a controlled setting, some studies have been set in a natural environment. Fortier et al. (2000) found the *N. coenophialum* may delay the onset of sexual maturity in wild prairie voles (*Microtus* *ochrogaster*). Additionally, endophytic tall fescue is not suitable habitat for northern bobwhites (*Colinus virginianus*), (Barnes et al., 1995). Fewer birds were located in the E+ than in the E- grass areas. The researchers determined that tall fescue lacks quality, structure, and composition to support large populations of northern bobwhites (Barnes et al. 1995).

The widespread use and success of tall fescue and perennial ryegrass throughout North America, along with the presence of fungal endophytes make both species potentially successful turf grasses for airports. Endophyte-infected seeds for both species are relatively inexpensive and germinate readily throughout much of their range. Consequently, they may be widely accepted as wildlife deterrents if shown to dissuade birds and other animals from using these species.

Zoysia Grass

Unlike tall fescue, perennial ryegrass and Kentucky bluegrass, zoysia grass is a warm-season grass. Zoysia grass remains dormant until late spring and becomes dormant in the fall when temperatures begin to cool, usually in early to mid-October in central Illinois. Most bird migration events in Illinois occur in April, May, and October. With the grass dormant during migration, birds may find it unappealing when compared to the green, cool-season grasses nearby.

Washburn and Seamans (2011) observed the behavioral responses of captive geese to 9 turfgrasses over 6 four-week trials. The captive geese preferred Kentucky bluegrass, creeping bentgrass, and fine fescue sods compared to centipedegrass, St. Augustinegrass, and zoysia grass. In one experiment, the bill contacts per minute by geese in the Kentucky bluegrass, tall fescue (a mixture of endophytic and non-endophytic cultivars), and Bermuda grass plots was more than 22 times greater than the bill contacts per minute by geese in the zoysia grass plots. Adult Canada geese tended to forage predominately in grasses with more than 20% protein or nitrogen content, which included Kentucky bluegrass, creeping bentgrass, and fine fescue (Washburn and Seamans, 2011). Additionally, acid detergent fiber may influence the turf selection by geese. The grasses fed upon most often by geese, Kentucky bluegrass and creeping bentgrass, had low levels of acid detergent fiber. Turfgrasses that were less fed upon, centipedegrass and zoysia grass, contained high levels of acid detergent fiber (Washburn and Seamans, 2011). Thus, the selection of certain turfgrass types over others may be partially based on nutritional value.

If birds prefer non-endophytic grasses, then the establishment of endophytic grasses at airports may prove effective at reducing bird use in the area. Likewise, birds may prefer green grass during migration months. Though non-endophytic, zoysia grass may be more suitable at airports in temperate climates due to its dormancy during peak migration periods. Additionally, the relatively low protein and high acid detergent fiber in zoysia grass may repel birds and other wildlife. Zoysia and endophytic grasses may also diminish the food source for raptors and insectivorous birds by reducing the numbers of invertebrates and small mammals. In this paper, I address these questions: 1) Do zoysia grass or endophytic grasses affect the use of turf patches by birds? And 2) Do the number of invertebrates and small mammals vary with turfgrass type? I predicted that birds, small mammals, and invertebrate use would be more prevalent in non-endophytic grasses. Specifically, I predicted that E- tall fescue and Kentucky bluegrass would have the most animal use. I expected zoysia grass and the endophytic grasses, perennial ryegrass and E+ tall fescue, to have the fewest animals observed during the study. Despite several lab and pen studies on the effects of endophytes on birds and mammals, few studies have analyzed the impact on wild birds or included zoysia grass as a treatment.

Methods

Study site

I used a study site situated around a pond located on the "South Farms" at the University of Illinois in Champaign, IL (40^{o}04'54.13"N; 88^{o}14'24.33"W). The site was established in 2007 and the location was chosen due to the central pond that serves to attract Canada geese and other waterfowl to the area. The average annual precipitation for this area was 104.3 cm (NOAA 2009). The average daily maximum temperature was 16.2 ^{o}C and the average daily minimum temperature was 5.3 ^{o}C. The overall matrix of the study site is urbanization and row-crop agricultural fields, primarily corn and soy beans. Immediately surrounding the site are grassy buffers, agriculture, and restored tallgrass prairie.

Plot establishment

The experimental design consisted of a randomized complete block design with three replicates and five grass types, for a total of fifteen plots, with individual plots measuring 18 m x 18 m. Each block was positioned directly adjacent to the pond and so differed in sloping gradient, aspect, and other uncontrolled variables (Figure 1.1). In 2009, the plot treatments were randomly rearranged into a different order from that of a previous study in 2007 and 2008 (Kissane, unpublished).

The five turf treatments included endophytic (E+) tall fescue (*Schedonorous phoenix* [Scop.] Holub) var. Matador, non-endophytic (E-) tall fescue (*Schedonorous phoenix* [Scop.] Holub) var. Tar Heel, endophytic (E+) perennial ryegrass (*Lolium perenne* L.) var. Paragon, Kentucky bluegrass (*Poa pratensis* L.) var. Arlene, and zoysia grass (*Zoysia japonica* L.) var. Zenith. I fertilized the plots with a granular fertilizer, Andersons Contec DG 18-3-18, once every two months from April through August. Because turf at airports is typically not watered, I refrained from irrigating the plots unless the turfgrass was exhibiting signs of distress due to drought. The plots were mowed throughout the study to approximately 6 cm high once or twice per month while the turfgrass was actively growing, mimicking standard airport practice.

Flood control and additional seeding were occasionally employed during the spring and fall to maintain turf coverage. All plots were maintained at 70% cover from March-September 2010 and May-October 2011. Three plots in block 1 (E+ PR, E- TF, KB) were flooded in October 2010 and March and April of 2011. The plots were reseeded and irrigated when water receded and returned to ≥70% within 14-20 days after reseeding. The three zoysia grass plots consistently had the highest percent cover in each block. The zoysia was sodded in 2009, leading to better establishment than the other turfgrasses. Additionally, water submersion tolerance may be higher in zoysia grass than for the other turf types.

Bird Use

Bird use data were collected on the plots by counting bird species and individuals present every 5 minutes for either 0.5-hr or 1-hr increments during daylight hours. From April 2010 through October 2011, the turf plots were observed for at least eight hours each week, weather and percent grass cover on each plot permitting. Observers were ≥ 50 m from the study area and used binoculars. Throughout the study period, five people served as observers, all of whom received training for consistency. As long as each plot was visible, all blocks were observed simultaneously. Observations from a block were not collected when at least one of the plots was partially covered by flooding, snow, ice, or was in use by the public.

I compared the average number of bird observations per hour on each plot of our 2010-2011 study to a previous, similar study from 2007 and 2008 (Kissane, 2008). Because the treatments across the three blocks and fifteen plots were rearranged after the 2007-2008 study, I compared each plot to determine if the birds were attracted to certain areas despite the turf type present. Additionally, I compared each treatment among the three blocks between the two studies. Again, the goal was to determine if the birds were attracted to a particular turf type or were simply drawn to a certain area of the study site.

Invertebrate abundance

I estimated the abundances of surface invertebrates during August of 2010 and May, June, August, and October of 2011. I used a modified leaf blower (model BG 55, Stihl®, Waiblingen, Germany; air flow rate 700 m^3/h, velocity 63 m/s) as a suction surface sampler (Richardson and Hanks 2009). The modified leaf blower vacuumed invertebrates and other loose material from the ground into a fine mesh net (0.2-mm mesh) at the opening of the sampler. Nine samples were collected from each plot, using a 0.25 m^2 quadrat. The quadrat presented a standard area for collecting each sample. The 18 x 18 m plot was divided into nine 6 x 6 m sample areas. I collected the samples with locations randomly selected within each of the 9 divisions. Each sample was collected for 10 seconds. I removed the mesh net and transferred the contents into marked plastic bags and stored them in a freezer. I separated and weighed every invertebrate > 1mm in length from each plot.

