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Birds, Buildings and LEED Mitigation Design at the University of Calgary Campus

by

Jessica Suzanne Wood

A THESIS

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Abstract

This appears to be the first study at the University of Calgary to assess bird collisions with buildings. Through an exploratory approach the intention was to gain an understanding of birds colliding with buildings at the university.

Bird collisions were documented at the University of Calgary during the 2013 spring and fall bird migration. Only five birds were found to collide with four building structures. The low sample size posed challenges in undertaking statistical analysis. This research contributes a new vegetation density matrix and additions to Leadership in Energy and Environmental Design (LEED) Pilot Credit 55.

The information in this study may be built upon in order to conduct confirmatory research that accurately determines the extent of bird-building collisions at the University of Calgary and will, in turn, contribute to conservation of resident and migratory bird populations.

Acknowledgements

I would like to thank my supervisor, Dr. Draper, for helping me through the thesis writing process. Thank you also to my defence team Dr. Quinn and Dr. Bender, and thank you to Dr. Alexander for your contributions during my proposal defence.

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Epigraph

"Of all the classes of animals by which we are surrounded in the ample field of nature, there are none more remarkable in their appearance and habits than the feathered inhabitants of the air… They diversify the still landscape with the most lively motion and beautiful association; they come and go with the change of the season, and as their actions are directed by an uncontrollable instinct of provident nature, they may be considered as concomitant with the beauty of the surrounding scene… Their lives are spent in boundless action; and nature, with an omniscient benevolence, has assisted and formed them for this wonderful display of perpetual life and vigor, in an element almost their own" (Nuttall 1832 p 1).

Chapter One: Introduction

1.1 Background

One needs only to picture a world without birds to understand that these creatures are intrinsically valuable and important contributors to local and global ecosystems. They directly and indirectly affect flora and fauna in any place they inhabit. Birds pollinate many plants and are responsible for the dispersion of seeds, leading to the survival of many sensitive flora. Birds are a major food source for predator species; in fact, some bird species have annual mortality rates close to 60 percent due to predation of their newly-hatched nestlings and fledglings. Birds also are important predators of vertebrates, such as other birds, mice, snakes; and invertebrates, including worms and insects. Species that birds rely upon for food could overrun many areas of the world if they were no longer alive to contribute to the ecosystem. Alternately, were bird populations to severely decline or vanish, species that prey upon them would turn to other food sources, leading to unexpected changes to the ecosystem.

Bird-watching as a recreational activity brings billions of dollars annually to the North American economy through travel, accommodation, food, and purchase of bird-watching equipment, such as binoculars, cameras, bird food, bird houses, and feeders. In 2001, 46-million bird-watchers spent $31,686,673 in the United States (US Fish and Wildlife Service 2003). In 1996, Canadians spent $1,301,800 on wildlife viewing, while Albertans spent $171,600 (Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians 1996). The Canadian Tourism Commission reported in 2006 that 49.9 percent, or 1,000,914 of Albertans, engaged in at least one Canadian wildlife-viewing trip between 2005 and 2006 (Lang Research Inc. 2006).

The overall economic and ecological importance of resident and visitor birds is difficult to quantify but is implicitly understood by the North American population. What is not so clearly understood is that two anthropogenic factors are responsible for more annual bird deaths than any other natural event. The leading cause of human-related bird deaths in Canada and the U.S. is habitat destruction, followed by bird collisions with buildings (Klem 2010). Many species are affected; for instance sparrows (Family *Emerizidae*) are declining in grassland areas (such as Alberta) from habitat loss and human infrastructure and are among the highest percentage of bird-building collision casualties (Gelb and Delacretaz 2009; Borden et al. 2010). The North American Bird Conservation Initiative Canada (2012) found a 44.7 percent decline in grassland birds, such as sparrows, and a 63.7 percent decline in aerial insectivores, such as swallows, in Canada since 1970. More than 56 million birds in Canada and more than one billion in the United States are killed in building collisions every year (Klem 2010). This number will continue to climb as urban development continues.

1.2 Problem statement and research questions

This research attempts to determine the extent of birds colliding (flying into the glass windows) with buildings on the University of Calgary campus. In order to best establish this, the following research questions were explored:

1. How frequently do birds hit University of Calgary campus-building windows?
2. Which species are most affected by collisions at the university?

3. Do birds collide only with windows of campus buildings—or are there additional structures (such as upper-level glass pedestrian links) that endanger these flying creatures?
4. Do weather conditions impact collision occurrences?
5. What mitigation measures could the campus adopt to foster conservation of birds?

1.3 Exploratory research approach

The objective of this study was to conduct exploratory research; a "pilot study" which could be used as a guide to frame future confirmatory (hypothesis-based) research (Jaeger and Halliday 1998). The exploratory approach is generally conducted for one of two purposes: either as a foundational investigation to gain insights and ideas and answer a specific question regarding a previously unexplored issue, or for information-gathering about a problem that can facilitate administrative decisions. The exploratory approach incorporates designing and conducting a small sample exploratory study and is the first step that leads to additional research in a more complex research project (Jaeger and Halliday 1998, Ford 2000). Exploratory research is often flexible and unstructured as the researcher has little or no prior knowledge about the issue or its components. The objective of a typical exploratory research design is to gain as much information as possible in a short period of time, such as during master's thesis research.

As it appears that bird-building collisions have not been previously studied on campus at the University of Calgary, I used exploratory methods to gather knowledge about the issue within the study area. I present the results as exploratory because attaining sufficient data to conduct meaningful statistical analysis was not guaranteed, thus data analysis could not be the

objective of this research (Heck 2007). From conducting a thorough literature review of past scientific research, I suggest enhancements to LEED Pilot Credit 55 (see Section 1.7) and a new vegetation density matrix. LEED Pilot Credit 55 is a collision-mitigation strategy utilized at other universities that could foster progressive administrative decisions about reducing collisions at the University of Calgary.

1.4 Research need

Calgary is located under the North American Pacific and Central Migration Flyways (Figure 1.1). Scientists estimate that along these two flyways 150 species stop over in Canada annually but that there has been a consistent decrease in numbers each year (Birdnature.com 2001). This decrease in migratory visitors is attributed partially to urbanization, and mortality by building collisions could play a sizeable role in this (Collister et al. 1997, Klem 2010). Similarly, this type of mortality may also affect local-resident bird populations. An understanding of the extent of collision mortality in Calgary is essential and, if necessary, conservation methods should be developed and implemented in order to protect both visiting and local birdlife.

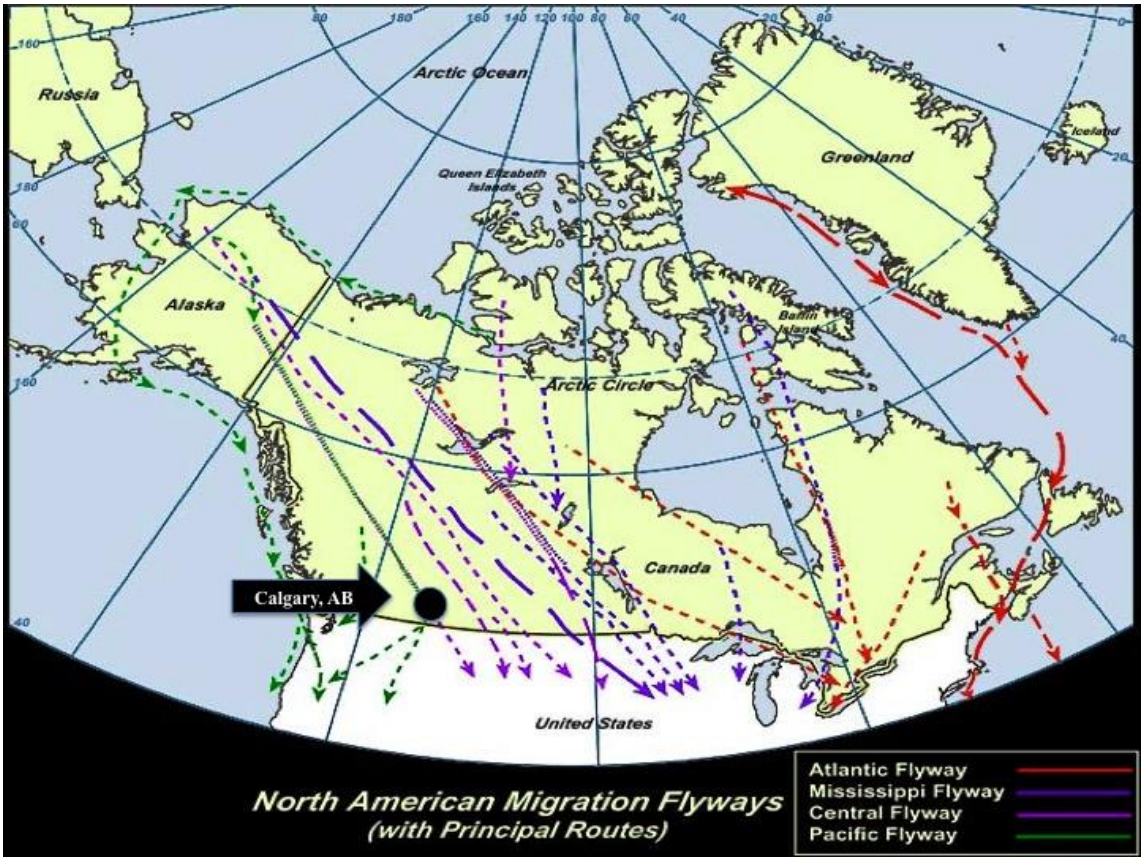


Figure 1.1 North American migration flyways

(Adapted from: Nutty Birdwatcher. 2001. North American migration flyways. Available from: http://www.birdnature.com/flyways.html)

1.5 Scope

This study was conducted at the University of Calgary main campus in the northwest quadrant of the City of Calgary. According to Klem (Pers. Comm. Jan 10, 2013), universities are notorious for bird-building collisions as they contain clusters of tall buildings with a high percentage of exterior glass. A knowledge gap existed in this topic as there has been no previous scientifically rigorous count of bird-building collision mortality in Calgary and at the University of Calgary.

The sites monitored on campus included eight institutional buildings and two upper-level glass pedestrian links. Each area offers varying bird-building collision risks by way of vegetation and buildings in proximity to other buildings as well as glass material. This study was limited to field counts of day-time collisions for one hour each morning between the hours of 6 a.m. and 10 a.m. during spring and fall migration 2013 and between 4 p.m. and 30 minutes before sunset during fall migration 2013 at the University of Calgary main campus.

According to the Alberta Institute for Wildlife Conservation's (AIWC) 2012 injury report data, bird collisions with windows occur in all areas of Calgary through day and night hours (Mathieson P Pers. Comm. May 11, 2013). Past collision injuries in Calgary seemed to cluster around two areas, namely City of Calgary Nose Hill (Nature Area) Park in the city's northwest (approximately 4.6 kilometres from the university) and Fish Creek Provincial Park in the southwest of the city (approximately 28.7 kilometres from the university) (Mathieson P Pers. Comm. May 11, 2013). In July 2011, a female Peregrine Falcon fledgling left her nest two weeks early during a high-wind event; she collided with the Biological Sciences Building and died (Fitch W Pers. Comm. Jan 9, 2013).

1.6 New development at the University of Calgary

According to Alberta Enterprise and Advanced Education (Alberta EAE [date unknown]) the University's student capacity for the 2012/2013 academic year was 25,335. About 4,147 students will be turned away each year through the 2020/2021 school year. The University of Calgary has responded to population growth by developing new buildings and gathering spaces on all (main, downtown, and west) campus grounds (University of Calgary 2013a). Two new

campus buildings included in this study are the Platinum Leadership in Energy and Environmental Design (LEED) certified Energy Environment Experiential Learning Building and the Gold LEED certified Taylor Family Digital Library building (University of Calgary 2010). The Taylor Family Quadrangle, situated between the Taylor Family Digital Library and the MacEwan Student Centre (no LEED certification), has been designed as an outdoor community green space that also serves as a wildlife habitat area (University of Calgary 2010). Existing buildings have also undergone extensive renovations. For instance, as stated in the University of Calgary Conceptual Master Plan, the renovations on the MacEwan Student Centre incorporate a "highly transparent three-storey solarium along the south face of the building fronting on the Taylor Family Quadrangle"; this structure is designed to feel like a campus 'living room' (GEC Architecture 2011 p 3).

1.7 LEED Pilot Credit 55: Bird Collision Deterrence

Advancements are being made to mitigate controllable bird-building collision risks through building and site design, human daily and seasonal sustainable practices, and through private and government organizations. Mitigation efforts by professional organizations as well as municipal, provincial, state, and federal governments in Canada and the United States are increasing and becoming well recognized. Notably, New York's Freedom Tower (built on the site of the former World Trade Center) has bird-friendly building designs incorporated in the construction designs (Raycom Media Station 2006). The City of Calgary has published the City of Calgary Bird-Friendly Urban Design Guidelines (Calgary Land Use Planning and Policy 2011), which gives advice to new- and existing-building owners on bird-friendly practices.

In a court hearing in Toronto, Ontario, the environmental legal charity Ecojustice brought Cadillac Fairview, a Toronto office tower building owner, to court for failing to install mitigation devices to deter bird collisions after 800 migrating birds either were killed or severely injured in 2010 (OHSInsider 2013). Although the violation charges under the Canadian Species at Risk Act, the Environmental Protection Act, and the Ontario Society for the Prevention of Cruelty to Animals Act against Cadillac Fairview were dismissed, the company chose to implement bird-deterrent window-film on its building windows (OHSInsider 2013). That this case was brought to court suggests Canadian judicial law is taking this issue seriously and charges could be placed on future defendants.

University campuses, including the University of Calgary, are currently making an effort to construct green buildings in order to be more economically and ecologically accountable. Leadership in Energy and Environmental Design (LEED) is the standard for green building design recognized in Canada and the United States. Since inception in 1998, architects, building owners, and operators have increasingly used LEED as a framework to identify and incorporate measurable green building technologies and solutions. The University of Calgary has an opportunity, through LEED, to manage the risk of bird collisions with buildings at existing and new/redeveloped buildings. The LEED Pilot Credit 55: Bird Collision Deterrence incorporates a Bird Collision Threat Rating calculation, which is a partial requirement of satisfying the full LEED Pilot Credit 55 requirements. The Bird Collision Threat Rating calculation is considered and improved upon in this research and helps to answer research question number five. I used the Energy Environment Experiential Learning Building to test the existing Bird Collision Threat

Rating formula and to experiment with additions to the calculation. LEED Pilot Credit 55 is explored in depth in Chapter Five.

1.8 Organization of the Work

The remainder of this thesis is divided into five parts. In Chapter Two, I review the literature on species-specific vulnerabilities and collision hazards that contribute to the risk of bird collisions with buildings, as well as current mitigation strategies. I detail in Chapter Three the methods used to collect data and in, Chapter Four, I review both the results of the data collection and discuss limitations of this research. In Chapter Five, I discuss additions to the current LEED Pilot Credit 55, as well as propose a vegetation density matrix. In Chapter Six, I conclude this investigation by recommending areas for future research opportunities.

Chapter Two: Literature Review

Klem (1990b p 127) has described bird collisions with buildings as a "valuable but largely neglected ornithological resource." Increased conservation efforts and awareness of the global ecological value of birds as well as "knowledge of geographic distribution and migration routes, can be enhanced through careful documentation of window casualties" (Klem 1990b p 127). Environment Canada reports that collisions have contributed to significant species decline in Canada (Wedeles 2010). As human populations continue to grow, and our building designs continue to incorporate reflective glass, we will perpetuate the problem of bird mortality.

2.1 Background

In 1832, Nuttall was the first to document a bird collision with a window when he witnessed a Sharp-shinned Hawk (*Accipiter striatus)* attempting to attack its prey through three layers of glass panes surrounding a Massachusetts botanical garden. As large glass windows became a regular architectural practice during the post-World War II building boom, avian fatalities have steadily increased.

Klem (1979) identified 62 historical documented accounts of bird collisions worldwide. In 1990, Klem estimated 10 bird collision deaths per building each year in North America. Dunn (1993) suggested a mortality rate of close to 0.85 per residential home per year across North America. Comparably, Bayne et al. (2012) estimated 1.7 collisions per home per year in Edmonton, Alberta. Currently, Klem's general approximation from 1990 still is widely accepted across North America and seldom refuted by other scientists (Klem 1990b, O'Connell 2001).

Since the 1960s, bird-building collisions have been widely recognized by North American, South American, West Indian, European, and African environmentalists who are concerned about "window predation on birds" (Klem 1979 p 3). These collisions occur regularly worldwide in rural, suburban, and urban environments, claiming resident and migrant birds at windows of various sizes at all building heights with a variety of facades, facing all directions.

Window mortality can affect all species, of both genders, at any age, any time of day or night, each season, and in all weather conditions (Klem 1989). As seen in Figure 2.1, a number of man-made tower structures (defined as a "tall narrow building" by Oxford University Press (2013 [Internet])) such as power lines, communication towers, and turbines, also cause avian mortality. Buildings are by far the largest source of bird deaths across North America, resulting in hundreds of millions of victims annually (Bird 2004, Erickson et al. 2005). Simply, all birds are vulnerable to colliding with a building when they fly through areas with human-built structures.

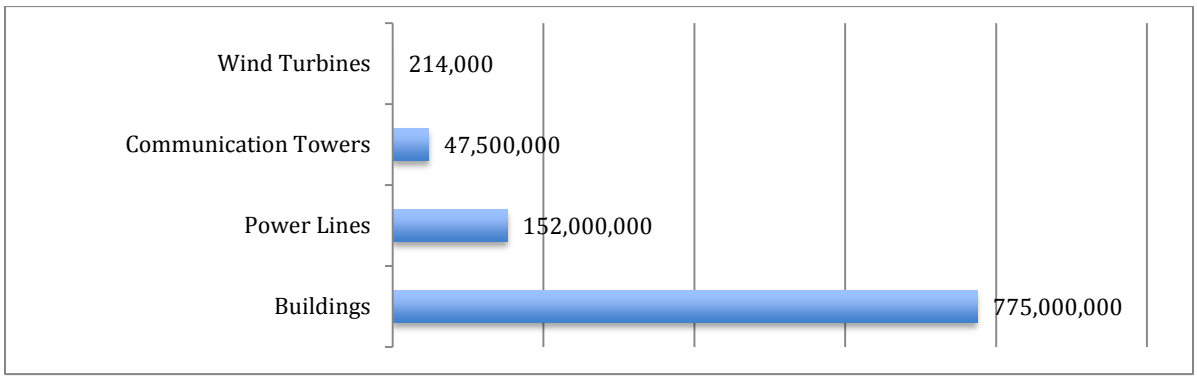


Figure 2.1 Estimated total mortality of various bird species by human-built tower structures in the United States per year[1]

(Adapted from: Bird 2004, Erickson et al. 2005)

[1] These are 2002 and 2005 counts, present day numbers are expected to be higher due to an increase in towers and buildings.

Over a span of the last 70 years, a number of theorists have attempted to explain why birds hit windows. Causes can include: distraction, alcohol intoxication (from ingesting fermenting fruit), diminished vision due to imperfect eyesight, mist, glare from the sun, and smoke (Willet 1945, Dunbar 1949, Konig 1963, Langridge 1960, Rogers 1978). Klem's 1979 foundational theory that bird vulnerability to building collisions is due to bird Ultraviolet (UV) vision, which means birds fail to perceive sheet glass, has been widely accepted and much ensuing research has been based on this theory (Martin 2011).

2.2 Bird vulnerabilities and collision hazards contributing to collision risk

"Since self-destruction or self-injury, at least at man-made structures, seems contrary to the survival interest of both the individual and the species", scientists have produced numerous studies on how avian physical characteristics will indicate whether a bird will be more or less vulnerable to a collision hazard and how those characteristics will contribute to collision risk (Klem 1979 p 68). Avian physiology characteristics of relevance to this research include: UV vision, stereopsis (3D vision), wing loading and aspect ratio, foraging techniques and resident status.

Gelb and Delacretaz (2006) suggested that proximity of a building to bird habitat is an important collision hazard. Bird attractants exist in many forms, from natural forests, grasslands and wetlands to planted shrubs, trees, and landfills; all will increase the abundance of birds in an area. When habitat areas are near buildings with sheet glass windows, birds can become confused as they look for places to drink, bathe, roost, and nest and may become injured and possibly die by colliding with a window.

To thoroughly understand collision risk, consideration of specific bird vulnerabilities and collision hazards is necessary. The following vulnerabilities and hazards can influence collisions: 1) morphological attributes of birds associated with niche specialization, 2) ecological site conditions and 3) building morphology.

2.2.1 *Bird morphology and niche specialization*

Johnson (1981 p 553) aptly states, "[T]o understand how flying animals work, their physiology, morphology, ecology, and wing function must be known… [n]atural selection is likely to act toward a wing structure that minimizes the power required to fly at the speed and style optimal for the animal, and is assumed to result in some near-optimal combination of these variables. The optimal flight speed varies with the flight goal and the type and abundance of food." The resident status, species, and eating habits of a bird are affected by evolutionary attributes such as brain- and eye-size, UV vision, stereopsis, and wing loading which, in turn, influences whether a bird is vulnerable to collisions at the sky zone (top floors) of a building or the habitat zone (bottom few floors) of a building (Figure 2.2).

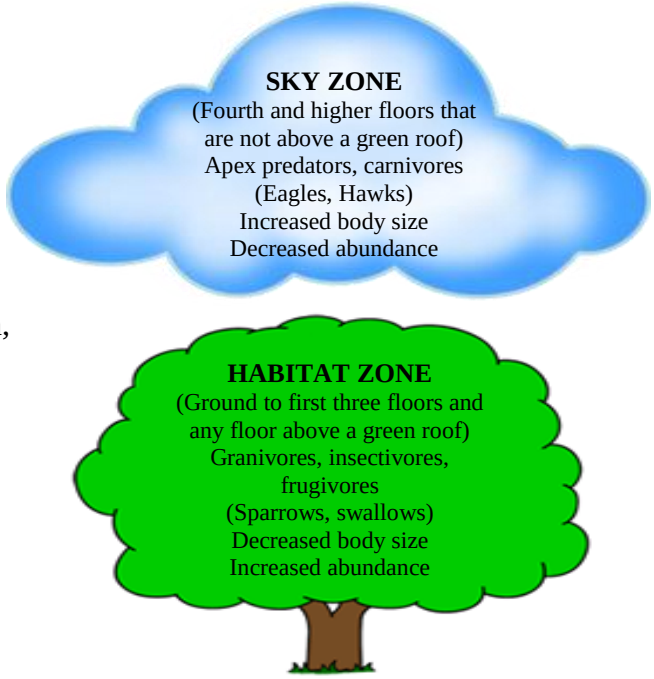


Figure 2.2 Habitat zone and sky zone of buildings

Note: Birds relatively higher on the food chain tend to increase in body size and decrease in abundance. Birds lower on the food chain tend to decrease in body size and increase in abundance.

2.1.1.1 Ultraviolet (UV) vision and stereopsis

Birds that are relatively lower on the food chain, such Passerines (perch birds), have evolved amplified UV vision (~360 nm) for deciphering colours when foraging for berries and insects and when choosing a mate (Maier and Bowmaker 1993, Bennett and Cuthill 1994, Osorio et al. 2000). However, increased UV acuity is positively correlated with a decreased ability to recognize glass as a solid (Bennett and Cuthill 1994; Cuthill et al. 1999). UV vision has been hypothesized to aid in avian flight orientation, ironic given that these birds are more vulnerable to collision risk (Klem 1989).

Many birds, such as grassland insectivorous granivore Passeriformes including the resident Chipping Sparrow (*Spizella passerine)* and neotropical migrants such as the Wilson's Warbler (*Cardellina pusilla)* have evolved amplified UV vision, at around 360 nm (Young et al. 2003). Predatory carnivores, including Falconiformes such as the Peregrine Falcon, have not evolved considerable UV vision (lower nm than other species) and have a UV photopigment with a peak sensitivity of close to 410 nm (Osorio et al. 2000, Rajchard 2009). Non-colour-specific hunting in high-flying predatory birds does not demand UV vision and this evolutionary characteristic (of a lower nm) helps them detect glass and avoid collisions.

Top-feeder predator birds' eyes are forward facing and much closer together, giving these species heightened stereoscopic (binocular) three-dimensional vision, which aids in detecting and avoiding human-built structures (Fox et al. 1977, Garamszegi et al. 2002). In contrast, lower-feeder prey birds are not privileged with attributes as resilient as those of their high-flying predators. Prey birds, with eyes placed further apart, do not have the need for long-distance

acuity when hunting and tend to look peripherally rather than forward when in flight, increasing vulnerability to collisions.

2.2.1.1 Wing morphology

Wing morphology involves wing loading (body weight / total wing area) and aspect ratio (wing length: wing breadth). Birds may have either high wing loading (small wing area relative to body mass) or low wing loading (large wing area relative to body mass). They also may have either high aspect ratio (long wing span relative to the width of the wing) or low aspect ratio (short wing span relative to the width of the wing).

Wing loading is a measurement of aerodynamic stability and can provide information on the distance a species flies as well as how and where it hunts. High wing loaded birds, such as divers, water birds, and "poor" fliers (pheasants), spend most of their time in the habitat zone of a building since they prefer to fly short distances at lower altitudes through cluttered habitats. In contrast, low wing loaded birds, such as marine soarers, aerial predators, and thermal soarers, excel at flying long distances and prefer to fly at higher altitudes. These birds hunt during flight in open, uncluttered areas. Their differing body mass affects wing loading. Smaller, lighter birds are able to achieve maximum flight speed relatively quickly when leaving a perch. These birds are at a much higher risk of collisions in the habitat zone of buildings.

Aspect ratio (wing shape) influences takeoff and landing speed as it affects drag, climbing rate, and manoeuvrability. Birds with high aspect ratio wings have a long wingspan in relation to the width of their wing. These birds, marine soarers, aerial predators, and diving birds, take off and land at faster speeds, fly at high speeds, and have good in-flight manoeuvrability but are susceptible to being impeded by wind gusts (Bevanger 1998). Low aspect ratio wings feature

short wingspan compared to wing width, which hinders lift off and extends the time it takes to attain maximum flight speed. Low aspect ratio birds tend to take off and land at slower speeds and prefer to fly at low speeds. Their wing shape hinders quick in-flight manoeuvrability. Larger low aspect birds have a heavier body mass to lift off from a perch, extending the time it takes to attain maximum flight speed. When there is "lag time" in lift-off, high wing loaded birds have time to sense a potential collision and re-route their direction. Some low aspect birds, such as water birds and "poor" fliers, have short broader wings and may be accompanied by a longer tail to aid in manoeuvrability. These birds excel at hovering and gliding at lower elevations. Figure 2.3 illustrates four aspect ratio wing types.

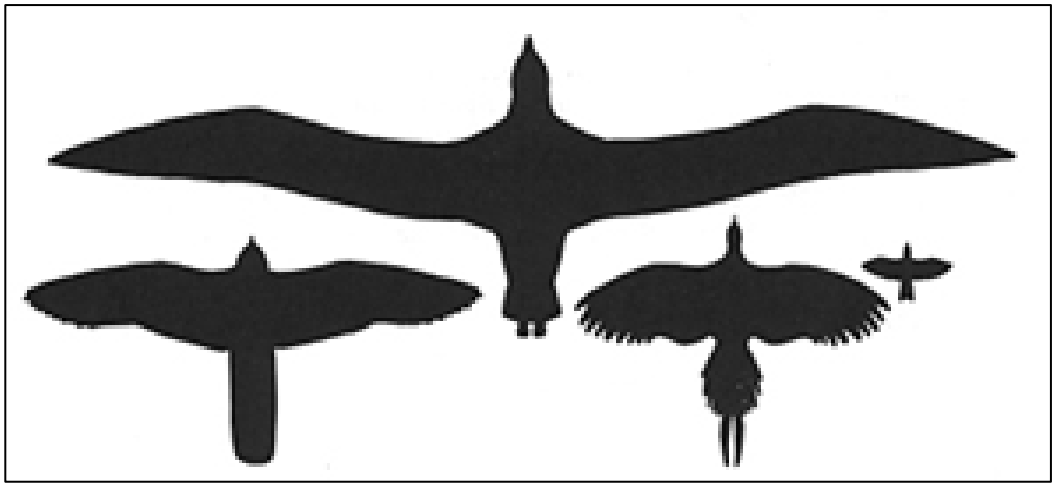


Figure 2.3 Differing aspect ratio wing types.

From left to right: Falcon (high aspect ratio), albatross (extremely high aspect ratio), pheasant (extremely low aspect ratio), and passerine (low aspect ratio)
(Ehrlich P, Dobkin D, and Wheye D. 1988. Wing shapes and flight. Available from: http://www.stanford.edu/group/stanfordbirds/text/essays/Wing_Shapes.html)

Combinations of flight performance and foraging behaviour differ according to where a bird species falls on the wing loading/aspect ratio axis. Figure 2.4 summarizes the combination of wing loading and aspect. Appendix One provides Bevanger's (1998) wing loading and aspect ratio axis with bird species examples.