Goose Pellet Survey

I estimated relative abundance of geese on plots with goose pellet surveys with the assumption that the number of pellets correlates with the number of geese present. There are currently no published studies verifying this assumption in Canada geese. However, the method has been used to measure relative abundance of the greater sage grouse in western Wyoming (Hanser et al. 2011). The surveys were conducted on a monthly or bi-monthly basis between May and October of 2011, for a total of six collections. All goose pellets were removed from each turf plot one week prior to the survey to ensure a standard amount of measurement time for each plot. One week after all pellets were removed, I returned to the plots and counted the pellets. A group of pellets within 15 cm of each other were considered one pellet or "event".

Small Mammal Abundance

Small mammal abundance was measured in September and October 2010. I set nine Sherman live animal traps in a 3x3 grid on each plot. Each trap was about 5 m from the closest trap and 2 m from the edge of the plot. The traps were baited with birdseed and set out each evening for three consecutive nights at dusk and checked at dawn and again two hours later. To provide warmth for the animals in October, a cotton ball was also put in each trap. For each animal trapped, I recorded species, trap location, and whether or not the animal was a recapture. To determine recaptures, fur was clipped on the right flank of each trapped animal on the first day of checking traps, on the left flank on the second day, and on the left shoulder on the third day. Fur clipped in the September sampling session grew back sufficiently by the

October sampling session so that animals with clips performed in September looked distinctly like an old clip in October. The mammal trapping followed approved Institutional Animal Care and Use Committee (IACUC) procedures. All trapped individuals were released directly after handling.

Statistical Analysis

Bird use. I compared the number of birds observed per hour over the course of the study to determine bird use, which I used as my response variable. Turfgrass treatment and block were the predictor variables. Due to flooding and therefore a lack of data from most of the spring of 2010 and fall of 2011, data from the two years were combined. The number of birds observed per hour between the three measured seasons was analyzed. Bird use was analyzed using generalized, linear, mixed model with repeated measures (α=0.05 throughout) with seasons being the repeated measures (RANDOM, SAS Institute, 2003). In order to test for season and turf effects, block was the random effect. Analysis was run via SAS 9.2 (PROC GLIMMIX, SAS Institute, 2003). Because the seasonal data from both years was combined, I used a split plot in time model. I used PROC GLIMMIX to fit the split plot in time model with negative binomial distribution. I divided the year into four seasons: spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February). Because of turf dormancy and snow cover in winter, I only collected and analyzed data in the spring, summer, and fall seasons. Data within each season, combined from both years, was summed and analyzed individually. The convergence criterion was relaxed slightly to achieve convergence in the seasonal analyses. I also analyzed July through October separately, the time period with the highest rate of birdstrikes (Dolbeer 2006). I used Tukey's adjustment for comparisons among the means. Additionally, to determine the impact of zoysia dormancy on bird use, I analyzed the zoysia plots before dormancy and after dormancy in both the spring and fall.

Each turfgrass type was given a hazard score based on the bird use data and the relative hazard score of each bird species (DeVault et al., 2011). Number of strikes reported, damage rank, and effect on flight were taken into account when determining the hazard score for each species (DeVault et al., 2011). The average birds/hr of each bird species on every turf type was multiplied by the bird species hazard score. I then summed the hazard scores of every bird species to establish a total hazard score rank for each turfgrass treatment.

I compared the average number of bird observations per hour on each plot of my 2010-2011 study to a previous, similar study from 2007 and 2008 (Kissane, 2008). Because the treatments across the three blocks and fifteen plots were randomly rearranged after the 2007-2008 study, I correlated bird abundance on plots between study periods to determine if the birds were attracted to certain areas despite the turf type present (PROC CORR, SAS Institute, 2003). Additionally, I determined if each treatment among the three blocks between the two studies were correlated via Pearson correlation (SAS Institute, 2003). Again, the goal was to determine if the birds were attracted to a particular turf type or were simply drawn to a certain area of the study site.

Invertebrate abundance. I compared the means of invertebrate biomass and individuals on each turf type and block using ANOVA with repeated measures (SAS Institute, 2003). Turf treatment was a fixed effect and block was a random effect. I also correlated the number of invertebrates and number of birds on each plot throughout the study (PROC CORR, SAS Institute, 2003).

Goose pellet abundance. I used ANOVA with repeated measures to compare means of goose pellets on each turf type (SAS Institute, 2003). Sample date was used as the repeated measure. Blocks and turf treatments were analyzed for differences in pellet abundance, with blocks as a random effect and treatments as a fixed effect. I also ran Fischer's Protected LSD as a post hoc analysis.

Small mammal abundance. I compared the average number of small mammals trapped on each plot type and block using ANOVA with repeated measures (SAS Institute, 2003). Sample date was the repeated measure. Treatment was a fixed effect and block was a random effect in the analysis.

Results

Bird Use

I identified a total of 20 bird species during my observations on the plots. In one case, the observed bird appeared to be a species of warbler, but we were unable to confidently identify the precise species, so the bird was referred to simply as a warbler. All other birds we identified to species level.

Bird observations. The five turfgrass treatments had no differences in bird use when the entire study was analyzed (Figure 1.2). However, differences in number of birds varied with both season and block (Table 1.1; Figures 1.3 and 1.4). Fewer birds were observed in the fall than in the summer and spring (Table 1.2). Again, only 3 seasons were analyzed as no data was collected in the winter months. Additionally, more birds were observed on block 2 and 1 than on block 3. The five turfgrass treatments had no differences in bird use during spring when combined over the two years of the study (Table 1.3). Furthermore, average number of birds did not vary among blocks in the spring months. Similarly, treatment and block did not influence the amount of bird use in summer during the two year study. Block was the only significant factor fall (September through November). Number of birds differed among the turf treatments for July to October (Tables 1.4 and 1.5; Figure 1.5), the time period with the highest rate of birdstrikes. Perennial ryegrass and E- tall fescue had more bird use than E+ tall fescue, Kentucky bluegrass, and zoysia grass.

Between the 2007-2008 and 2010-2011 study, bird abundance was not correlated among the plots (r = 0.36, P = 0.192). Additionally, the treatments within the same blocks between the two studies were not correlated (r = -0.20, P = 0.483).

Hazard scores. Canada geese and mallards shaped the hazard score results based on their relatively high individual scores (46 for Canada goose and 29 for mallard) and overall abundance on the plots (Table 1.6 and 1.7). Of 6,072 individual bird observations, 4,484 were Canada geese and 559 were mallards. Thus, 83% of total birds observed in the study were either Canada geese or mallards. Hazard scores were not different among treatments across sampling periods. The blocks differed in avian hazard scores in the spring ($F_{2,88}$ = 8.833, P < 0.0001), summer ($F_{2,407}$ = 5.431, P < 0.01), and fall ($F_{2,98}$ = 4.854, P = 0.01). Hazard scores varied in the summer months and in the July through October sampling period ($F_{58,234}$ = 2.137, P < 0.0001).

Goose pellet abundance. The greatest number of pellets was counted in May, with 510 pellet events. The sampling period with the smallest number of pellets counted was in August, with 3 pellet events. Treatments did not vary in terms of average number of pellets ($F_{4,74}$ =1.2430, P = .366; Figure 1.6). The number of pellet events did, however, vary based on the sampling date (P < 0.0001).

Invertebrate Abundance

Total invertebrate biomass differed between turf treatments with zoysia having less invertebrate biomass than all other treatments ($F_{4,59}$ = 4.0310, P = 0.040; Figure 1.7).

Invertebrate biomasses were also affected by sampling date and blocks ($F_{4,16}$ = 6.866, P < 0.01 ; $F_{2,48}$ = 4.611, P = 0.015).

Number of individual invertebrates differed among treatments ($F_{4,16}$ = 7.730, P = 0.001) (Figure 1.8). All treatments, including E+ perennial ryegrass, E+ tall fescue, E- tall fescue, and Kentucky bluegrass, had more individual invertebrates than zoysia grass (P < 0.01 for each treatment compared to zoysia grass). Treatment block and treatment date also affected the average numbers of individual invertebrates ($F_{2,48}$ = 5.717, P < 0.01; $F_{4,16}$ = 42.379, P < 0.0001). There was no direct correlation between invertebrate abundance and bird use among turf treatments during the study (r = 0.17800, P = 0.5256).