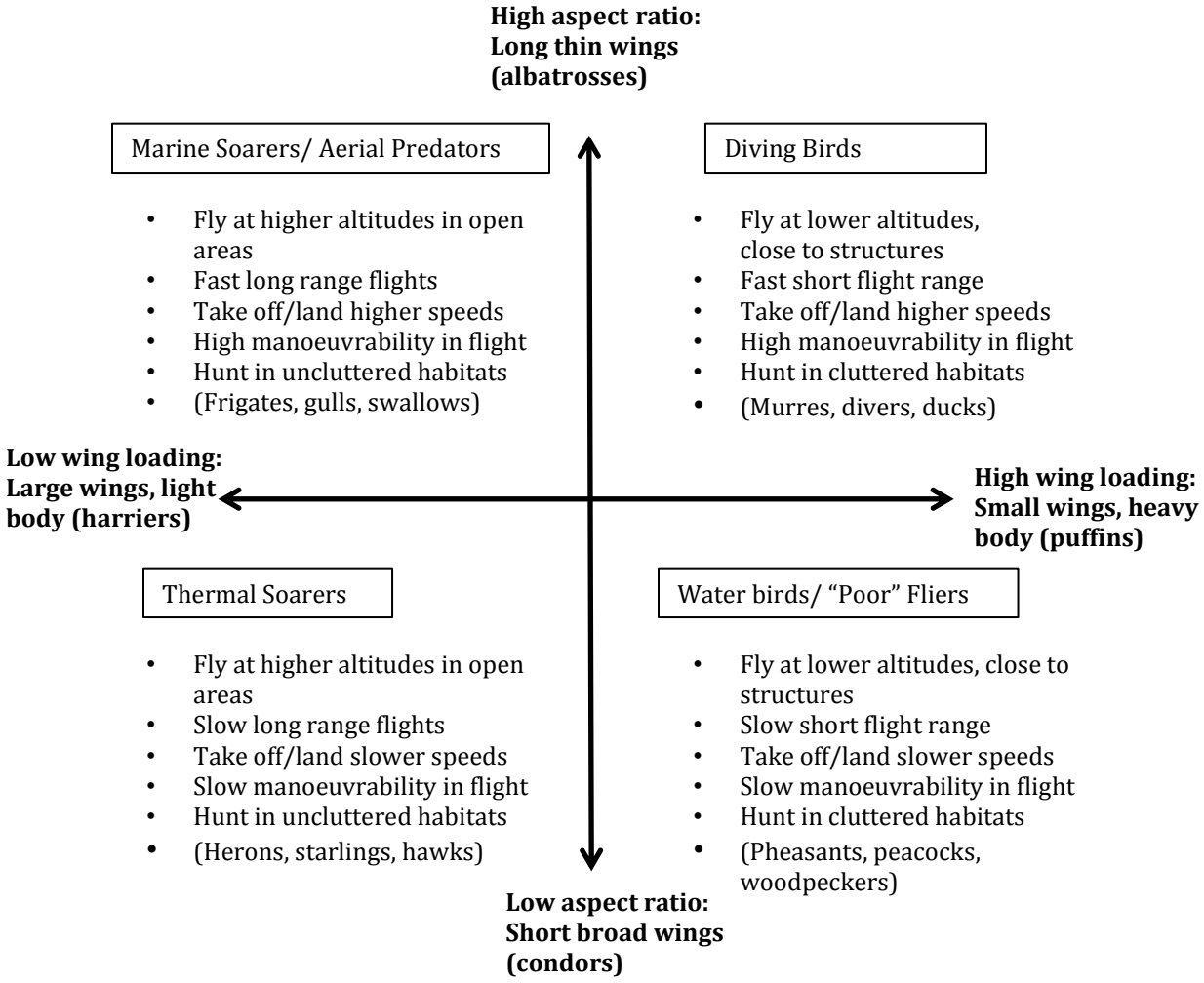


Figure 2.4 Bird wing loading and aspect ratio axis showing vulnerability to collisions based on the four different combinations

(Adapted from Rayner 1988, Bevanger 1998, Canals et al. 2011)

2.2.2 Ecological site conditions

2.2.2.1 Bird abundance

An important environmental factor contributing to collision risk is seasonality (Klem 1989). Migration seasons influence the abundance of birds in an area and, when near buildings, can be the "best predictor of strike [collision] rate" (Klem 2010 p 244). Hager et al. (2008) also found a positive correlation between abundance of birds and collision rate. Evans Ogden (1996 p 14) suggests that a high-collision rate of a certain species could be "a factor of its relative abundance in the composition of migration traffic" but also attributes this to species-specific vulnerability and not necessarily to the abundance of a particular species.

2.2.2.2 Bird habitat in proximity to buildings

Studies have shown heightened collision numbers at areas near natural features and buildings (Gelb and Delacretaz 2006, Borden et al. 2010, Bayne et al. 2012). Some researchers suggest that collisions are due to "zoning laws for, and societal interest in, increased naturalized habitat around houses and businesses" (Hager et al. 2008 p 559). Klem (1990a) studied residential homes and observed more collisions when bird feeders were present than when they were not available and collisions were heightened at feeders placed a greater distance (up to 10 metres) from glass windows (Klem 2010). Here, birds flew toward the reflection of attractants with enough flight momentum to cause injury and death. Gelb and Delacretaz (2006) found that Manhattan collisions tended to occur diurnally at ground level near buildings with abundant vegetation. It stands to reason that bird attractants will encourage more birds to arrive and stay longer in an area. Simply, the longer the time a bird spends in an area, flying and feeding where habitat and windows co-exist, the higher the collision risk.

Grassland low-flying birds are more vulnerable to collisions than are higher-flying predators and migrants because low-fliers spend more time in proximity to buildings. Grassland birds spend a great deal of time foraging in low-level habitat, so have a higher chance of misinterpreting mirrored habitat as authentic. They subsequently may fly into a window at high speed.

2.2.3 Building morphology

Most bird-building collisions occur during the day at the lower three floors of buildings, or habitat zone (Figure 2.2), making this area "an important source of mortality for [both migratory and residential] birds" (Klem 1990b, O'Connell 2001, DeCandido 2005, Gelb and Delacretaz 2009, Klem 2010, Bayne et al. 2012 p 583).

The sky zone area of a building can be hazardous to high-flying birds. Sky-zone hazards include reflective material that mirrors the sky during the day and evening light pollution. Evening light pollution is a nocturnal collision danger and is not further explored as this research is focused on diurnal collisions. The five-story Energy Environment Experiential Learning Building at the University of Calgary campus is shown in Figure 2.5. The habitat zone of Energy Environment Experiential Learning includes the lowest three floors including ground level. The upper two floors encompass the sky-zone area.

Figure 2.5 University of Calgary Five-story Energy Environment Experiential Learning Building

2.2.3.1 Expanse and type of glass (transparent and reflective)

Collisions tend to occur on clear days when glass windows are easily seen through and reflections are clear (Klem 1989). When indoor vegetation is showcased through clear glass, such as in an atrium, lobby, or glass walkway, the greenery is more inviting for birds. As the expanse of glass on a building façade is increased, the number of collisions tends to escalate (Borden et al. 2010). Klem et al. (2009) argues that every 10 percent increase in expanse of glass could equate to a 32 percent increase in collision risk.

Research has found that two specific classifications of sheet glass are most likely to contribute to bird mortality: transparent and reflective. Transparent windows can display vegetation inside a building or through a second window, such as in an atrium, lobby, or glass walkway. Buildings with sizable amounts of highly transparent glass also are a danger at night if emitting artificial light (light pollution) as this interferes with bird-flight navigation (Klem et al. 2009, Klem 2010). Reflective windows can mirror the sky, surrounding vegetation, or the bird

itself. Borden et al. (2010) found a correlation between an increase in reflectiveness and collision risk. In either instance, when birds hit glass, some die instantly from intracranial haemorrhaging. Others may fly away but die near the collision site as the effects of their head trauma set in (Klem 1990a, Veltri and Klem 2005).

2.2.3.2 Building sites in proximity to other buildings

Building sites in proximity to other buildings with clear windows or see-through corridors can confuse birds, resulting in an inability to find their way out of the 'maze'. Here, birds will become frightened, flap around, and collide with a window. Studies have shown that birds with UV vision that naturally fly through constricted passageways will be vulnerable to collisions when they frequent these areas (Ross 1946, Snyder 1946).

2.2.3.3 Window angling

Window angling with regard to collisions has been studied in depth. Klem et al. (2004) found that the more vertical the window placement, the more prone birds are to collisions. Birds most vulnerable to vertical windows tend to be low-flying birds relatively lower on the food chain that frequent building habitat zones (Klem et al. 2004). Windows in the sky zone that are angled 90 degrees or angled upwards and reflect the sky are hazards for high-flying birds. Figure 2.6 shows the University of Calgary's MacEwan Student Centre and the vertical and southwest upward-sloped windows on the south side of the building.

Figure 2.6 Vertical and upward-sloped windows on the University of Calgary's MacEwan Student Centre

2.2.3.4 Windows in proximity to other windows

Tunnel fliers, birds that naturally fly through constricted passageways, look for food and find refuge in low-lying trees and shrubs and are "extremely" vulnerable to hitting windows in these areas (Ross 1946, Snyder 1946). Atriums, lobbies, and walkways that have windows on two sides of a corner, are placed in a rounded fashion around a corner, or have glass on two opposite sides of a wall, generally will be invisible to birds and be perceived as a flythrough, inviting collisions. Courtyards can also confuse birds, especially those that have just collided with a window. Here, birds may become disoriented, scared, and flap around frantically trying to exit the area, only to hit another window that reflects vegetation or the sky.

Figure 2.7 shows the University of Calgary's upper-level pedestrian link located between Biological Sciences and Social Sciences. This structure is comprised of see-through glass on two opposite sides and is in close proximity to habitat.

Figure 2.7 Upper-level pedestrian link at the University of Calgary

2.3 Summary of bird vulnerabilities and collision hazards contributing to collision risk

Klem (2010 p 75) states: "A bird's… resident status has little to no influence on its vulnerability to windows." Based on my literature review, I have reached a different understanding. The species and physiological makeup of a bird inherently influences whether the bird is migratory or resident in addition to the abundance of species in a particular location.

Species and physiology also affect the type of vegetation to which a bird is attracted and the height at which it will fly and perch. Birds that perch and feed at lower elevations are more vulnerable to collisions than those that prefer higher areas. Characteristics such as UV vision and wing loading are aspects of physiology that also contribute to resident status, and are some of the greatest contributors to bird-building collision risks.

Bird morphology and niche specialization, ecological site conditions, and building morphology all contribute to bird-building collision risk. Bird morphology and niche

specialization include predisposed species traits contributing to collision risk. Ecological site conditions either are natural or human-originated collision hazards, and building morphology incorporates human-originated collision hazards. Figure 2.8 outlines the collision risk continuum, a summary of natural and human contributors to collision risk.

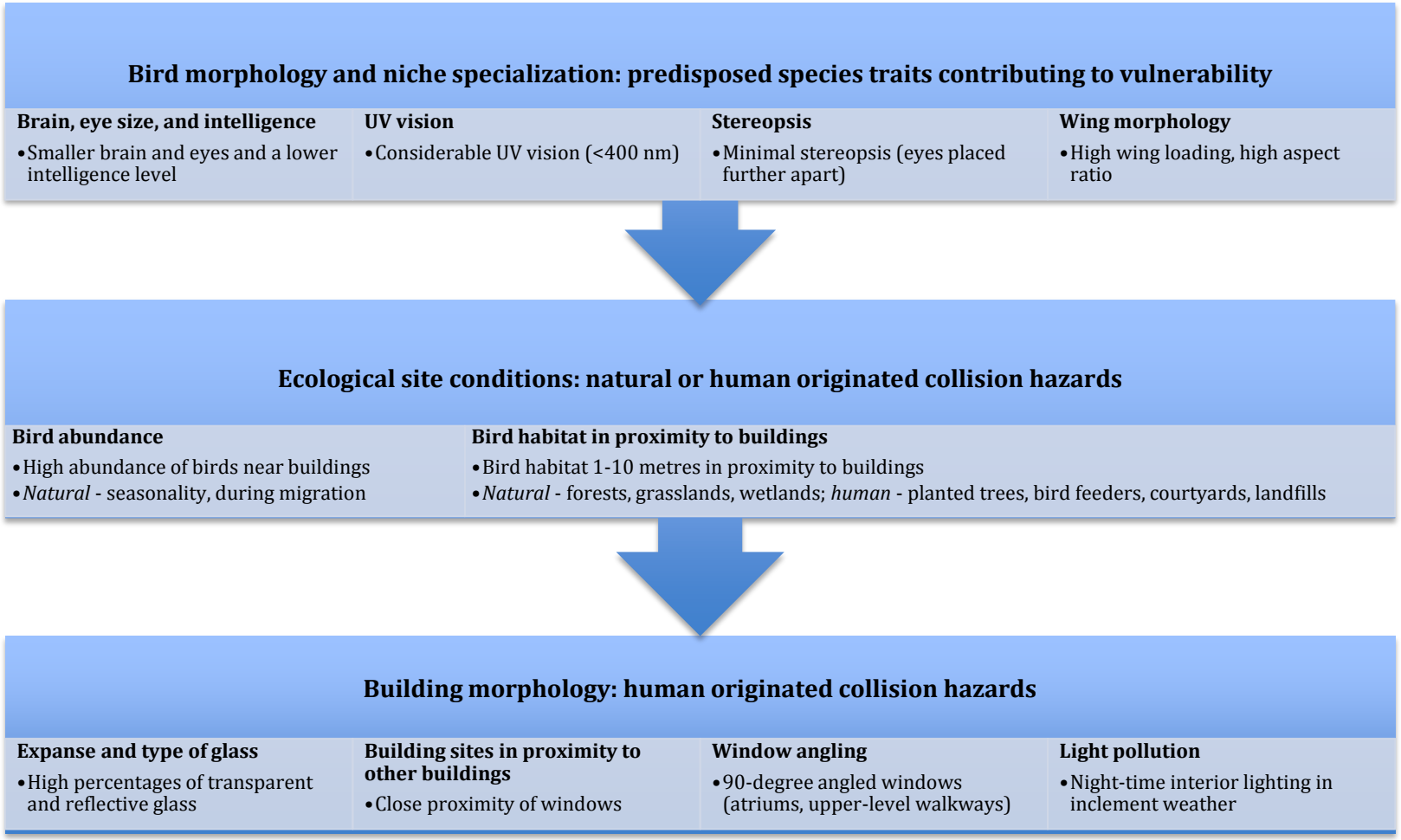


Figure 2.8 Collision risk continuum – a summary of natural and human contributors to collision risk

(Adapted from: Ross 1946; Fox et al. 1977; Bevanger 1998; Osorio et al. 2000; Klem et al. 2004; Garamszegi et al. 2005; Klem 1989, 1990a, 2009a, 2010)

2.4 Collision hazards and mitigation strategies

Martin (2011 p 251) states, "there is unlikely to be a single effective means of reducing collisions for multiple species at any one site. Warning or diversion and distraction solutions may need to be tailored for particular target species." In the following sections, I discuss mitigation efforts by various organizations as well as review the literature on various mitigation strategies.

2.4.1 Organizational mitigation efforts

Mitigation of controllable collision hazards through building and site design as well as through daily and seasonal human practices are ongoing and evolving. Non-governmental organizations as well as municipal, provincial, state, and federal governments in Canada and the United States undertake a number of collision mitigation efforts. The main theme of these efforts is to create new or to retrofit existing structures to be bird-friendly. Bird-friendly is interpreted as a structure that is an intentionally low-collision risk to birds. While some organizations such as the City of Toronto focus on migratory birds, others such as the City of Calgary broaden their definition to incorporate all birds.

The City of Calgary's Bird-Friendly Urban Design Guidelines offer "bird-friendly urban design strategies and guidelines which address the direction of the Calgary Planning Commission, the Centre City Plan policies, and environmental objectives outlined in the City of Calgary's Environmental Policy and the Municipal Development Plan (MDP)" (Calgary Land Use Planning and Policy 2011 p 1). This City of Calgary effort and other important mitigation efforts are outlined in Appendix Two. This is not an exhaustive list; but is a good representation

of how Canada and the United States are placing importance on mitigation of bird-building collisions.

2.4.2 Visible barriers

In order for birds to detect a window, scientists recommend that visible barriers break up the glass on large windows (Klem 2010). Lowering blinds during migration seasons and at hazardous windows is a good method of reducing collisions. However, windows are built to let in light and scenery during the day. Filmy fabric that can be seen-through is a good alternative but when that is not possible, adhesives, decals, and etchings of any shape placed (preferably) on the exterior surface using the "2x4 Rule" is suggested (Klem 1990b, Shepard 2011). The American Bird Conservancy (Shepard 2011) created the "2x4 Rule" and recommends adhesives be spaced a maximum of two inches (5.08 centimetres) apart horizontally and four inches (10.16 centimetres) apart vertically for maximum detection of all birds (Figure 2.9). Decals placed close together will obstruct a clear view out of a window, so this method is primarily recommended at known collision sites. Online companies sell decal packages for as little as $6.50 CDN for four decals or $8 CDN for UV reflective decals (WindowAlert 2012). UV reflective decals claim to be superior deterrents to the regular decals. However, in order to ensure the effectiveness of these deterrents, more research is needed to understand bird vision and perception.

Figure 2.9 Window decals

(Shepard C. 2011. Tape decals placed following the 2x4 rule can be effective at deterring collisions. Available from: https://www.abcbirds.org/newsandreports/special_reports/Bird-friendly%20Building%20Guide_WEB.pdf)

2.4.3 Bird attractant placement

Bird attractants located within one to 10 metres of a window are a proven collision hazard (Klem et al. 2004, 2009b). Placing or moving bird feeders and other habitat features to within one metre of a nearby window will prevent birds from gaining sufficient flight speed to cause injury or death (Klem et al. 2004, 2009b). This solution is simple and easily implemented at most sites where an attractant can be placed or relocated. If birds are drawn to an area by a tree or a similarly more secured structure, a different solution may be required or a new feeder should be installed close to the building. One must be aware that, using this method, they also may be feeding other wildlife unintentionally. Gray Squirrels (*Sciurus carolinensis*) are extremely

common in Calgary and these acrobats regularly help themselves to available bird feeders (Figure 2.10).

Figure 2.10 Gray Squirrel on bird feeder at south Calgary residence

2.4.4 Other mitigation methods

Klem et al. (2004 p 74) states that "[Mitigation] techniques are often unacceptable to homeowners and managers of commercial buildings because they are costly, impractical, or aesthetically unpleasing". Mitigation design needs to be simple and cost-effective in order to be widely accepted and easily implemented and can include turning out lights, placing bird attractants at appropriate distances from windows, and using visible barriers on windows.

Simple and cost-effective measures, such as those discussed in this chapter, have the highest probability of adoption by owners of all buildings. As science has not yet discovered the causes (or effects) of all collisions, deterrent methods need to be tailored to each area and testing of chosen methods is recommended. Due to the site-specific species availability and the variability of other parameters impacting bird-building collision risk, selected mitigation measures should be evaluated in the target area for effectiveness before implementation.

BirdAvert (2008) recommended that netting be placed in front of a window to catch birds before they hit windows. While 100-percent effective, this solution may only be practical in specific areas. ORNILUX, a UV reflective transparent glass, apparently reduces collision risk by appearing as a solid to birds and transparent to humans (Klem 1991, Glas 2011). The cost to purchase and install this product can be outweighed by effectiveness in high collision areas. Other measures such as hazing chemicals, noise, and radar are useful in large open areas such as airports but are thought to be impractical in urban settings and have the potential to cause negative health and safety risks to both humans and wildlife.

Chapter Three: Methods

3.1 Reconnaissance study

From 1995 to 1997, the Calgary Bird Banding Society conducted a study at downtown Calgary commercial office buildings, aligned with Toronto's Fatal Light Awareness Program (FLAP). I attempted to repeat the study but did not find any quantitative data (dead birds). Throughout this reconnaissance period, I also spoke with Michael Mesure, founder of FLAP. He admitted his ongoing frustration with building property managers in Toronto who purposely try to sweep up dead birds before FLAP volunteers can document them (Pers. Comm. Dec 18, 2012). Mesure assumes building managers are attempting to avoid the stigma of becoming known as a "building that kills birds." Due to the challenges with recovering birds in downtown Calgary, I switched my focus to the University of Calgary campus.

3.2 Study area

Alberta provides breeding habitat and migration stopover sites for Neotropical migrant birds. Migration through Alberta appears to be primarily northwest-southeast (Collister Pers. Comm. Jun 6, 2013). Approximately 150 species stop over in Canada annually but scientists are finding a consistent decrease in numbers each year (Macdonald et al. 2012). This decrease has been attributed partially to urbanization with mortality due to building collisions likely being a significant factor (Klem 2010).

The City of Calgary is uniquely-placed in an area that neighbours five of the six primary natural classification regions in the province of Alberta: Boreal Forest, Rocky Mountain, Foothills, Parkland and Grassland, the sixth natural region, Canadian Shield, is located in

northeastern Alberta (Figure 3.1). Diverse sub-regions such as alpine, montane, mixed-grass prairie and wetlands also are featured in the Calgary area. Biodiversity in this localized area promotes fascinating bird-watching.

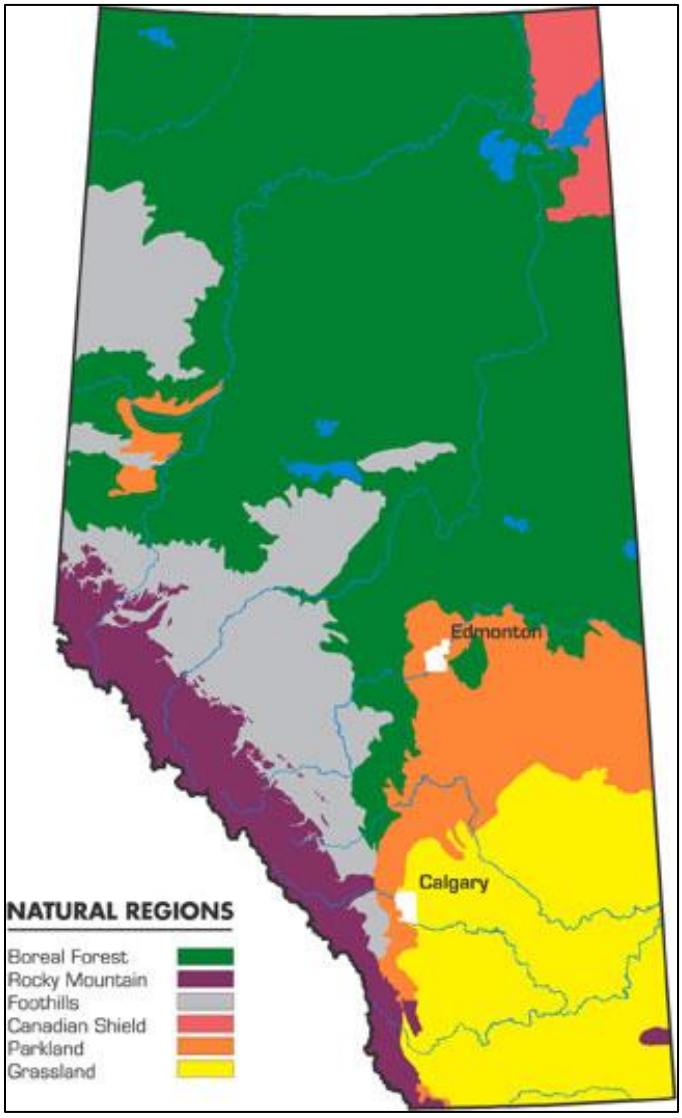


Figure 3.1 Natural regions found in Alberta
(Rocky View Schools. 2013. Alberta Natural Regions. Available from: http://resource.rockyview.ab.ca/rvlc/science7/ABnaturalRegions.jpg)

This research was conducted at the University of Calgary main campus located at 51°6'N, 114°10'W. The main campus comprises 66 buildings situated in an area of two square kilometres near various bird attractants such as the Bow River, Nose Hill Park, Spyhill Landfill, as well as wetlands, other parks, and open green spaces. The Inglewood Bird Sanctuary, less than 10 kilometres southeast of the University of Calgary, is a Federal Migratory Bird Sanctuary covering 36 hectares with a bird list to date of more than 270 species (City of Calgary 2013). Many of the species recorded at Inglewood Bird Sanctuary visit the University of Calgary campus (Collister et al. 2012, Collister Pers. Comm. Jun 6, 2013). The University of Calgary campus grounds offer deciduous and conifer trees, shrubs, ponds, short and tall buildings with ledges that birds use for foraging, nesting and hunting. The campus hosts a variety of species including resident and migrant passerines as well as Peregrine Falcons that have successfully nested in an opening on the side of the Craigie Hall roof since 1995. Because of the diversity of birds close to the University of Calgary, a variety of collision risk factors exist. These include bird habitat in close proximity to campus buildings and buildings with windows comprised of different reflective and tinting properties in close proximity to other buildings.

3.3 Research design

I obtained data using my personal observations and observations of volunteer fieldwork assistants. I also relied on happenstance discovery by University of Calgary grounds and security staff. I used Klem's 1979 dissertation, *Biology of collisions between birds and windows*, as a guideline for designing my fieldwork[2]. I also incorporated a combination of methods more

[2] During a phone conversation, Klem suggested I use his dissertation as a guideline (Pers Comm. Jan 10, 2013).

recently used by other researchers, such as Dunn (1993), Gelb and Delacretaz (2009) and Bayne et al. (2012).

Monitoring for carcasses and other collision indicators, such as feather imprints (Figure 3.2), fecal matter, and blood smears on windows, was conducted during spring and fall migration 2013. Klem (1989), Yanagawa and Shiuya (1998), O'Connell (2001), and Hager et al. (2008) found that collisions occur more frequently during migration seasons. Spring data collection occurred from April 20 to June 10, 2013 and fall data collection occurred from August 1 to September 30, 2013 similar to Booth and Collister's informal study in 1998, Gelb and Delacretaz (2009), Klem et al. (2009) and Mesure (2012). The decision to limit the monitoring route to the northeastern side of campus was to keep it to a manageable size while incorporating a wide array of building façades found on campus.

Figure 3.2 Feather imprint from a collision

(Bradley P. 2011. The window imprint left by a Mourning Dove. Available from: http://www.allaboutbirds.org/Page.aspx?pid=1184.)

The site area was monitored once daily during the spring, any time between 30 minutes after dawn and 10 a.m. (Klem 1989, Gelb and Delacretaz 2006, Borden et al. 2010). Dawn is an important time for bird movement and has proven to be a collision "danger" time (Mesure 2012). The campus site was monitored twice daily during the fall. I extended the monitoring in the fall because of the lack of data found in the spring and due to the higher number of volunteers available in the fall. Fall morning hours were the same as in spring. The evening monitoring hours were between 4 p.m. and sunset. The monitoring hours were between sunrise and sunset because Gelb and Delacretaz (2006) found all, and Klem (1989) found most collisions occurred during daylight hours and because these researchers tended to count any specimens found near sunrise as day-time collisions. Following Klem et al. (2009), the monitoring route was completed between 45 minutes and two hours.

The monitoring area consisted of buildings, pavement, grass, bushes, and trees; nearby bird attractant areas on campus offer water, conifer and deciduous trees, bushes, building ledges, and rooftops. A total of 26 fieldwork assistants were recruited to monitor 21 façades (different sides of buildings and pedestrian links). This is somewhat similar to Klem et al. (2009) who utilized 30 volunteers to monitor 73 sites. I trained all fieldwork assistants myself to ensure that all monitoring and documentation procedures were conducted using the same methodology, similar to Klem et al. (2009). Similar to O'Connell's (2001) method, fieldwork assistants scanned from the base of each building and upper-level glass walkway to approximately three metres out from the building base. The sidewalk distance to each building façade varied, so I chose to monitor three metres from the base of each building to maintain consistency. Fieldwork assistants also scanned the tops of lower ledges and bushes that could easily be seen from the

ground, as smaller lighter birds may not fall to the ground (Mesure 2012). Starting locations were chosen randomly each day because I did not want predators to become used to fieldwork assistants walking the same route and causing birds to flee in the same direction each day. The field assistants searched more rigorously when bushes and other thick vegetation were present (Klem et al. 2009).

A collision was registered when a dead or injured bird was found close to a building, following the protocol of Klem (1989, 1990a, 2009b), Dunn (1993), O'Connell (2001), Klem et al. (2004), and Gelb and Delacretaz (2006). Fieldwork assistants documented on their field data collection sheet any dead birds, injured birds, or other signs of collisions. Appendix Three outlines the collision data collected. If a collision was witnessed, a note was made of the event. Dead birds were photographed and donated to the University of Calgary Vertebrates Museum.

3.3.1 Monitoring route

This study included one of the 12 campus skyscrapers (the Social Sciences Building) plus seven shorter buildings and two adjoining upper-level glass pedestrian links. The study area was observed using a walking route that was 2.25 kilometres long. The study site encompassed buildings of varying height, age, façade, vegetated area where birds visit regularly, and area with little or no vegetation where birds are rarely seen or heard. Included in the study area were three sites where collisions have been known occur, specifically the Biological Science and Social Sciences buildings as well as their adjoining upper-glass pedestrian link (Fitch W Pers. Comm. Jan 9, 2013) as well as other buildings and one pedestrian link where no collisions have previously been observed.

The research site contained similar characteristics to the Borden et al. (2010) study at Cleveland State University. The survey route at in Cleveland was 1.8 km long and encompassed an assortment of vegetation and buildings. The study area in my research also is comparable to the O'Connell (2001) and Gelb and Delacretaz (2006) survey routes where the areas were initially selected to include buildings where bird collisions previously had occurred. It is important to note, however, that although collisions may have occurred at a site historically, this does not determine whether collisions will or will not occur at a site in the future. Although the monitoring route began as defined, outlined in Figure 3.3, I acknowledged all collisions that occurred on campus throughout the research period.