Small Mammal Abundance

Small mammal species trapped included deer mice (*Peromyscus maniculatus* Wagner), prairie voles (*Microtus ochrogaster* Wagner), meadow voles (*Microtus pennsylvanicus* Ord), and northern short-tailed shrews (*Blarina brevicauda* Say). Any individuals captured more than once per month were included as only one capture in that month in the analysis. Overall, 13 mammals were trapped during the study, 11 of which were voles; 7 meadow voles and 4 prairie voles. Turfgrass treatment affected abundances of small mammals with E- tall fescue containing more small mammals than all other treatments ($F_{4,20}$ = 4.623, P < 0.01; Figure 1.9).

Discussion

Although turf type did not impact the amount of bird use throughout the overall study, certain results provide insight into possible solutions for airport landscaping as well as potentially informing future studies. In the period with the greatest number of birdstrikes, July through October, turf type impacted the amount of bird use on plots. E- tall fescue had the most bird use, an unsurprising result given that the E- grasses do not contain the alkaloids produced by E+ grasses. Thus, the E- grasses should be preferred by birds and other wildlife. Zoysia grass had the least amount of bird use. The birds may have been less attracted to the zoysia grass because of the density of the turf. Compared to the other turf species analyzed which often form clumps, the density of zoysia was extremely high. Birds also might have avoided the zoysia grass because it was brown and dormant during 4-5 weeks of the analyzed time period. Based on the July through October data, as well as results from other experiments in my study, zoysia grass may be the best option for turf for airports in the temperate climatic zone where zoysia grass is dormant from October through May.

Turf type did not impact the hazard scores in this study. However, the shaping of the hazard scores by only two species, Canada geese and mallards, is important to note. Both species are primarily aquatic, so along with selecting an uninviting turf, focus must also be on limiting or securing standing water at airports.

Invertebrates tended to avoid zoysia grass. Zoysia had the fewest number of individual invertebrates and also had the smallest average invertebrate biomass. The relatively small amount of invertebrates suggests that they may be repelled from zoysia grass due to the frequent dormant state or the density of the turf. Alternatively, it is possible that there were invertebrates present in the zoysia, but because of the density of the turf, they were not easily picked up. Also, the zoysia plots consistently had the highest percent cover. The density of the turf and lack of other vegetation may have also repelled the invertebrates. Given that most birds are insectivorous, the lower numbers of invertebrates in zoysia grass bodes well for it being a turfgrass that does not attract birds.

Small mammal trapping results suggest that small mammals may prefer non-endophytic tall fescue. Again, the E- tall fescue is not a surprising animal preference as it does not contain the harmful alkaloids that other turf types include. Although my results are clear that the mammals were choosing the E- tall fescue plots, because I trapped in only two months during the fall, further analysis throughout the year is required to infer with certainty that the small mammals avoided zoysia, Kentucky bluegrass, and endophytic grasses and were drawn to the non-endophytic turf.

Throughout the study, variations in bird use on the plots were often associated with season. Fewer birds were observed in the study area in the fall than in the spring and summer. Many birds may have used the plots in the spring as a food source after migration. The pond water and open grass areas for feeding likely attracted many birds seeking a location with adequate food, open area, and water. With a prairie mix likely abundant with food and cover as an immediate buffer to the study area, several bird species may have been attracted to the area for nesting in the spring and thus used the nearby study plots as well.

In addition to season affecting bird use, blocks repeatedly influenced the number of birds on each plot throughout much of the study. The relatively small plot sizes may not have been adequate space for the full impacts of the treatment to take place. The blocks affected the location and number of bird visits based on the different slopes and aspects of the plots adjacent to the pond. Two of the blocks had very abrupt and jutting edges whereas one of the blocks had a very gradual slope into the pond, which allows easier access to those plots by waterfowl and other birds.

Similarly to the bird use data, the goose pellet survey was largely dependent on sample date. The greatest number of pellets was collected in May when goose abundance and loafing in grass areas is high after spring migration. At least 3 geese were observed building or guarding nests in areas adjacent to the study site in the spring and so were most likely present near or on the study site for a large portion of the spring. The fewest pellets were collected in August, when geese may be fairly inactive or spending much of their time in the water because of the heat. As evidenced by goose pellet numbers, the turf treatment did not seem to have a direct effect on the location geese choose to loaf and eat. The slope of the land leading to the pond may have played more of a role in where geese loafed. Geese often wade up to and walk on shore to get to grass areas. They may have prefer areas with low slopes compared to those with a more drastic slope which require jumping or flying to get to solid land.

From my observations of bird use as well as invertebrate sampling, zoysia grass may be a solution for a reduction in birdstrikes at airports. In the time period that consistently has the most birdstrikes, the zoysia grass had the fewest birds, significantly fewer than E- tall fescue in particular. Zoysia grass was also among the treatments used least by both invertebrates and small mammals. Additionally, once the zoysia was established, it consistently had the highest percent cover and required comparatively little landscaping throughout the year. Although zoysia is most often established from sod, which can cost much more money than seeding, the money saved on a reduction in mowing and other landscaping over time could nullify the high cost of establishment. Seeding zoysia is also an option, though successful irrigation and establishment can prove to be a challenge under airport conditions. Thus, zoysia may not only potentially reduce the risk of birdstrikes at airports, it may reduce the amount of landscaping required for functional and effective turf.

Not only do the results suggest zoysia may be a prime choice of turf for airports, they also suggest that non-endophytic grasses, particularly E- tall fescue should be avoided at airports. These results support those of Washburn and Seamans (2011) who found that penned geese avoided zoysia grass and preferred grasses such as Kentucky bluegrass and fescue cultivars. The results of the small mammal trapping further suggest that non-endophytic grasses should be avoided in airport settings whenever possible. Although the results of this study support the use of zoysia and a reduction in the use of non-endophytic tall fescue, further studies are needed to augment my findings.

I recommend a study with larger turf plots, at least 1-acre each, to be more confident that birds are in fact attracted to a certain area because of the turf. If possible, a study with more plots of each turf grass might also strengthen the results of this study. Another option to increase data in such a study is to run cameras on the plots all day and count the birds from the recorded videos instead of relying on observations from only a few hours a week. Finally, an important follow-up study could involve multiple airports collecting bird use data with the current turf seed mix used at the facility and comparing it with data from zoysia grass. The study could involve the entire turf spaces of small, regional airports or extensive turf areas of large airports. It is difficult to establish a turf area with identical attributes to that of an airport, so running experiments in airfields themselves is an important step in deciding which landscaping will reduce birds. Although collecting the data and sodding such widespread areas would be extremely expensive, the money spent on the study would be well worth the price if the results lead to saved lives.

Tables

Table 1.1. Significance of various effects on mean birds/hour on five turfgrass types throughout the 2010 and 2011 study in central Illinois

Effect	Num DF	F Value	P > F
Treatment	4	1.39	0.2959
Season	2	12.63	0.0002
Season*Treatment	8	1.5	0.2163
Block	2	5.09	0.0125
Block*Treatment	8	1.28	0.2924

Table 1.2. Differences in season and block least square means of birds/hr observations throughout the 2010 and 2011 central Illinois study

Season	**_Season**	**DF**	**SE**	**t Value**	**P > t**
Fall	Spring	21.44	0.4559	-4.65	0.0001
Fall	Summer	24	0.3443	-4.27	0.0003
Spring	Summer	18.85	0.3781	1.72	0.1016
Block	**_Block**	**DF**	**SE**	**t Value**	**P > t**
1	2	29.49	0.3465	-1.19	0.2431
1	3	30	0.3489	1.97	0.058
2	3	30	0.3482	3.16	0.0036

Table 1.3. Significance of various effects on mean birds/hour on five turfgrass types in the central Illinois study based on season

Season	Effect	Num DF	F Value	P > F
Spring	Treatment	4	0.91	0.4999
Spring	Block	2	47.27	0.1023
Spring	Block*Treatment	8	3.63	0.3863

Season	Effect	Num DF	F Value	P > F
Summer	Treatment	4	2.43	0.1346
Summer	Block	2	19.32	0.1588
Summer	Block*Treatment	8	13.41	0.2083

Season	Effect	Num DF	F Value	P > F
Fall	Treatment	4	0.16	0.9525
Fall	Block	2	5.394	0.006
Fall	Block*Treatment	8	0.81	0.864

Table 1.4. Significance of various effects on mean birds/hour on five turfgrass types in July through October, the time period with the greatest number of birdstrikes

Effect	Num DF	F Value	P > F
Treatment	4	3.77	0.0191
Block	2	1.24	0.3179
Block*Treatment	8	1.33	0.3006

Table 1.5. Differences in treatment least square means of birds/hr observations in July through October in the 2010 and 2011 central Illinois study. Treatments are endophytic tall fescue (E+ TF), perennial ryegrass (PR), non-endophytic tall fescue (E-TF), Kentucky bluegrass (KB), and zoysia (Z)

Treatment	**_Treatment**	**DF**	**SE**	**t Value**	**P > t**
E+ TF	E- TF	20	0.5921	-2.62	0.0165
E+ TF	KB	20	0.6154	-0.1	0.9207
E+ TF	PR	20	0.5924	-2.31	0.0319
E+ TF	Z	20	0.6038	0.13	0.899
E- TF	KB	20	0.5976	2.49	0.0217
E- TF	PR	17.96	0.574	0.32	0.7524
E- TF	Z	19.48	0.5857	2.78	0.0118
KB	PR	20	0.5979	-2.18	0.0413
KB	Z	20	0.6092	0.23	0.821
PR	Z	19.52	0.5861	2.46	0.0232

Season	**Treatment**	**Grouping**	**Mean Birds/hr**	**SE**
July-Oct	E+ TF	B	0.4348	0.1876
July-Oct	PR	A	1.7049	0.6924
July-Oct	E- TF	A	2.049	0.8311
July-Oct	KB	B	0.4626	0.203
July-Oct	Zoysia	B	0.4023	0.4023

Table 1.6. Ranking and average birds/hour of each bird species on the five turfgrass treatments throughout the entire study. Relative hazard score and composite ranking from DeVault et al. 2011

Species	**Relative Hazard Score**	**Composite Ranking**	**E- Tall Fescue**		**E+ Perennial Ryegrass**		**E+ Tall Fescue**		**Kentucky Bluegrass**		**Zoysia**	
			Rank	Avg Birds/ Hour	Rank	Avg Birds/ Hour	Rank	Avg Birds/ Hour	Rank	Avg Birds/ Hour	Rank	Avg Birds/ Hour
Agelaius phoeniceus (Red-winged blackbird)	9	46	3	0.0888	4	0.0724	4	0.0495	5	0.0569	3	0.0492
Anas platyrhynchos (Mallard)	29	21	2	0.4504	3	0.1227	3	0.0912	3	0.1257	5	0.0356
Ardea herodias (Great Blue Heron)	31	17	7	0.0235	10	0.0042	11	0.0014	9	0.0055	12	0.0014
Branta canadensis maxima (Canada Goose)	46	5	1	1.5525	1	0.9751	1	1.0131	1	2.0471	1	0.8354
Carduelis tristis (American Goldfinch)	4	65	11	0.0028	14	0.0015	10	0.0015		0		0
Ceryle alcyon (Belted Kingfisher)	7	*	12	0.0015	12	0.0029	10	0.0015		0		0
Charadrius vociferus (Killdeer)	7	49	5	0.0758	5	0.0413	12	0.0014	7	0.0086	4	0.043
Columba livia (Rock Dove)	20	30		0		0		0	11	0.0041		0
Corvus brachyrhynchos (American Crow)	12	41	8	0.0099	15	0.0014		0	13	0.0028	11	0.0015
Hirundo rustica (Barn Swallow)	2	62	10	0.0041	8	0.0126	9	0.0028	12	0.0029	8	0.0071
Lophodytes cucullatus (Hooded Merganser)	48	7		0		0		0	14	0.0015		0

Melospiza melodia (Song Sparrow)	4	58		0	15	0.0014	7	0.0043		0	8	0.0071
Molothrus ater (Brown-headed Cowbird)	9	*	9	0.0084	9	0.0111	11	0.0014	2	0.3568	9	0.0057
Quiscalus quiscula (Common Grackle)	9	46		0	7	0.0215	6	0.0073	10	0.0055	6	0.0218
Sturnella magna (Eastern Meadowlark)	5	55		0		0	8	0.0041		0		0
Sturnus vulgaris (European Starling)	9	47	13	0.0014	13	0.0028	10	0.0015	8	0.0056	10	0.0029
Turdus migratorius (American Robin)	5	60	6	0.0753	2	0.1536	2	0.1375	4	0.1011	2	0.0736
Tyrannus tyrannus (Eastern Kingbird)	4	*	13	0.0014	11	0.0042		0	15	0.0014	12	0.0014
Warb sp.	2	*	13	0.0014		0		0		0		0
Zenaida macroura (Mourning Dove)	10	45	4	0.0773	6	0.0351	5	0.0264	6	0.0145	7	0.0143

Table 1.6 (cont.)

Table 1.7. Hazard scores of the observed bird species. Hazard scores were determined by multiplying the average birds observed per hour by the relative hazard score from DeVault et al. 2011. Species are ranked in order from highest to lowest average hazard score

Species	Overall Average Hazard Score	E- Tall Fescue Hazard Score	E+ Perennial Ryegrass Hazard Score	E+ Tall Fescue Hazard Score	Kentucky Bluegrass Hazard Score	Zoysia Hazard Score
Branta canadensis maxima (Canada Goose)	59.0932	71.413	44.85524	46.605	94.16485	38.4281
Anas platyrhynchos (Mallard)	4.78839	13.061	3.559083	2.646	3.644546	1.03162
Molothrus ater (Brown-headed Cowbird)	0.69012	0.0754	0.099711	0.0125	3.21156	0.05148
Agelaius phoeniceus (Red-winged blackbird)	0.57021	0.7988	0.651627	0.4453	0.512478	0.44283
Turdus migratorius (American Robin)	0.54103	0.3765	0.767785	0.6873	0.50548	0.36804
Zenaida macroura (Mourning Dove)	0.33503	0.7727	0.35069	0.2637	0.14509	0.143
Charadrius vociferus (Killdeer)	0.23806	0.5304	0.02002	0.0096	0.06006	0.30089
Ardea herodias (Great Blue Heron)	0.22354	0.729	0.131378	0.0429	0.171492	0.04294
Quiscalus quiscula (Common Grackle)	0.10111	0	0.193707	0.0658	0.049599	0.19646
Corvus brachyrhynchos (American Crow)	0.03712	0.1182	0.016536	0	0.03306	0.01778
Sturnus vulgaris (European Starling)	0.0254	0.0124	0.02493	0.0133	0.050535	0.0258
Columba livia (Rock Dove)	0.01653	0	0	0	0.08266	0
Lophodytes cucullatus (Hooded Merganser)	0.01423	0	0	0	0.071136	0

Hirundo rustica (Barn Swallow)	0.01179	0.0083	0.025246	0.0055	9	0.01419
Melospiza melodia (Song Sparrow)	0.01018	0	0.005512	0.017	0	0.02839
Ceryle alcyon (Belted Kingfisher)	0.00815	0.0104	0.02002	0.0104	0	0
Tyrannus tyrannus (Eastern Kingbird)	0.00664	0.0055	0.01662	0	0.005512	0.00554
Carduelis tristis (American Goldfinch)	0.00458	0.011	0.005928	0.0059	0	0
Sturnella magna (Eastern Meadowlark)	0.00413	0.0055	0	0.0207	0	0
Warb sp.	0.00055	0.0028	0	0	0	0

Table 1.7 (cont.)