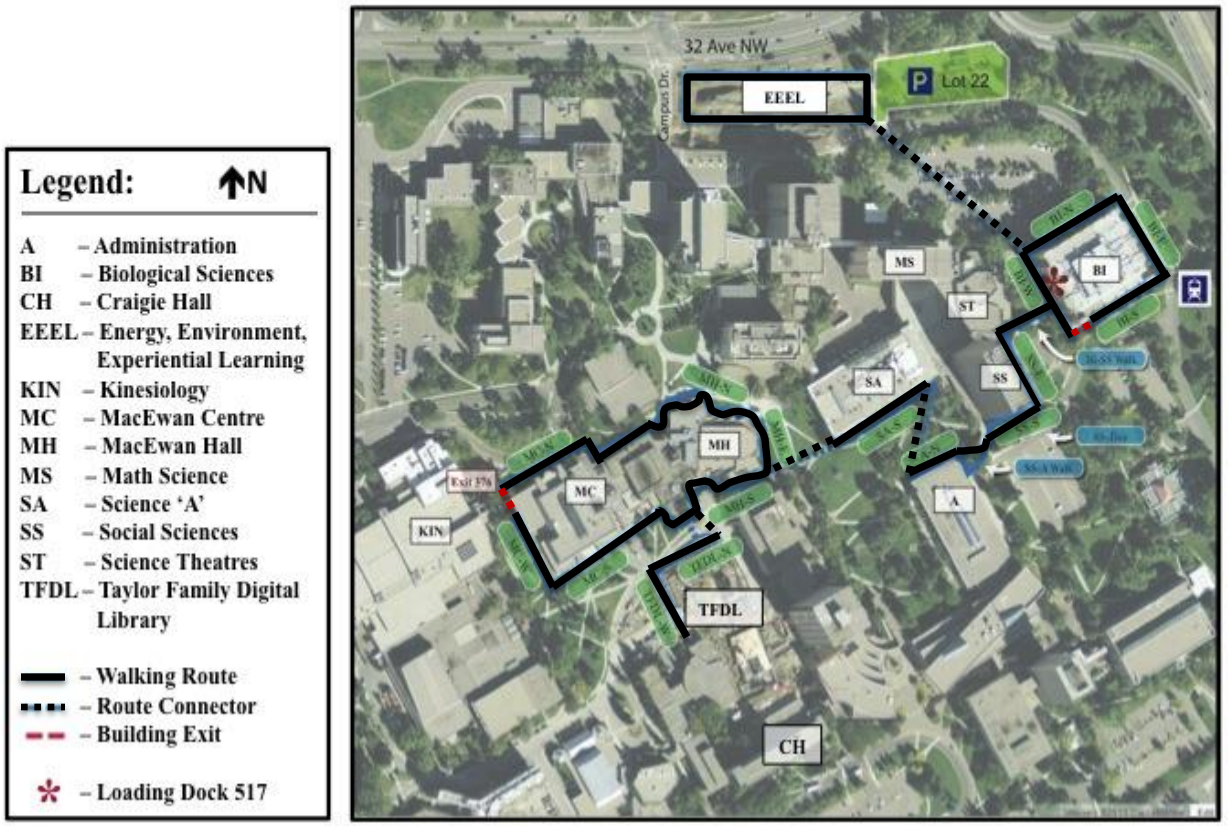


Figure 3.3 Modified 2013 Google Earth image of University of Calgary bird-building collision monitoring route

(Adapted from UCMAPS. 2013. Interactive Room Finder. Available from: http://www.ucalgary.ca/ma

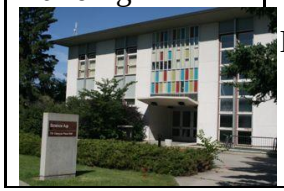
The buildings monitored were of various ages and heights and have either no LEED certification or have qualified for Gold- or Platinum-level LEED certification. Building window reflectivity and tinting varies from building to building. I assessed reflectivity by standing in front of each building window and judging how easily I could see the reflection of the surrounding environment. At the same time, I used Figure 3.4 as a reference guide to measure the tinting percentages of the building windows.

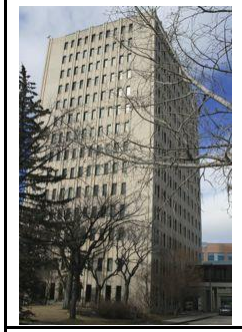
Figure 3.4 Window tinting reference guide
(Sunset Tint N Trim. 2011. Window tint example. Available from: http://www.sunsettintntrim.com/auto_tinting.php)

Ecological site conditions at the University of Calgary present varying collision risk when associated with the morphology of the buildings included in this study. The route encompassed the two oldest (Administration and Science A Building) and the two newest (Energy Environment Experiential Learning and Taylor Family Digital Library) institutional

buildings at the University of Calgary. The route also included a variety of buildings from the 1960, 1970, 1980, 2000, and 2010 eras. Incorporating buildings from an array of eras was intended to represent the variety of architectural styles on the University of Calgary campus and, perhaps, those found on other campuses in urban areas. The newer buildings tended to have a larger expanse of glass, while the older buildings tended to have more mature vegetation, such as conifers and shrubbery. The buildings with a high percentage of glass present a risk of collisions and the risk heightens when windows are reflective, tinted, and in close proximity to vegetation, other windows and areas where birds are abundant. I expected that the buildings with more vegetation and a moderate (45 to 75 percent) expanse of windows would attract more collisions than those with less vegetation and more expansive (100 percent) glass. I predicted that structures with less (30 percent) reflective glass had less overall window-covering (35 percent) and less (35 percent) tinting, would present a lower collision risk. The structures with most (100 percent) and least (20 percent) expansive glass tended to have less tinting and, I assumed, presented a lower collision risk than the buildings with a moderate (50 to 60 percent) expanse of glass. There seemed to be no relation between a higher percentage of reflectiveness with more tinting and a broader expanse of glass. Similarly, there did not appear to be a relation between glass qualities (expanse, reflectiveness, and tinting) and proximity to vegetation. Only the two newest buildings (Taylor Family Digital Library and Energy Environment Experiential Learning) were LEED certified and they both presented a seemingly low collision risk. The following table (Table 3.1) summarizes the specifications of the University of Calgary buildings monitored throughout this research and the collision risk I predicted.

Table 3.1 University of Calgary building attributes and anticipated volume of collisions

Building	Relative collision predictions	Year completed	Height (m) /Stories	LEED certification	Vegetation Type	Nearest structure	Glass		
							Expanse	Reflective	Tinting
Administration	Low	1960	10/2	None	Deciduous trees	>10m	30%	80%	15%
Energy Environment Experiential Learning	Low	2011	31/5	Platinum	Deciduous trees	>10m	40%	100%	10%
Science A Building 	Low	1960	15.3/3	None	Shrubs & trees	Attached	20%	50%	30%

Building	Relative collision predictions	Year completed	Height (m) /Stories	LEED certification	Vegetation	Nearest structure	Glass		
							Expanse	Reflective	Tinting
Taylor Family Digital Library	Low	2011	28/6	Gold	Deciduous trees	Attached	45-75%	50%	35%
Social Sciences 	Low to Moderate	1969	61/14	None	Shrubs & trees	Attached	35%	30%	35%
MacEwan Hall	Moderate	1967	10/3	None	Shrubs & trees	Attached	5-70%	80-100%	5-50%

Building	Relative collision predictions	Year completed	Height (m)	LEED certification	Vegetation	Nearest structure	Glass		
							Expanse	Reflective	Tinting
MacEwan Student Centre	Moderate to High	1987	17/4	None	Shrubs & trees	Attached	50-70%	100%	5%
Biological Sciences	High	1972	30.77 /6	None	Shrubs & trees	Attached	50%	50%	15%
Pedestrian Link 2	High	~1970	0-10 /0-2	None	Shrubs & trees	Attached	100%	75%	35%

Building	Relative collision predictions	Year completed	Height (m) /Stories	LEED certification	Vegetation	Nearest structure	Glass		
							Expanse	Reflective	Tinting
Pedestrian Link 1	High	~1970	10/2	None	Shrubs & trees	Attached	100%	75%	35%

3.3.2 Carcass removal by scavengers

The University of Calgary campus is composed of a variety of vegetated green spaces and pathways regularly used by wildlife and offers bird habitat frequented by a variety of resident, migrant, predatory, and prey birds. The high percentage of vegetation mixed with building environment attract predator and prey avian species alike, throughout Calgary's contrasting seasonal changes. Accurately estimating the extent of carcass removal can assist in more precise estimates of collisions (Morrison 2002). Vertebrate scavengers (birds of prey, cats, raccoons, squirrels, dogs, skunks, and rats) and human interferences have led to carcass removal bias in past bird-building collision research (Klem et al. 2004, Hager et al. 2012). Predators and scavengers occasionally remove dead or injured birds before researchers have a chance to observe them. If a bird hits a window and falls into nearby shrubs or bushes out of plain sight, scavengers can quickly discover its scent and carry off the carcass to a different location or consume it on site.

Scavenger removal rates have ranged considerably in past research but have been estimated at close to 13 percent of casual findings (Klem et al. 2004). Scavenger removal bias experiments were beyond the scope of this research and I did not want to invite scavengers to the University of Calgary grounds unnecessarily (to calculate scavenger removal rates), since collision victims could attract predators and scavengers and affect public safety by exposure to animals that may carry zoonosis (infectious diseases that can be transmitted from animals to humans).

3.3.3 Carcass removal by humans

Humans also can interfere with data collection by removing carcasses before a researcher has a chance to document the occurrence. This tends to occur in urban areas by groundskeepers, security staff, and passersby (Borden et al. 2010). To assist in preventing this from occurring I asked the University of Calgary grounds and security staff to alert me when a dead or injured bird was found on campus and circulated the aforementioned posters around campus. Fitch, in the Department of Biology, is usually the individual to whom students or faculty bring any dead birds and I solicited him to alert me of any specimens he received. There were more than 31,000 students and staff at the University of Calgary on campus during the time of this research, so any additional support and "eyes on the ground" that I could solicit would benefit my data collection and help reduce human removal bias.

3.3.4 Searcher efficiency

How proficient the fieldwork assistants were at finding dead or injured birds (searcher efficiency) affected the amount of collisions detected. Searcher efficiency was important to consider, as smaller birds could be more difficult to detect than larger birds and also tend to be scavenged more quickly. I tested searcher efficiency by placing ceramic birds (Figure 3.5) at random locations along the monitoring route throughout the spring and fall monitoring time periods. Young et al. (2003) placed bird carcasses using the same placement regime. To ensure the birds were returned to me, I taped a piece of paper with my name and phone number to each bird. The fieldwork assistants were unaware that searcher efficiency testing was taking place and when a bird was found the searcher was asked not to mention the find to other fieldwork assistants. In the spring, the route was monitored 57 times, and I placed a bird 14 times along the

monitoring route. In the fall, the route was monitored 122 times and I placed a bird 26 times along the route.

Figure 3.5 Ceramic birds used to assess searcher efficiency

The goal of this searcher-efficiency testing was to approximate the proportion of bird-building collisions the fieldwork assistants discovered. I planned to use this percentage to adjust for searcher-efficiency bias in the total number of collisions found.

3.4 Data analysis

As stated by Klem (2009a p 127), "this methodology provided a conservative estimate of strike frequency, as it did not account for removal of carcasses by scavengers… injured birds that died outside the search area, or post-strike movements of survivors." Assuming sufficient data is collected, a chi-square binomial goodness-of-fit test (SPSS Statistics Software 2013) will be used to evaluate the results (Klem et al. 2004; Gelb and Delacretaz 2006, 2009; Heck 2007). This test is regularly used in bird-collision analysis to measure the association of variables in two-way

tables, where the presumed independent variable is compared to the dependent (observed) variables. Klem et al. (2004) and Gelb and Delacretaz (2009) considered tests to be statistically significant when $P < 0.05$. This research will use the same significance threshold.

Chapter Four: Results and Limitations

In this chapter, I used an exploratory approach to analyze the results. I provide narrative of each collision and then examine the limitations of this study. A full quantitative statistical analysis was not possible because the results lacked adequate sample size to conduct the planned statistical procedures. As previously mentioned, a full statistical analysis was not the objective of this study. Unfortunately, also due to a lack of data, I was unable to answer the research questions with scientific robustness. Considering the limitations of my study, and taking into account many of the issues I encountered, suggesting enhancements for future studies is an important part of my (and any) exploratory research.

4.1 Results

In total, five collisions were documented at the University of Calgary campus during the study period (Figure 4.1). Collisions One, Two, and Three were found on May 4, 7, and 10 (respectively) during the birds' spring migration, between 8 a.m. and 9 a.m. at three different locations during mild, sunny, and partial cloudy weather. Collision Four was found on September 29, during fall migration, at 5 p.m., during mild partial cloudy weather. The first two collisions were discovered by fieldwork assistants during monitoring periods at two individual institutional structures along the monitoring route (MacEwan Student Centre and Pedestrian Link One); while two collisions were discovered by University of Calgary grounds staff at one institutional structure along the monitoring route (Energy Environment Experiential Learning Building), and one residential structure (Rundle Hall) which was independent of the monitoring route (see Figure 4.2). The casualties included (in chronological order) one Mallard (*Anas*

playtyrhynchos), one Dark-eyed Junco (*Junco hyemalis*), one Song Sparrow (*Melospiza melodia*), one immature Goshawk (*Accipiter gentillis*), and one Rock Dove (*Columba liva*).

Figure 4.1 2013 Google Earth image of five collision sites
in relation to the 10 monitored building structures

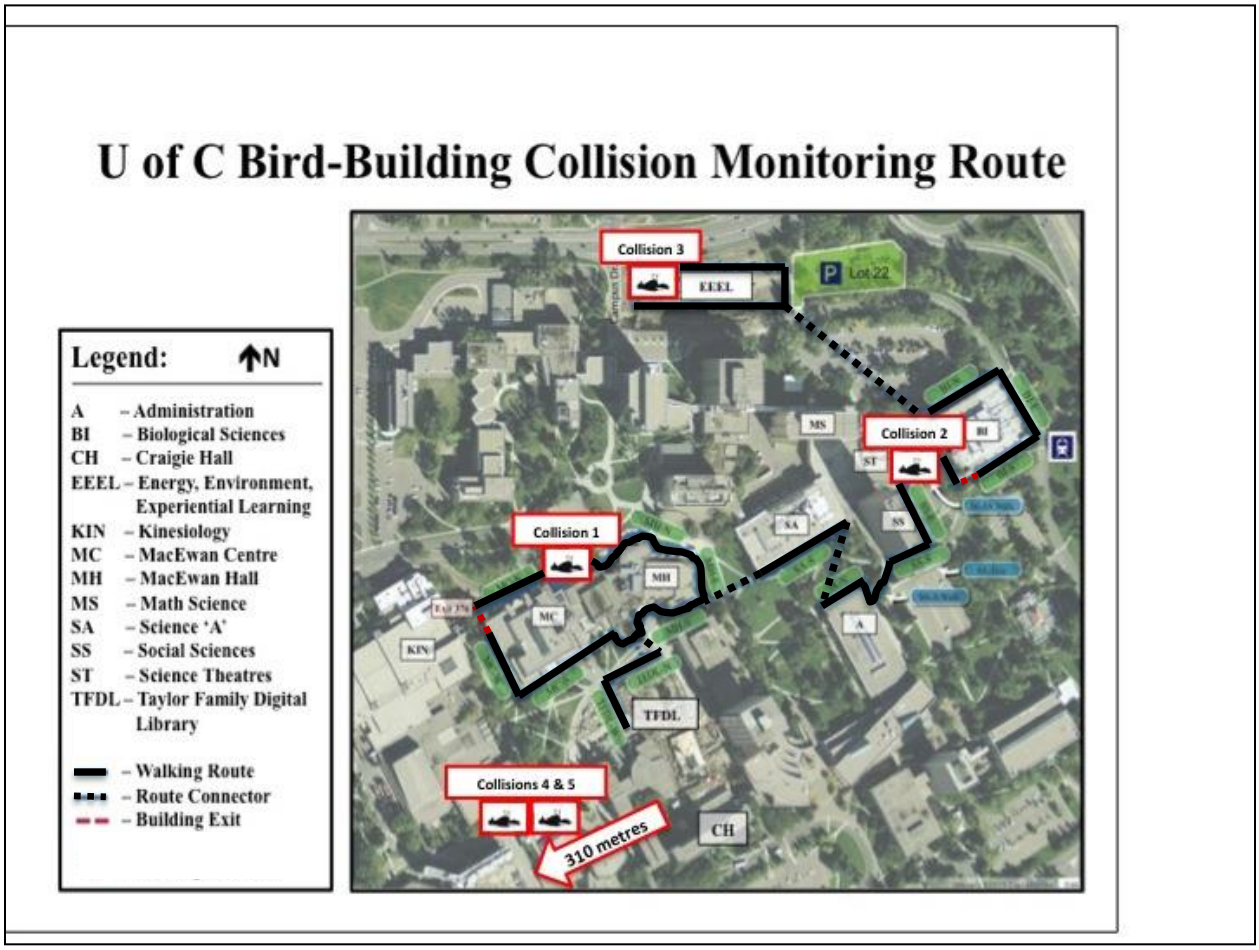


Figure 4.2 Modified 2013 Google Earth image of five collision sites
in relation to the monitoring route

4.1.1 Collision One: Mallard

In spring migration, a fieldwork assistant observed the first collision at 8:39 a.m. on May 4 at the north side of the MacEwan Student Centre. A Mallard (Figure 4.3) was sitting in a fenced-in brick courtyard; the fieldwork assistant attempted to approach the bird to ensure it was not injured. When the fieldwork assistant was within six feet of the bird, the Mallard attempted to fly away – but instead collided with a northeast-facing window of the MacEwan Student Centre. The bird hit the window approximately three feet above the ground, collided breast-first beating its wings against the glass, and flew up the window to about 10 feet above the ground.

When the bird realized it was unable to fly forward (through the glass), it landed on the ground near the spot from which it had taken off (Figure 4.4). The Mallard then rested for a few moments and flew away slowly in an easterly direction. Because the bird flew out of sight, I documented it as unharmed by the incident.

Figure 4.3 Collision One, Mallard

Figure 4.4 Collision One, Mallard post-collision in foreground of MacEwan Student Centre
(Solemn J. May 4, 2013)

4.1.2 Collision Two: Dark-eyed Junco

A fieldwork assistant discovered the second collision incident, a Dark-eyed Junco on May 7 at 9:30 a.m. during spring migration. The bird was found lying lifeless on the cement sidewalk (Figure 4.5) below the southwest side of Pedestrian Link One (Figure 4.6), which connects the Biology and Social Sciences Buildings.

Figure 4.5 Collision Two, Dark-eyed Junco post mortem

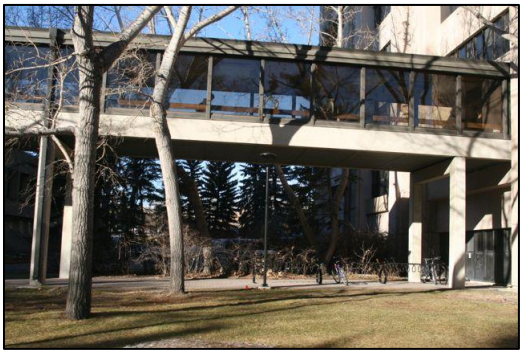


Figure 4.6 Collision Two, Pedestrian Link One

4.1.3 Collision Three: Song Sparrow

University of Calgary grounds staff discovered the third collision in spring migration on May 10 at 9 a.m. A Song Sparrow (Figure 4.7) was found at the glass bus stop attached to the northwest side of Energy Environment Experiential Learning Building (Figure 4.8). The bird was lying on the sidewalk at the base of the bus stop glass and was dead when found. I suspect it collided with the glass on the bus stop. From ground level, the bus stop extends to 4.5 metres.

Figure 4.7 Collision Three, Song Sparrow post mortem

Figure 4.8 Collision Site Three, bus stop at the Energy Environment Experiential Learning Building

4.1.4 Collision Four: Goshawk and Rock Dove

During fall migration, on September 29, a University of Calgary grounds staff member discovered one immature Goshawk and one Rock Dove laying side-by-side on the sidewalk (Figure 4.9) at the east side of Rundle Hall (Figure 4.10), a university student resident building located on the east side of campus. A grease smear also was present on the second-storey window directly above where the birds lay. I suspected the collisions occurred within seconds of one another, that the Goshawk chased the Rock Dove into the window and then also collided with the glass, so I regarded this as a single incident. This is not an unusual occurrence; however, this circumstance has not previously been documented at the University of Calgary campus grounds (DeCandido 2005).

Figure 4.9 Collisions Four and Five, Goshawk (below) and Rock Dove (above)

Figure 4.10 Collision Site Four, front entrance at Rundle Hall

4.1.5 Summary of collisions

The results of this study indicate that bird-building collisions do not appear to occur frequently at the University of Calgary campus during migration periods. They also revealed that birds that have been involved in collisions on campus are a Mallard, Dark-eyed Junco, Song Sparrow, Rock Dove, and Goshawk (and anecdotally a Peregrine Falcon) with the most common order of victims being Passeriformes (the Dark-eyed Junco and Song Sparrow). Collision One did not result in injury or death, while Collisions Two though Four were fatal. Birds do hit a variety of structures, such as institutional and residential buildings as well as upper-level glass pedestrian links and a bus stop attached to an institutional building. These results also showed that collisions occur at the university during mild weather through spring and fall migration. The following table is a summary of the five collisions that occurred throughout spring and fall migration 2013.

Table 4.1 Summary of collision results

Collision	Date (Mo /day time)	Species	Result	Location	Structure type	Weather	Discoverer
1	05/04 08:00	Mallard	Alive, uninjured	MacEwan Student Centre	Institutional building	Mild, sunny	Fieldwork assistant
2	05/07 09:30	Dark-eyed Junco	Dead	Pedestrian Link One	Link attached to institutional building	Mild, sunny	Fieldwork assistant
3	05/10 09:00	Song Sparrow	Dead	Energy Environment Experiential Learning	Bus stop attached to institutional building	Mild, part. sun /cloud	U of C staff
4	09/29 17:00	Goshawk & Rock Dove	Dead	Rundle Hall	Residential building	Mild, part. sun /cloud	U of C staff

4.2 Limitations of the study

I encountered a number of issues while conducting this research that very likely restricted the ability to accurately estimate the number of collisions. By exploring these limitations, any future confirmatory research might be able to more closely estimate the number of birds colliding with buildings on the University of Calgary campus. Future research may also identify any high collision areas to be considered for mitigation strategies.

4.2.1 Carcass removal on campus

Carcass removal by humans was expected to be low, as the University of Calgary grounds and security staff was extremely co-operative and contributed significantly to the collection of data. It also is unlikely that the general public would move dead birds, partly because many people would worry about zoonosis, and partly because my posters — that

remained posted during both spring and fall migration — would have alerted campus users to my research. However, this limitation cannot be entirely eliminated.

Carcass removal by scavengers and predators tends to be a significant limitation in similar studies (Dunn 1993, O'Connell 2001, Klem et al. 2004, Gelb and Delacretaz 2009) and on the University of Calgary campus I expected removal rates to be high. While consistent data was not collected, newly scavenged bird carcasses were discovered along the monitoring route approximately every few days. Observable predators (hawks, falcons) and scavengers (gulls, magpies) at the University of Calgary primarily consist of avian predators, however less obvious scavengers most likely include mammals and rodents such as coyotes, raccoons, foxes, house cats, and mice, among others. Past research has found that predators and scavengers tend to remove carcasses more frequently at buildings with more dense and mature vegetation, while avoiding high traffic areas (Prange and Gehrt 2004, Santos et al. 2011).

The structures that likely would have the highest carcass removal rates due to dense mature vegetation are Biological Sciences, Social Sciences, Pedestrian Links One and Two, Administration, and MacEwan Student Centre. The structures that could possibly have the least carcass removal rates are Energy Environment Experiential Learning and Taylor Family Digital Library. It is interesting to note that intact non-scavenged bird carcasses (collision victims) were found at structures in high pedestrian and vehicle traffic areas such as Energy Environment Experiential Learning and in lower traffic areas with dense mature vegetation, such as Biological Sciences.

I believe predation and scavengers may have been an important factor in my data collection for this study. While I did not have the foresight to regularly collect predation and scavenger data to confirm this suspicion, regular sightings of scavenged bird carcasses along the monitoring route suggest that birds are a main food source for predators and scavengers in the area. In hindsight, it would have been useful to collect all bird carcass parts found along the monitoring route. This would have helped gain a better understanding of the extent of scavenger and predator carcass removal. Past research has accounted for this bias by increasing the monitoring time periods per day and conducting a rigorous study over three days (Gelb and Delacretaz 2006).

4.2.2 Searcher efficiency

I calculated the total searcher efficiency rate of 60 percent for the current study from nine clay bird findings out of 14 placements (67 percent) in the spring and 15 findings out of 26 placements (58 percent) in the fall, totalling 24 findings out of 40 (Table 4.2). This is comparable to Young et al. (2003) where searcher efficiency rates totalled 64 percent for small birds – 61 percent in the spring and 68 percent in the fall. I did not collect data on medium and large-sized bird searcher efficiency rate data due to financial constraints and lack of resources to find medium- and large-sized imitation birds. I did not account for finds where searchers may have found a clay bird but left the find untouched.

Table 4.2 Searcher efficiency rates compared to historical research

	Spring	Fall	Total
Current study	9/14* (64%)	15/26 (58%)	24/40 (60%)
Young et al. (2003)	20/33 (61%)	15/22 (68%)	35/55 (64%)
			*(# discovered / #placed)

It is apparent that happenstance discovery can play an integral part in collecting bird collision data, as the University of Calgary grounds staff discovered three of the five dead birds on campus. As monitoring cannot occur during all hours of the day and night at all buildings, perhaps this group could be included in the monitoring and data-collection training program prior to the commencement of data collection to ensure, if they find a dead bird, they follow the same protocol as the fieldwork volunteers.

4.2.3 Study length and seasonality

While some research has found higher collision numbers throughout migration times, past research at Cleveland State University (which was conducted over a full year, albeit in a different geographical location), found collisions can occur during 11 months of the year (Borden et al. 2010). Other scientists have successfully collected statistically significant data during one-year studies at shorter buildings, such as residences and a suburban office park (Klem 1989, O'Connell 2001). More accurate results may have been collected during the current research if the study length had spanned over a full 12 months and not solely during the bird's migratory periods.

In 2013, Calgary experienced more rainfall than usual and lower overall temperatures than in past recent years, lessening bird-habitat availability. As mentioned earlier in this chapter, the drastic flooding in June 2013 may have stressed wildlife and could have affected overall bird subsistence throughout the city. I assumed this may have reduced bird-building collision events at the University of Calgary during the research time period. June 2013 was a notably wet month during which extreme rain conditions emerged on Alberta's snow-covered watershed and in Calgary itself, as rivers overflowed, trees and bridges were wiped out, and homes were completely destroyed. The implication of this flood on bird habitat is

difficult to estimate. Inglewood Bird Sanctuary was heavily hit and experienced damage to pedestrian walkways and bridges. Chris Manderson, Natural Area Management Lead of Calgary Parks, stated some animals at Inglewood Bird Sanctuary were stressed during and following the flood (Inglewood Bird Sanctuary trails still closed by flood debris [video on the internet]). As the University of Calgary and Inglewood Bird Sanctuary share bird populations, it is reasonable to assume that wildlife at the University of Calgary might have been stressed and less abundant during summer and possibly into fall, 2013. Spring bird abundance; however, may not have been affected by the June flooding event.

4.2.4 Nocturnal collisions

The literature does not support an assumption that the University of Calgary's infrastructure and night time lighting might be a danger area for nocturnal collisions, so nocturnal collisions were not investigated in this study. However, future research might explore this issue. Past studies have shown that an intense study that monitors an area every two-to-three hours over three days may better indicate high collision times of day than more lengthy studies that monitor once or less than once per day (Gelb and Delacretaz 2006).

4.2.5 A second, shorter, more intensive study

A further limitation was the absence of a second, shorter, more intensive study. In previous studies, researchers have incorporated a short-termed concentrated study that divided monitoring into a number of time periods (four or more) throughout the day (Klem 1989, Gelb and Delacretaz 2006). Gelb and Delacreataz (2006) conducted a three-day study in Manhattan to better determine if strikes occurred during the day or night and found a "statistically significant disparity" in the data collected compared to the year-long study that "periodically" monitored the study area. Incorporating one or more short-term studies into a

year-long study that involves monitoring multiple times throughout the day and night can assist in more accurately understanding when and where strikes occur, as well as better account for carcass removal. An intensive study improves the probability of observing strike occurrences and carcass removal by scavengers and predators. This data might then be considered when analyzing the full dataset collected over the year-long study.

Chapter Five: Additions to LEED Pilot Credit 55

5.1 LEED Pilot Credit 55

As discussed in Chapter Two, birds collide with buildings during the day. While the current study did not yield enough data to recommend a customized mitigation strategy for the University of Calgary, past research shows that it is important to reduce day-time collisions with buildings. One approach is to investigate buildings and design. University campuses, including the University of Calgary, are currently making an effort to construct green buildings in order to be economically and ecologically accountable through Leadership in Energy and Environmental Design (LEED) design[3]. LEED has responded to some of the issues regarding bird collisions through Pilot Credit 55 (PC 55), which addresses bird collision deterrence.