Figures

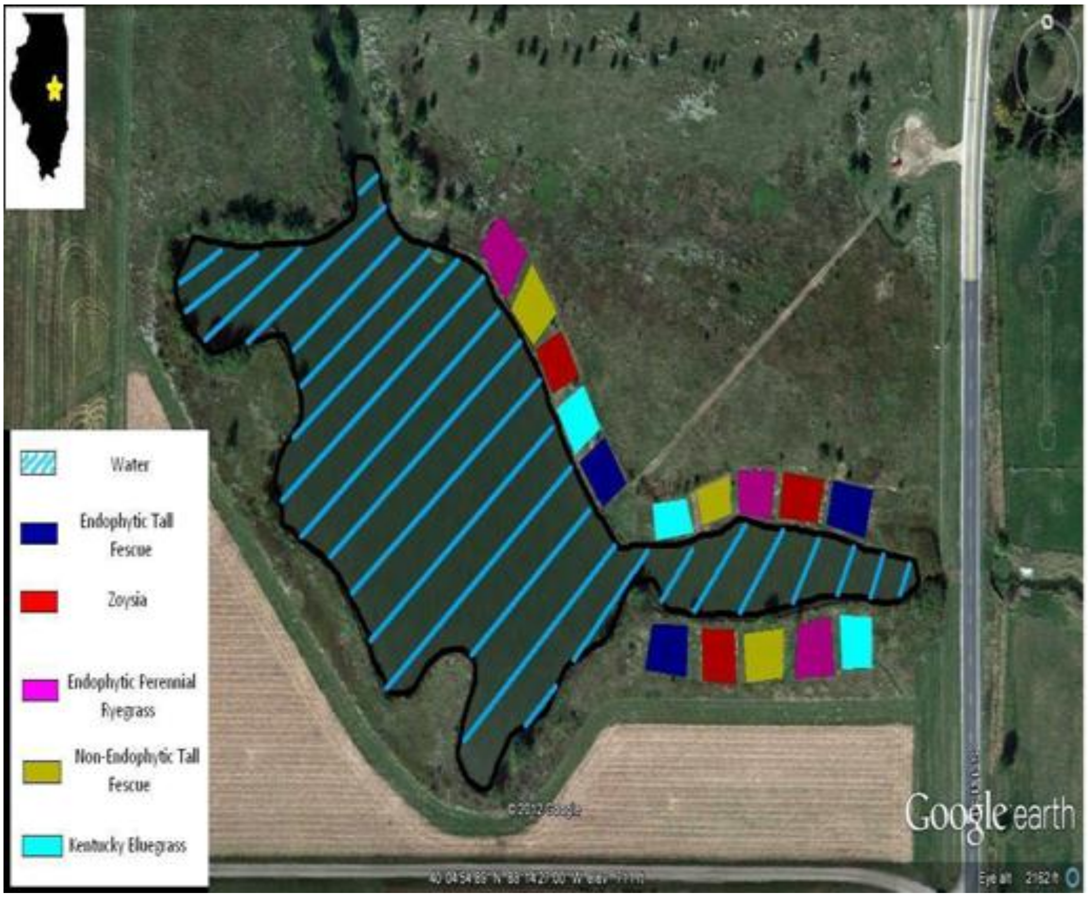

Figure 1.1. Map of turfgrass plots surrounding a pond in central Illinois located on the "South farms" at the University of Illinois, Urbana- Champaign
Source: 40°04'54.13"N and 88°14'24.33"W. **Google Earth**. November 21, 2010. January 11, 2012.

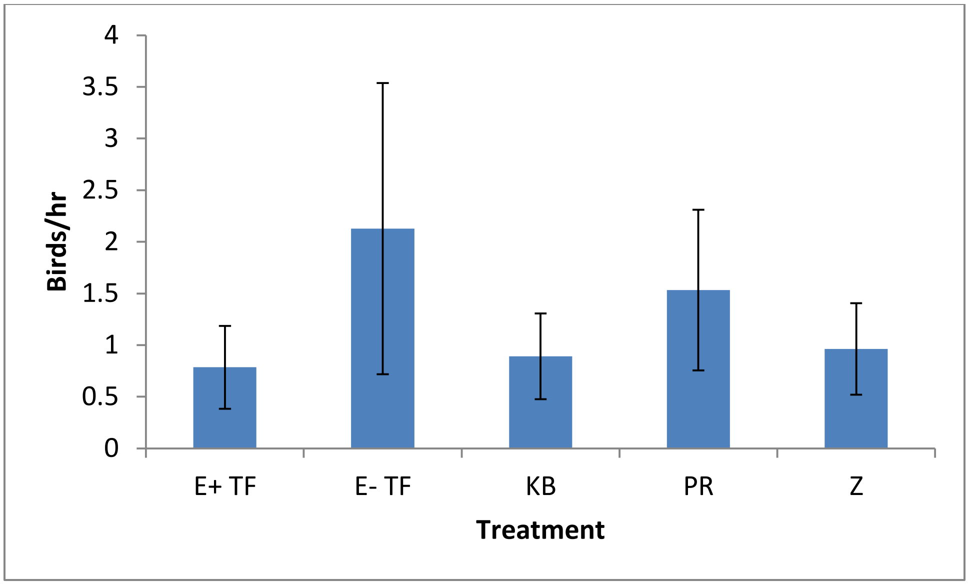

Figure 1.2. Average bird observations/hour among the five treatments: endophytic tall fescue (E+ TF), non-endophytic tall fescue (E- TF), Kentucky bluegrass (KB), perennial ryegrass (PR) and zoysia grass (Z). Figure represents averages throughout the 2010-2011 study. Error bars represent ± 1 standard error.

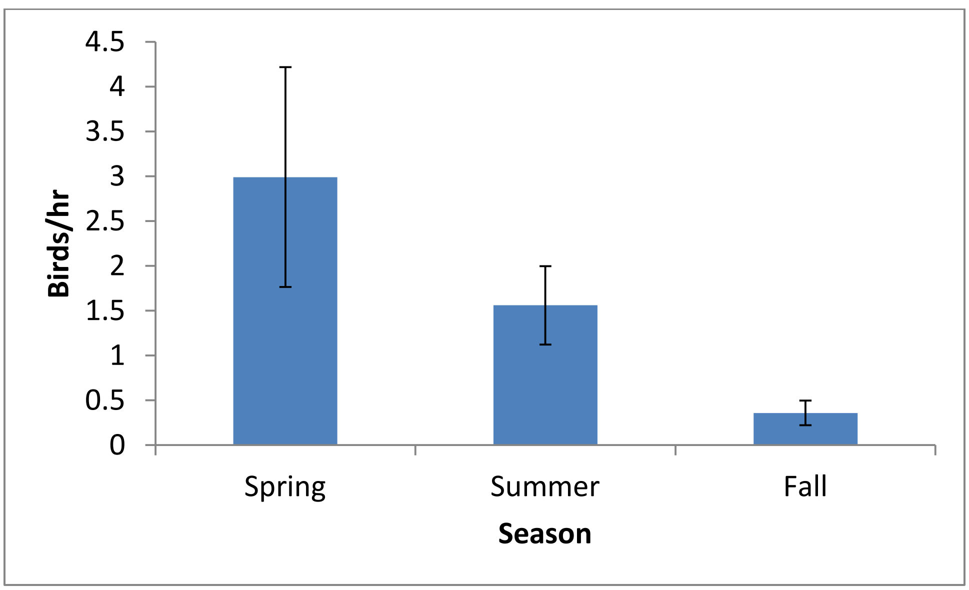

Figure 1.3. Average bird observations/hour among seasons throughout the 2010-2011 study. Error bars represent ± 1 standard error.

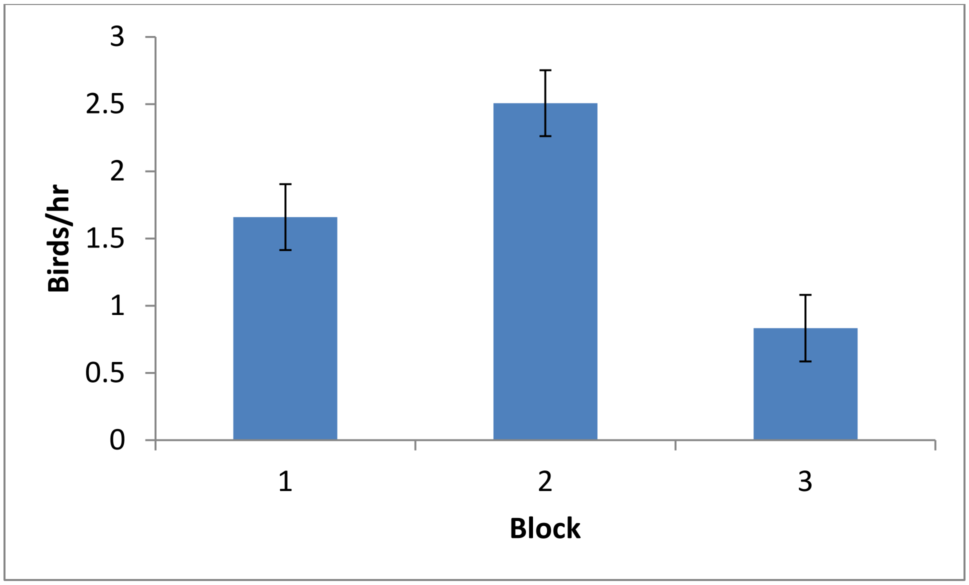

Figure 1.4. Average bird observations/hour among blocks throughout the 2010-2011 study. Error bars represent ± 1 standard error.