PC 55, created in 2009, is intended to "Reduce bird injury and mortality from in-flight collisions with buildings" (LEEDuser 2013b). The pilot credit focuses on building design, including glass material and expanse of glass as well as night-time lighting (LEEDuser 2013a). These components are designed to address glass reflectivity, which addresses diurnal collisions, and evening light pollution, which addresses nocturnal collisions. For PC 55 to function best as both a nocturnal and diurnal collision risk analysis and deterrent strategy, I recommend that three other equally important diurnal collision-threat factors be integrated into the assessment process for attaining PC 55 certification. They are: Glass type, window morphology, and bird habitat in close proximity to a building.

[3] LEED is the standard for green building design recognized in Canada and the United States. Since its inception in 1998, architects, building owners, and operators have increasingly used LEED as a framework to identify and incorporate measurable green building technologies and solutions.

These additions more thoroughly address collisions caused by reflections, the abundance of birds in proximity to a building, and other collision threat factors such as predators, loud noises, and sudden movements. While PC 55 currently does a good job of addressing nocturnal collisions, through additions of the elements I propose, PC 55 could become more suited to address diurnal collisions.

In this chapter, I recommend additions to PC 55 Requirement One, the Bird Collision Threat Rating (BCTR) guide and to the BCTR formulas, I do not recommend amendments to Requirements Two through Four. The existing PC 55 Requirement One calculations and details on Requirements Two through Four are provided by the U.S. Green Building Council (USGBC 2011).

5.2 Additions to Pilot Credit 55

Pilot Credit 55 identifies building-design material as well as internal and external lighting as contributors to bird collisions with buildings. PC 55 does not recognize three other significant collision-threat factors, they are: (1) glass type, (2) window morphology, and (3) bird habitat in close proximity to the building. As built structures and bird habitat are not materials, I named them site attribute threat factors, and noted that each attribute has several subcategories. In this section I suggest how the new material threat factor (glass type) and the two new site attribute threat factors (window morphology and bird habitat) might be included in PC 55.

PC 55 could also include window angling, a fourth noteworthy collision threat factor that is missing from PC 55. However, I did not include this threat factor because: (a) angled windows are less threat to birds than windows at 90 degrees, (b) angled windows are less

commonly used in built structures, and (c) aside from structural changes, the solutions are no different than for 90-degree windows. Structural changes are not simple or cost-effective solutions to bird collisions with buildings and solutions that are simple and cost will be more widely accepted and implemented by building owners and operators.

To incorporate the three previously identified collision risk factors into PC 55, I look at other pilot credits in order to employ shared procedural elements. The best fit with PC 55 is Pilot Credit 45 (PC 45), which addresses site assessment. The foundation of PC 45 is environmental preservation (flora, fauna, soil and water) incorporated with human elements (air pollution, security, and aesthetics, among others). As determining eligibility for PC 45 is subjective[4] and does not focus on birds, I did not investigate this option further.

The most practical solution to incorporate the three additions into PC 55 is to:

1. Add glass type to the existing BCTR formula and calculate the *revised BCTR*.
2. Create the window morphology threat rating formula and determine the *WMTR*.
3. Create the bird habitat threat rating formula and determine the *BHTR*.
4. Add WMTR and BHTR to the revised BCTR to determine the *new total BCTR*.

I assumed that glass type, window morphology, and bird habitat were threat factors that could be calculated in a manner similar to the existing BCTR formula. Following a similar outline to the original BCTR steps, I altered the original Steps A through C (from USGBC 2011) as follows:

Step A: Revised Material Threat Factor (MTF) and Site Attribute Threat Factors (WMTF, BHTF) – Identify glass types and site attributes that may exist on or near most

[4] In order to be considered for PC 45, applicants are asked to submit maps and aerial photos.

buildings, add these to the Summary of Material Threat Factors Rating Guide, and assign threat factor ratings. Determine acceptable ranges for the revised MTF, WMTF, and BHTF. If any threat factor exceeds 15 then Step B is mandatory.

Step B: Threat Factor Percentage (TF%) – Calculate square footage of material and site attributes of zone one. Then determine the percentage of the revised MTF, WMTF, and BHTF on the façade zone of the building. If more than 15 percent of the façade has a total of 75, then Step C is mandatory.

Step C:

1. Revised Bird Collision Threat Rating (BCTR) – Create new formula based on the original BCTR that includes glass type and calculate the revised BCTR. If the total exceeds 25, then Requirements Two through Four are mandatory.
2. Window Morphology Threat Rating (WMTR) – Create new formula and calculate the WMTR. If the total exceeds 15, then Requirements Two through Four are mandatory.
3. Bird Habitat Threat Rating (BHTR) – Create new formula and calculate the BHTR. If the total exceeds 15, then Requirements Two through Four are mandatory.

Table 5.1 illustrates the acceptable ranges for calculating Steps A through C in determining the revised BCTR, WMTR, and BHTR.

Table 5.1 Acceptable ranges for MTF, TF%, and revised threat ratings

	Step A Material Threat Factor (MTF)	Step B Threat Factor Percentage (TF%)	Step C Revised BCTR, WMTR, BHTR
Acceptable Ranges:	Each material may have an MTF rating of 15 or less. WMTF and BHTF site attributes may have a rating of 15 or less.	15% or less of zone one may have MTF, WMTF, and BHTF ratings of 75 or less.	Revised BCTR may total 25 or less. WMTR and BHTR may total 15 or less.

Table 5.2 shows the calculations (in Step C) that I used to ultimately establish the new total BCTR. I analyze these calculations and the preceding Steps A through C in more detail in this section, again using the EEEL building as an example.

Table 5.2 New Bird Collision Threat Rating (BCTR) calculation

Zone one:	(Material threat factor incl. glass type)	x	(Material type area)	/	Total area	=	Zone one BCTR
Zone two:	(Material threat factor incl. glass type)	x	(Material type area)	/	Total area	=	Zone two BCTR
BCTR:	((Zone one BCTR) x 2)	+	(Zone two BCTR)	/	3	=	Revised BCTR
Zone one:	(Window morphology threat factor	x	(Window morphology area)	/	Total zone one glass area	=	Zone one WMTR
Zone two:	(Window morphology threat factor)	x	(Window morphology area)	/	Total zone two glass area	=	Zone two WMTR
WMTR:	((Zone one WMTR) x 2)	+	(Zone two WMTR)	/	3	=	Total WMTR
Zone one:	(Bird habitat threat factor	x	(Bird habitat area)	/	Total zone one glass area	=	Zone one BHTR
Zone two:	(Bird habitat threat factor)	x	(Bird habitat area)	/	Total zone two glass area	=	Zone two BHTR
BHTR:	((Zone one BHTR) x 2)	+	(Zone two BHTR)	/	3	=	Total BHTR
New BCTR:	Total BCTR + Total WMTR + Total BHTR			/	3	=	New total BCTR

5.2.1 Addition of glass type to the existing BCTR formula

Step A: Material Threat Factor for Revised BCTR

I began by creating subcategories for glass type and, based on the literature, determined the threat each subcategory might pose to birds. From these data, I created Table 5.3: Glass Type Material Threat Factors Rating Guide. As glass-tinting and reflectivity contribute to the existing threat of clear-glass façade material, these ratings were added directly to the original clear-glass rating of 100. The large expanse (41.6 percent) of glass on EEEL rated above 15, so I proceeded to Step B.

Table 5.3 Glass type material threat factors rating guide

Material Type / Site Attribute	Threat Factor
Glass Tinting and Reflectivity	
Glass tinting 5-25%	50
Glass tinting 26-50%	25
Glass tinting 51-75%	15
Glass tinting 76-100%	25
Glass reflectivity 5-25%	15
Glass reflectivity 26-50%	20
Glass reflectivity 51-75%	35
Glass reflectivity 76-100%	50

Step B: Threat Factor Percentage (TF%)

The criteria for determining the new Threat Factor Percentage (TF%) remains unchanged from the original BCTR, where no more than 15 percent of any material may have a threat factor above 75. I added glass-type threat factors (tinting and reflectivity) to the original material type threat factor (glass) to reflect the revised threat factor of 185; I already

had determined that glass material comprised 41.6 percent of zone one. As EEEL rated far higher than the acceptable ranges, I proceeded to Step C.

Step C: Revised Bird Collision Threat Rating (revised BCTR)

To calculate the revised BCTR (that included glass-type threat factors), I first calculated glass material on façades one and two for EEEL. The imperial values I noted and calculated are included in Table 5.4.

Table 5.4 Revised bird collision material threat ratings and façade (glass) areas for EEEL

	Zone one			Zone two		
Material:	Glass	Tinting	Reflectivity	Glass	Tinting	Reflectivity
Threat factor rating:	100	50	35	100	50	35
Material (glass) area (sq ft):	741.11			530.39		
Total façade (glass) area (sq ft):	1566.15					

I then created the revised BCTR formula and used the values from Table 7.4 to calculate the new total.

<u>Revised BCTR threat factor</u>

Formula:
Material type one threat factor (100)
+ Glass tinting threat factor (50)
+ Glass reflectivity threat factor (35)
= Total material type one threat factor

Calculation:
100 + 50 + 35 = 185

Revised BCTR calculations for zone one

Formula:

[((Material type one threat factor) x (Material type area))
+ ((Material type two threat factor) x (Material type area))…]
/ [Total façade zone area]
= Façade zone one BCTR

Calculation:

[(185 x 741.11 sq ft) → glass
+ (0 x 613.25 sq ft) → aluminum
+ (0 x 427.22 sq ft)] → other material
/ [1781.58 sq ft]
= 76.96 Façade zone one BCTR

Revised BCTR calculations for zone two

Formula:

[((Material type one threat Factor) x (Material type area))
+ ((Material type two threat Factor) x (Material type area))…]
/ [Total façade zone area]
= Façade zone two BCTR

Calculation:

[(185 x 530.39 sq ft) → glass
+ (0 x 510 sq ft) → aluminum
+ (0 x 525.76 sq ft)] → other material
/ [1566.15 sq ft]
= 62.65 Façade zone two BCTR

Total revised BCTR

Formula:

[((Zone one BCTR) x 2) + (Zone two BCTR)] / 3
= Total building BCTR

Calculation:

[(76.96 x 2) + 62.65] / 3
= 72.19 Total façade BCTR

I totalled the revised BCTR for EEEL to be 72.19 – this number later was calculated with WMTR and BHTR to determine the new total BCTR and then was compared to the new total BCTR acceptable range.

5.2.2 New window morphology threat factor formula

Step A: Window Morphology Threat Factor (WMTF)

I first created subcategories for window morphology and assigned threat factors in Table 5.5. Glass corridors and walkways include windows on two opposite sides of a wall that can be easily seen through. The closer a glass corridor or walkway is to a building with windows, the higher the collision threat for a bird. I rated the distances of these subcategories (attached, less than three metres, three to five metres) as 100, 80, and 50, respectively, as glass corridors and walkways tend to have very high glass content and could confuse birds trying to exit an area. Following the PC 55 Material Threat Factor Rating Guide, I created this threat factor table based on the percentage of glass on a building or an adjacent walkway. The more windows in closer proximity to a building and an increase the percentage of glass where a bird flight path could be disrupted, the higher the threat factor.

Table 5.5 Additions to the PC 55 – summary of material threat factors rating guide

Window Morphology	*Threat Factor*
Glass corridor/walkway (windows on two opposite sides of a wall) – attached	100
Glass corridor/walkway <3 metres from building	80
Glass corridor/walkway 3-5 metres from building	50
Angular glass corner (windows on two sides of a corner) – attached	90
Angular glass corner <3 metres from a building	60
Rounded glass (corner, skylight, etc.) – attached	60
Rounded glass <3 metres from a building	40

Angular glass corners consist of windows on two sides of a corner, such as glass atriums and lobbies. I rated the threat factors of these subcategories as higher (90) when

attached to the building and lower (60) when this structure was more than three metres from a building. I assumed that the threat factor of glass corners further than three metres from the building would significantly decrease and so further distances were not included. Angular glass corners tend to been seen through more easily than rounded corners, so I rated these features at higher threat factors than rounded corners; since rounded glass, such as on a rounded corner or skylight, pose lower threats to birds than those on an angular corner, I rate these 60 and 40 respectively.

Step B: Window Morphology Threat Factor Percentage (WMTF%)

To determine the Window Morphology Threat Factor Percentage (WMTF%), I used the same criteria as TF%, where no more than 15 percent of zone one can have a threat factor above 75. I determined that the only window morphology feature that exists on EEEL is a glass bus stop located on the northwest side of the building. It is composed of large sheets of glass and an opaque roof that is attached to the first floor of the building (Figure 5.1). This area of EEEL also is comprised of sheet glass (Figure 5.2). The bus stop and EEEL together form a see-through glass corridor, and I rated this window morphology threat factor at 100.

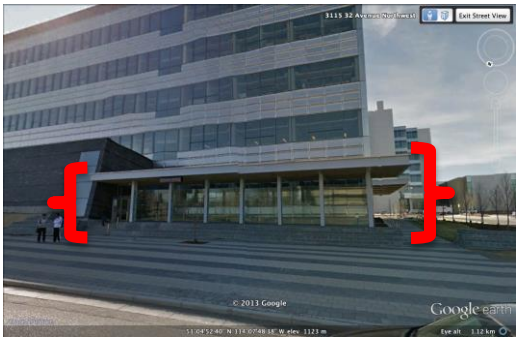


Figure 5.1 Glass bus stop at northwest side of EEEL

Figure 5.2 Glass corridor formed by EEEL and northwest bus stop

To calculate the square footage of the glass corridor at EEEL, I used building plans to measure the north wall of the corridor (glass on the bus stop) and the south wall of the corridor (glass on EEEL). In determining the total square footage of glass, I subtracted the south corridor glass area from the total sheet glass area in façade zone one of EEEL, as I did not want to count the south corridor glass twice. I divided the area of the glass corridor by the area of glass in zone one, to establish that 9.31 percent of the surface area in zone one had a threat rating above 75.

<u>WMTR calculations for glass corridor</u>
Formula:
North wall of glass corridor (glass on the bus stop)
+ South wall of glass corridor (glass on EEEL)
= Total area of glass corridor

Calculation:
10.05 m^2 + 10.05 m^2 = 20.10 m^2

Conversion to imperial:
10.05 m^2 x 3.281 = 32.97 sq ft
32.97 sq ft + 32.97 sq ft = 65.94 sq ft of glass corridor

<u>WMTR calculations for zone one of EEEL</u>

Formula:
Façade zone one glass area
– South wall of glass corridor (glass on EEEL)
= Total façade zone one glass area

Calculation:
741.11 sq ft – 32.97 sq ft = 708.14 sq ft

<u>WMTF% calculations</u>

Formula:
Area of glass corridor / Area of glass in zone one = WMTF%

Calculation:
65.94 / 708.14 = 9.31%

At this point Step C is not mandatory; however, I chose to calculate the total WMTR to illustrate how the WMTR should be determined.