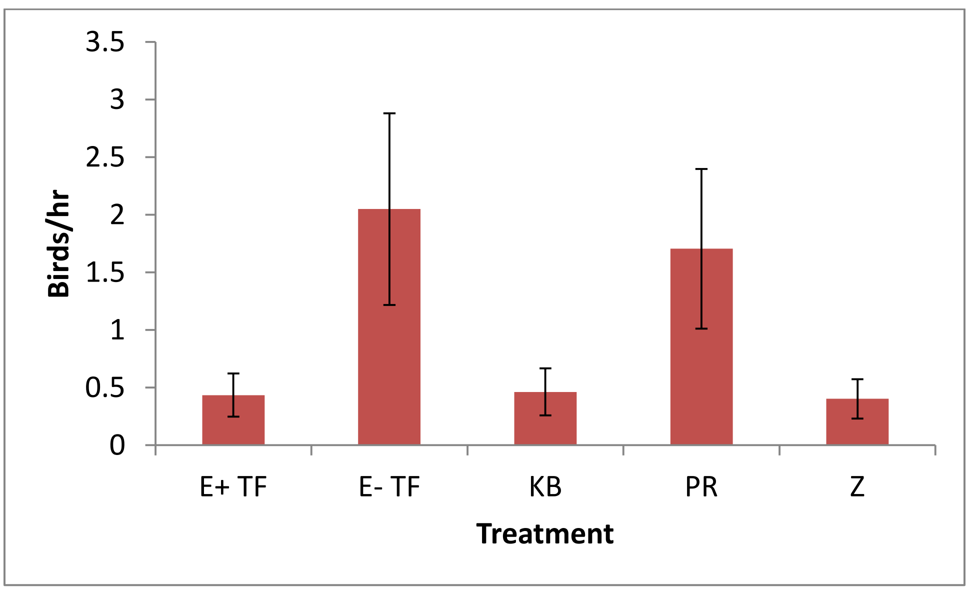

Figure 1.5. Average bird observations/hour among turf treatments in July-October, the time period with the highest rate of birdstrikes. Treatments are endophytic tall fescue (E+ TF), non-endophytic tall fescue (E- TF), Kentucky bluegrass (KB), perennial ryegrass (PR), and zoysia grass (Z). Error bars represent ± 1 standard error.

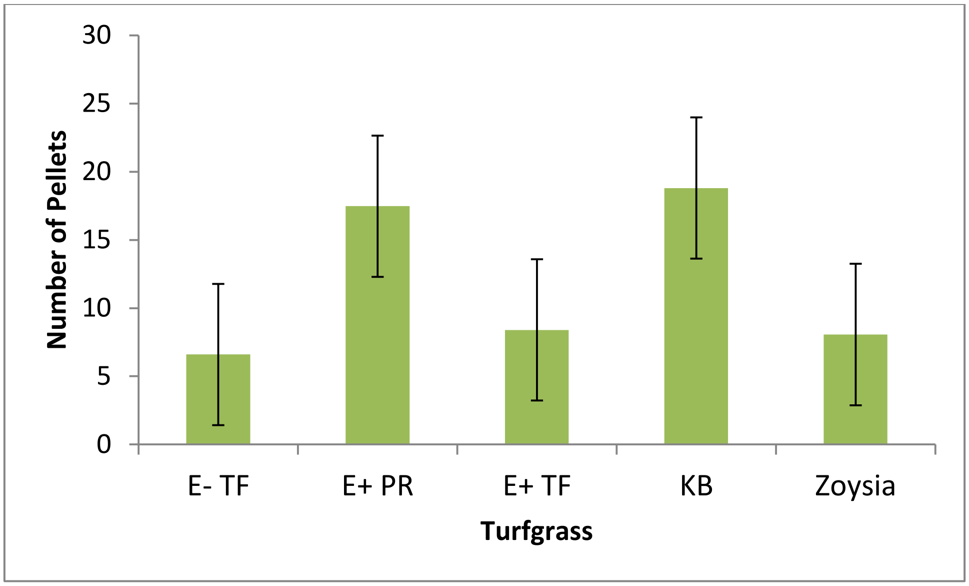

Figure 1.6. Average number of goose pellets per turfgrass treatment in 2011. Treatments are non-endophytic tall fescue (E- TF), perennial ryegrass (E+ PR), endophytic tall fescue (E+ TF), Kentucky bluegrass (KB), and zoysia grass (Z). Error bars represent ± 1 standard error.

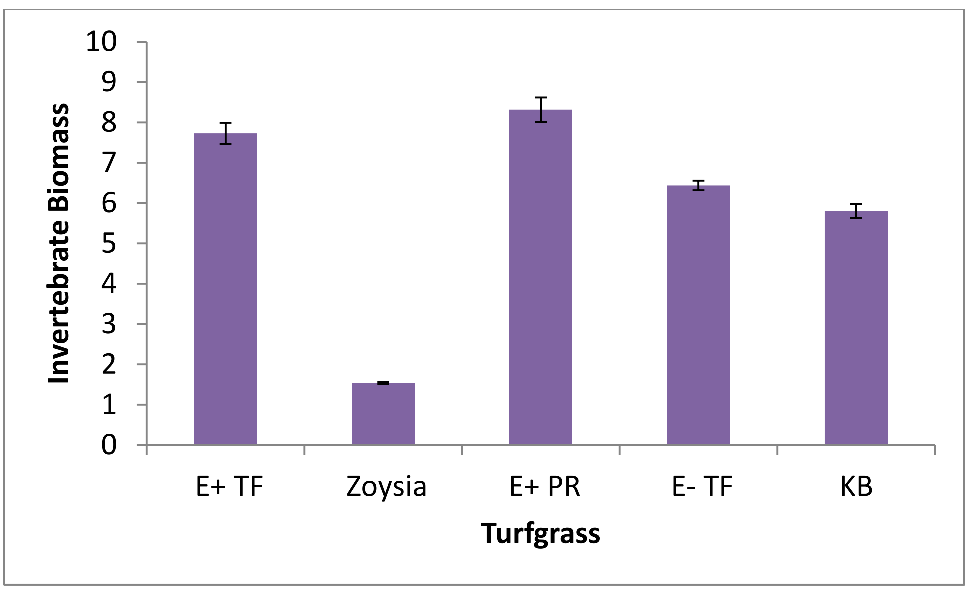

Figure 1.7. Total invertebrate biomass among turf treatments in 2010 and 2011. Treatments are non-endophytic tall fescue (E- TF), perennial ryegrass (E+ PR), endophytic tall fescue (E+ TF), Kentucky bluegrass (KB), and zoysia grass (Z). Error bars represent ± 1 standard error.

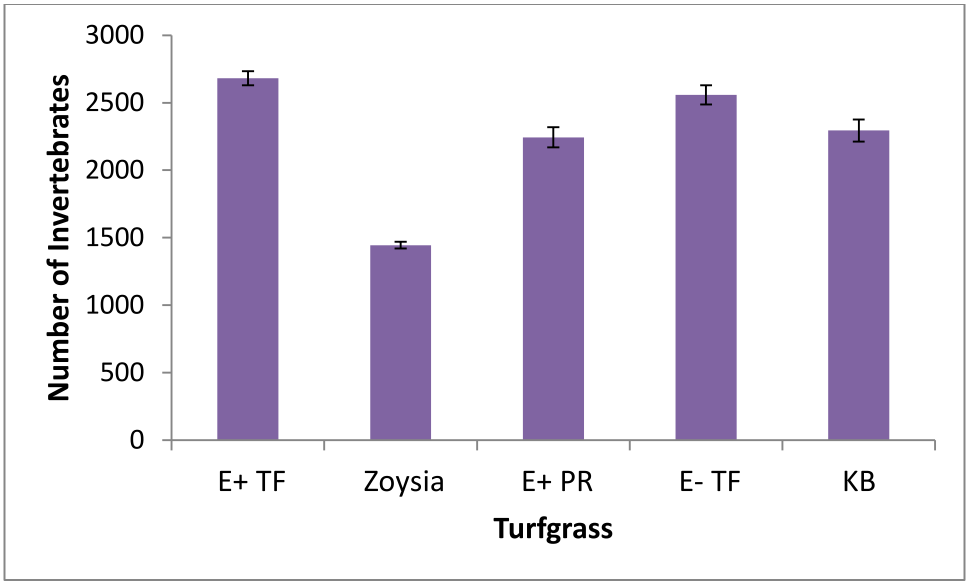

Figure 1.8. Total number of invertebrate individuals among turf treatments in 2010 and 2011. Treatments are non-endophytic tall fescue (E- TF), perennial ryegrass (E+ PR), endophytic tall fescue (E+ TF), Kentucky bluegrass (KB), and zoysia grass (Z). Error bars represent ± 1 standard error.

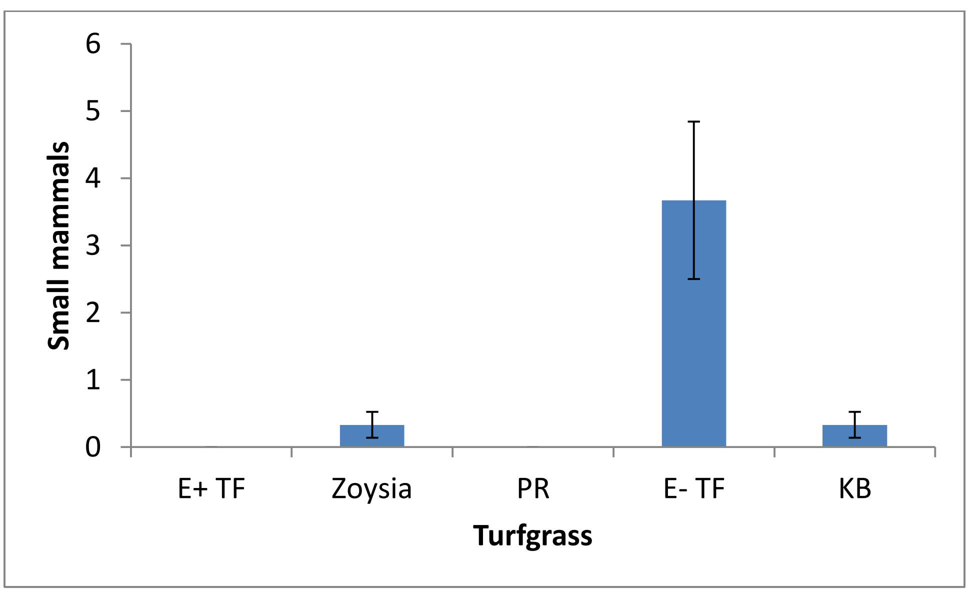

Figure 1.9. Average number of small mammals trapped in fall of 2010 on each turf treatment. Treatments are endophytic tall fescue (E+ TF), non-endophytic tall fescue (E- TF), Kentucky bluegrass (KB), perennial ryegrass (PR), and zoysia grass (Z). Error bars represent ± 1 standard error.

References

Alcock, J. 1979. Animal behavior: an evolutionary approach. Sunderland, MA.: Sinauer Associates; 596 p.

Allan, J.R. 2002. The costs of bird strikes and bird strike prevention. In: Clark, L., Hone, J., Shivik, J.A.,Watkins, R.A., Vercauteren, K.C., Yoder, J.K. (Eds.). Proceedings of the Third NWRC Special Symposium. National Wildlife Research Center, Fort Collins, CO, USA, pp.147–153.

Ankney, C.D. 1996. An embarrassment of riches: too many geese. J. Wildlife Manage. 60(2): 217-223.

Austin-Smith, P.J., and H.F. Lewis. 1969. Alternative vegetative ground cover. Proceedings of the world conference on bird hazards to aircraft. Kingston, Ontario, Canada: National Research Council of Canada; pp.153-160.

Bacon, C. W., and N. S. Hill. 1997. *Neotyphodium*/grass interactions. New York: Plenum Press.

Baker, J.A., and R.J. Brooks. 1981. Distribution patterns of raptors in relation to density of meadow voles. Condor. 83:42-47.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for Northern Bobwhite in tall fescue-dominated fields. Wildlife Soc. B. 23:231-237.

Barras, S. C., and T. W. Seamans. 2002. Habitat management approaches for reducing wildlife use of airfields. Proceedings of the Twentieth Vertebrate Pest Conference.20: 309–315.

Belant, J.L. 1997. Gulls in urban environments: Landscape-level management to reduce conflict. Landscape Urban Plan. 38:245-58.

Blackwell, B.F. and S.E. Wright. 2006. Collisions of red-tailed hawks (*Buteo jamaicensis*), Turkey (*Cathartes aura*), and black vultures (*Coragyps atratus*) with aircraft: implications for bird strike reduction. J. Raptor Res. 40:76–80.

Blokpoel, H. 1976. Bird hazards to aircraft: problems and prevention of bird/aircraft collisions. Ottawa: Clarke, Irwin & Company Limited. 235 p.

Brough, T.E., and C.J. Bridgman. 1980. An evaluation of long-grass as a bird deterrent on British airfields. J. Appl. Ecol. 17:243–253.

Burger, J. 1983. Bird control of airports. Environ. Conserv. 10(2):115-124.

Clay, K. 1993. The ecology and evolution of endophytes. Agric. Ecosyst. & Environ. 44:39.

Cleary, E.C. and R.A. Dolbeer. 2005. Wildlife Hazard Management at Airports (second ed.), Federal Aviation Administration, Office of Airport Safety and Standards, Airport Safety and Compliance Branch, Washington, DC, USA.

Cleary E.C., Dolbeer R.A., and Wright S.E. 2006. Wildlife strikes to civil aircraft in the United States, 1990-2005. Washington, DC: US Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards.

Coley, A.B., Fribourg, H.A., Pelton, M.R., and Gwinn, K.D. 1995. Effects of tall fescue endophyte infestation on relative abundance of small mammals. J. Environ.Qual. 24:472-475.

Conover, M. and T. Messmer. 1996. Feeding preferences and changes in mass of Canada geese grazing endophyte-infected tall fescue. Condor. 98:859-862.

Cummings, J.L., D.L. Otis and J.E. Davis. 1992. Dimethyl and methyl anthranilate and methiocarb deter feeding in captive Canada Geese and Mallards. J. Wildlife Manage. 56(2):349-355.

DeVault, T.L., J.L. Belant, B.F. Blackwell, and T.W. Seamans. 2011. Interspecific variation in wildlife hazards to aircraft: implications for airport wildlife management. Wildlife Soc. B. 35(4):394-402.

DeVault,T.L., B.D. Reinhart, I.L. Brisbin Jr. and O.E. Rhodes Jr. 2005. Flight behavior of black and turkey vultures: implications for reducing bird–aircraft collisions, J. Wildlife Manage. 69:592–599.

Dolbeer, R.A. 2009. Birds and aircraft- fighting for airspace in ever more crowded skies. Human-Wildlife Confl. 3:165-166.

Dolbeer, R.A. 2000. Birds and aircraft: fighting for airspace in crowded skies. Proceedings of the 19th Vertebrate Pest Conference. University of California-Davis. 19: 37-43.

Dolbeer, RA, JL Belant, and JL Sillings. 1993. Shooting gulls reduces strikes with aircraft at John F. Kennedy International Airport. Wildlife Soc. B. 21: 442-450.

Dolbeer, R.A., S.E. Wright and E.C. Cleary. 2000. Ranking the hazard level of wildlife species to aviation. Wildlife Soc. B. 28:372–378.

Dolbeer, R.A. and P. Eschenfelder. 2002. Population increases of large birds, airworthiness standards and high-speed flight: a precarious combination. Proceedings of the 55th International Air Safety Seminar, Dublin, Ireland. Flight Safety Foundation Alexandria, VA, USA. pp. 273–281.

Dolbeer, R. A. and P. Eschenfelder. 2003. Amplified bird-strike risks related to population increases of large birds in North America. Proceedings International Bird Strike Committee. 26(1):49–67.

Dolbeer, R.A. 2006. Height distribution of birds as recorded by collisions with civil aircraft. J. Wildlife Manage. 70:1345–1350.

Dolbeer, R.A., and J.L. Seubert. 2009. Canada goose populations and strikes with civil aircraft: challenging trends for aviation industry. Special report. U.S. Department of Agriculture, Wildlife Services, Sandusky, Ohio, USA.

Dolbeer, R.A., Wright, S.E. 2008. Wildlife strikes to civil aircraft in the United States, 1990–2007. U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Serial Report No.14, Washington, DC, USA. 57 p.

Dolbeer, R.A. and S.E. Wright. 2009. Safety management systems: how useful will the FAA national wildlife strike database be? Human-Wildlife Conflicts. 3(2):167-178.

Engeman, R.M., J. Peterla, B. Constantine. 2002. Methyl anthranilate aerosol for dispersing birds from the flight lines at Homestead Air Reserve Station. Int Biodeter Biodegr. 49**:**175-178.

Federal Aviation Administration. FAA aerospace forecast fiscal years (2008–2025). 2008 [cited 2010 Jun 6]. Available from: http://www.faa.gov/data_statistics/aviation/aerospace_forecasts/2008-2025/.

Fellows, D.P. and P.W.C. Paton. 1998. Behavioral response of Cattle Egrets to population control measures in Hawaii. Proc. Vertebr. Pest Conf. 13:315-318.

Fortier, G. M., N. Bard, M. Jansen, and K. Clay. 2000. Effects of tall fescue endophyte infection and population density on growth and reproduction in prairie voles. J. Wildlife Manage. 64:122–128.

Godfrey, V. B., S. P. Washburn, E. J. Eisen, and B. H. Johnson. 1994. Effects of consuming endophyte-infected tall fescue on growth, reproduction and lactation in mice selected for high fecundity. Theriogenology. 41:1393-1409.

Hanser, S. E., Aldridge, C. L., Leu, M., Rowland, M. M., Nielsen, S. E., & Knick, S. T. 2011. "Greater sage-grouse: general use and roost site occurrence with pellet counts as a measure of relative abundance." In *Sagebrush Ecosystem Conservation and Management*, edited by Hanser, S. E., Aldridge, C. L., Leu, M., Rowland, M. M., Nielsen, S. E., & Knick, S. T, 112-140. U.S. Geological Survey.

Harris, R.E. & Davis, R.A. 1998. Evaluation of the efficacy of products and techniques for Airport Bird Control. LGL Report TA2193. LGL Limited, Environmental Research Associates. King City, Ontario.

International Civil Aviation Organization Civil Aviation Statistics of the World: 1993. ICAO Statistical Yearbook. Montreal. 1994.

Kelly, T.C., and J. Allan. 2006. Ecological effects of aviation. In: J. Davenport and J.L. Davenport (eds). The ecology of transportation: managing mobility for the environment. Springer, The Netherlands. pp. 5–24.

Kissane, T. "Bird activity on five turf types." MA Thesis. University of Illinois at Urbana-Champaign. 2008.

Linnell, M. A., M. R. Conover, and T. J. Ohashi. 1995. Wedelia: a potential ground cover for reducing the attractiveness of tropical airfields to birds. Proceedings of the Twelfth Great Plains wildlife damage control workshop, Tulsa, Oklahoma, USA.

Madej, C.W. and K. Clay. 1991. Avian seed preference and weight loss experiments: the effect of fungal endophyte–infected tall fescue seeds. Oecologia. 88:296-302.

Marra, P. P., C. J. Dove, R. A. Dolbeer, N. F. Dahlan, M. Heacker, J. F. Whatton, N. E. Diggs, C. France, and G. A. Henkes. 2009. Migratory Canada geese cause crash of US Airways Flight 1549. Front Ecol Environ. 7:297–301.

Mead, H. and A.W. Carter. 1973. The management of long grass as a bird repellent on airfields. J. British Grassland Soc. 28:219–221.

National Oceanic and Atmospheric Administration. National Weather Service. 2009 [cited 2010 Dec 11]. Available from: http://www.nws.noaa.gov/climate/index.php?wfo=ilx.

Richardson, M.L., and L.M. Hanks. 2009. Partitioning of niches among four species of orb -weaving spiders in a grassland habitat. Environ Entomol. 38(3): 651-656.

Richardson, W.J. and T. West. 2000. Serious birdstrike accidents to military aircraft: updated list and summary, Proceedings of the 25th International Bird Strike Committee Meeting. Amsterdam, Netherlands. pp. 67–98.

Sauer, J. R., J. E. Hines, and J. Fallon. 2006. The North American breeding bird survey, results and analysis 1966 - 2005. Version 6.2.2006. U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, MD, USA.

SAS Institute. 2009. SAS, version 9.2. SAS Institute, Cary , North Carolina, USA.

Schmidt, S. P., and T. G. Osborn. 1993. Effects of endophyte-infected tall fescue on animal performance. In: R. Joost and S. Quisenberry (eds). *Acremonium*/grass interactions. Agriculture, Ecosystems and Environment. Special Issue. Elsevier, Amsterdam. The Netherlands. pp.233-262.

Seamans, T.W., S.C. Barras, G.E. Bernhardt, B.F. Blackwell and J.D. Cepek. 2007. Comparison of two vegetation-height management practices for wildlife control at airports. Human–Wildlife Confl. 1:97–105.

Settivari R.S., T.J. Evans, E. Rucker, G.E. Rottinghaus, D.E. Spiers. 2008. Effect of ergot alkaloids associated with fescue toxicosis on hepatic cytochrome P450 and antioxidant proteins. Toxicol Appl Pharm. 227:347-356.

Shelby, R. A. and L.W. Dalrymple. 1987. Incidence and distribution of the tall fescue endophyte in the United States. Plant Dis. 71:783-86.

Sodhi, N.S. 2002. Competition in the air: birds versus aircraft. Auk. 119:3. pp.587-595.

Stuedemann, J. A., and C. S. Hoveland. 1988. Fescue endophyte: History and impact on animal agriculture. J. Prod. Agric. 1:39.

Thorpe, J. 2003. Fatalities and destroyed aircraft due to bird strikes, 1912–2002. Proceedings of the 26th International Bird Strike Comm. Meeting Warsaw, Poland. pp.85-113.

Thorpe, J. 2005. Fatalities and destroyed aircraft due to bird strikes, 2002–2004 (with an appendix of animal strikes) Proceedings of the 27th International Bird Strike Comm. Meeting Athens, Greece. pp.17-24.

Washburn, B.E., S.C. Barras and T.W. Seamans. 2007. Foraging preferences of captive Canada geese related to turfgrass mixtures. Human–Wildlife Confl. 1:188–197.

Washburn, B.E., and T.W. Seamans. 2004. Management of vegetation to reduce wildlife hazards at airports. Proceedings of the 2004 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, New Jersey, USA.

Washburn, B.E., and T.W. Seamans. 2007. Wildlife responses to vegetation height management in cool-season grasslands. Rangeland Ecol. Manag. 60:319–323.

Washburn, B.E., and T.W. Seamans. 2012. Foraging preferences of Canada geese among turfgrasses: Implications for reducing human-goose conflicts. J. Wildlife Manage. 76(3):600-607.

York, D.L., J.L. Cummings, R.M. Engeman, K.L. Wedemeyer. 2000. Hazing and movements of

Canada geese near Elemdorf Air Force Base in Anchorage, Alaska. Int Biodeter Biodegr. 45:103-110.