Step C: Window Morphology Threat Rating (WMTR)

To calculate the WMTR, I:

1. Noted all WMTR features, their threat factor ratings, and areas in Table 5.6.
2. Created the WMTR formula and calculated the total WMTR, using the glass corridor on EEEL.

I created Table 5.6 to note all window morphology features in zones one and two as well as the corresponding threat factors, square footage, and total glass area in each zone.

Table 5.6 Window morphology threat ratings and façade (glass) areas for EEEL

	Zone one	Zone two
WMTR features:	Glass corridor	No WMTR features
Threat factor ratings:	100	0
Feature area (sq ft):	65.95	0
Total façade (glass) area (sq ft)	741.11	530.39

I then used the values in Table 5.6 to calculate the WMTR of EEEL, using 708.14 square feet as I had previously subtracted the area of the glass corridor. My calculations are below.

WMTR calculations for zone one

Formula:
[((Site attribute one threat factor) x (Site attribute one area))
+ ((Site attribute two threat Factor) x (Site attribute two area))…]
/ [Total sheet glass area in façade zone one]
= Façade zone one WMTR

Calculation:
[(100 x 65.94 sq ft) / [708.14 sq ft] = 9.31 Total WMTR

No vegetation extended into zone two and this is reflected in the final WMTR calculations.
WMTR calculations for zone two

Formula:
[((Site attribute one threat factor) x (Site attribute one area))
+ ((Site attribute one threat Factor) x (Site attribute two area))…]
/ [Total sheet glass area in façade zone one]
= Façade zone one WMTR

Calculation:
[(0 x 0 sq ft) / [530.39 sq ft] = 0 Total WMTR

Total WMTR

Formula:
[((Zone one WMTR) x 2) + (Zone two WMTR)] / 3 = Total WMTR

Calculation:
[(18.62 x 2) + 0] / 3
= 6.21 Total WMTR

5.2.3 New bird habitat threat rating formula

Bird habitat may include trees, shrubs, bird feeders, and any other natural features within 20 metres located with an unobstructed view of the building of interest. To calculate the BPBH threat factor, I worked through the two following steps:

Step A: Bird Habitat Threat Factor (BHTF)

I divided bird habitat into three heights (<1 metre, 1 to 5 metres, and >5 metres), and three distances (<1 metre, 1-10 metres, and 10-20 metres). Based on findings from Klem's (1989) scientific experiments I assigned threat factor ratings to each subcategory and included these in Table 5.7. Bird habitat proximate to EEEL comprises all heights and distances found in this table excluding bird habitat greater than five metres in height.

Table 5.7 Additions to the PC 55 – summary of material threat factors rating guide

Building Proximity to Bird Habitat *(Examples: Natural forests, grasslands, wetlands, parks, landfills, planted trees, bird feeders)*	*Threat Factor*
Bird habitat <1 metre in height and <1 metre distance from building	10
Bird habitat <1 metre in height and 1-10 metres distance from building	80
Bird habitat <1 metre in height and 10-20 metres distance from building	10
Bird habitat 1-5 metres in height and <1 metre distance from building	10
Bird habitat 1-5 metres in height and 1-10 metres distance from building	100
Bird habitat 1-5 metres in height and 10-20 metres distance from building	50
Bird habitat >5 metres in height and <1 metre distance from building	50
Bird habitat >5 metres in height 1-10 metres distance from building	80
Bird habitat >5 metres in height 10-20 metres distance from building	75

Step B: Bird Habitat Threat Factor Percentage (BHTF%)

The criteria for establishing BHTF% is also similar to TF%, where no more than 15 percent of zone one may have a threat factor above 75. Bird habitat proximate (within 20 metres) to EEEL includes deciduous trees, conifer trees, and shrubs. No bird feeders or other habitat features are within 20 metres of the building.

To calculate vegetation density surrounding EEEL, I used Impulse XL, a measurement tool with laser technology software, to measure the distance of the nearby vegetation. I documented the distance of the nearest shrubs and tree branches surrounding EEEL on the all sides by standing beside or directly underneath the closest branch and measuring to the nearest exterior wall of EEEL.

I measured height and width of vegetation by using silhouettes of the vegetation on the façade area of the building. To do this, I stood in front of and beside each patch of vegetation and sketched any vegetation that was 20 metres-or-less in distance away on to the building plans for

EEEL, creating a two-dimensional diagram that was as close to true height and width as I could determine. EEEL is faced with aluminum tiles of equal measurements and, similarly, glass windows of equal measurements, which allowed me to count the vegetation density to an accurate measure. For any vegetation that is located on the building corner (directly between two sides) I stood at a 90-degree angle from the building and sketched the vegetation on the building sides it overlapped. I calculated the most reasonable estimate of vegetation density that I could, within the time and financial limitations of this study. Ideal conditions would be to hire a survey specialist to calculate exact measurements.

I then used the map scale on the building plans to calculate the vegetation heights. If any trees had been taller than zone one, I would have distinguished between vegetation density in zones one and two. As no vegetation density extended past zone one, I grouped all vegetation on each side of EEEL together by the different height and distance categories (from Table 5.7). I show my metric measurements in Table 5.8 as well as the conversion to square feet, which is needed to total the BHTF%.

Table 5.8 Vegetation surrounding EEEL (m^2/sq ft)

Height	Distance		
	< 1 metre	*1 – 10 metres*	*10 – 20 metres*
<1 metre	14.15 / 46.43	1.36 / 4.46	.58 / 1.91
1 – 5 metres	29.79 / 97.74	6.86 / 22.51	2.8 / 9.19
>5 metres	0 / 0	0 / 0	0 / 0

I used Table 5.7 to determine which height and distance combinations were above 75 (the threat factor limit). The two combinations that were above 75 were: vegetation at <1 metre high and 1-10 metres in distance (with a threat factor of 80), and vegetation at 1-5 metres high and 1-10 metres in distance (with a threat factor of 100). I added the square footage of each and divided the area of the bird habitat features that had a threat rating over 75 (26.97 square feet) by the area of glass in zone one (741.11 square feet) to establish that 3.64 percent of the surface area in zone one has a threat rating above 75. As 3.64 percent is below the 15 percent maximum, Step C is not mandatory; however, I proceeded to Step C to illustrate how I recommend calculating the total BCTR. My calculations are as follows:

Formula:
[(Bird habitat type area one) + (Bird habitat type area two)…] = Total bird habitat above 75

Calculation:
4.46 sq ft + 22.51 sq ft = 26.97 sq ft

Formula:
(Total bird habitat above 75) / (Total zone-one glass) = BHTF%

Calculation:
26.97 sq ft / 741.11 sq ft = 3.64%

Step C: Bird Habitat Threat Rating (BHTR)

I used EEEL as an example to show how to determine the BHTR through the following steps:

1. Calculate total vegetation density of bird habitat surrounding EEEL.
2. Create the BPBH threat factor formula and calculate the total BPBH threat factor for EEEL.

Table 5.9 is an amalgamation of the imperial measurements from Table 5.8 and threat factors from Table 5.7 and portrays the height and distance calculations necessary for calculating the BHTR. I created the BCTR formula and used the values in Table 5.9 to calculate the total BHTR for zone one.

Table 5.9 Vegetation surrounding EEEL (sq ft → threat factor)

Height	Distance		
	< 1 metre	*1 – 10 metres*	*10 – 20 metres*
<1 metre	46.43 → 10	4.46 → 80	1.91 → 10
1 – 5 metres	97.74 → 10	22.51 → 100	9.19 → 50
>5 metres	0 → 50	0 → 80	0 → 75

BHTR calculations for zone one:

Formula:
[((Site attribute one threat factor) x (Site attribute one area))
+ ((Site attribute two threat factor) x (Site attribute two area))…]
/ [Total sheet glass area in façade zone one]
= Façade zone one BHTR

Calculation:
[(10 x 46.43 sq ft)
+ (80 x 4.46 sq ft)
+ (10 x 1.91 sq ft)
+ (10 x 97.74 sq ft)
+ (100 x 22.51 sq ft)
+ (50 x 9.19 sq ft)]
/ [741.11 sq ft]
= 6.11 Total BHTR

No vegetation extended into zone two and this is reflected in the final BHTR calculations.

BHTR calculations for zone two

Formula:
[((Site attribute one threat factor) x (Site attribute one area))
+ ((Site attribute two threat factor) x (Site attribute two area))…]
/ [Total sheet glass area in façade zone one]
= Façade zone one BHTR

Calculation:
[(0 x 0 sq ft)] / [530.30 sq ft]
= 0 Total BHTR

Total BHTR Formula:
[((zone one BHTR) x 2) + (zone two BHTR)] / 3 = Total BHTR

Calculation:
[((6.11) x 2) + (0)] / 3 = 4.07 Total BHTR

5.2.4 The new Pilot Credit 55 formula

I then created the new total BCTR formula and integrated the revised BCTR, WMTR, and BHTR values into this formula to determine the new BCTR. The formula and calculations are as follows:

New Total BHTR

Formula:
[(Revised BCTR) + (WMTR) + ((BHTR) x 2)] / 3 = Total new BCTR

Calculation:
[(72.19) + (6.21) + ((4.07) x 2)] / 3 = 28.85 Total new BCTR

I compared the EEEL building to the acceptable ranges for the new BCTR in Table 5.10. The building rated above the acceptable ranges on Steps A through C. With the new total BCTR for the University of Calgary EEEL building totalling 28.85, higher than the acceptable range of 25, it is apparent that this structure is a risk for bird-building collisions. I discuss this further in the subsequent section.

Table 5.10 Acceptable ranges and EEEL calculations for the new total BCTR

	Step A	Step B	Step C
	Material Threat Factor (MTF) Window Morphology Threat Factor (WMTF) Bird Habitat Threat Factor (BHTF)	Threat factor percentage (TF%)	New total BCTR
Acceptable Ranges:	The new MTF must have a threat factor rating of 25 or less. WMTF and BHTF must have a threat factor rating of 15 or less.	15% or less of zone one must have a TF% of 75 or less.	New total BCTR must total 25 or less.
Ratings for EEEL:	Highest threat factor was MTF, which totalled 185.	Highest TF% was 41.6%.	New total BCTR totalled 28.85.

Threat factors, threat factor percentages, and threat factor ratings together yield the new total BCTR. When analyzing these figures, it is important to consider the individual ratings that comprise the new total BCTR. While the BCTR will suggest whether the building under review is in need of modifications, the individual scores can help the evaluator understand which areas are of most concern with regard to bird collisions and which areas warrant less attention. The high ratings at EEEL (Table 5.11) demonstrate the necessity for mitigation in some subcategories. These subcategories can assist future evaluators in determining appropriate mitigation strategies.

Table 5.11 Summary of threat factors, TF%, and acceptable ranges for EEEL

	Threat Factor (over 15)	TF% (>15% of TF over 75)	Threat Rating (over 25, 15)
Revised BCTR	**185 / 15**	**41.60% / 15%**	**72.19 / 25**
Window morphology (WMTF / WMTR)	**100 / 15**	8.90% / 15%	9.31 / 15
Bird habitat (BHTF / BHTR)	**180 / 15**	3.36% / 15%	6.10 / 15
New total BCTR	-	-	**28.85 / 25**

* Bold indicates value that exceeds acceptable range

The revised BCTR threat factor rates extremely high (185) compared to the acceptable range of 15 or less, due to the tinted and reflective clear glass. To lower this score, a building manager could focus mitigation strategies on breaking up the clear glass with decals or etchings so it appears as a solid object to birds.

A closer look at WMTF rating (100) shows that the rating of 185 is solely due to the glass corridor bus stop. In this instance, a building manager may use similar mitigation measures as used on the rest of the building glass so that birds recognize the glass corridor as a solid object. The BHTF rating (180) is composed of bird habitat that is one-to-10 metres in distance, and either less than one metre high (80) or one-to-five metres high (100). In these habitat areas building managers could trim branches to keep any vegetation out of these ranges, or more habitat (trees, bird feeders) could be added closer to the building to obstruct any potential flight path to, or reflection on, the building.

The threat factor percentages show the extent that each of above-mentioned threats pose compared to the building façade square-footage. While all areas with a threat factor above 15 are of concern, the two areas covering less than 15 percent of the façade, WMTF and BCTF, are of

less concern and do not need to be addressed for a PC 55 application. The revised BCTR, however, is of concern, particularly when paired with a threat factor rating of 72.19 (against the new BCTR acceptable range of 25). To achieve PC 55 credits, a building manager would need to alter the clear glass on the EEEL building in order to lower the threat factor rating below 25. The new BCTR totals 28.85, somewhat higher than the new allowable BCTR figure (of 25). This suggests that either (a) EEEL presents a low-to-moderate risk of bird collisions, or (b) other lower threat factors can skew the total BCTR rating. If the latter is the case, then I suggest modifying the above-mentioned calculations in order to best portray the significance of high collision risk areas. This could perhaps occur by keeping the three threat factor values discreet, as not all hazards of conflating the data examined in the previous sections of this chapter may be immediately apparent.

5.2.5 Completion of Requirements One through Four using the new Pilot Credit 55 formula

I compiled the information necessary to fully assess the EEEL building according to Requirements One through Three of PC 55 (with help from Stoker A. Pers. Comm. Aug 1, 2013) and created Table 5.12 to portray PC 55 standards and how the EEEL building measured against these standards. As mentioned in the previous section, the new BCTR for EEEL is slightly higher than the acceptable range and I recommend the aforementioned mitigation strategies to lower the BCTR to an acceptable level. EEEL currently has all interior- and exterior-lighting in place to satisfy Requirements Two and Three. However, a three-year post-construction monitoring plan to satisfy Requirement Four is currently absent.

Table 5.12 Pilot Credit 55 requirement standards with comparison to EEEL

Requirements	*Standards*	*EEEL*
Requirement One: Bird Collision Threat Rating (BCTR)	The new BCTR may total 25 or under	28.85
Requirement Two: Interior Lighting	- Night-time personnel shut off interior lights at minimum between midnight and 6 a.m.	- All lights other than emergency lighting are occupancy sensor-controlled
	OR	AND
	- Lights automatically shut off when unoccupied for 30 minutes	- Lighting in common areas are turned off between midnight and 6 a.m.
Requirement Three: Exterior Lighting	- All lights are covered and do not radiate light higher than 90 degrees, all non-safety lights automatically shut off between midnight and 6 a.m.	- All lighting is compliant with LEED NC SS Credit 8: Light Pollution
	OR	
	- All lights comply with LEED NC SS Credit 8: Light Pollution	
Requirement Four: Three-year post construction monitoring plan	A three-year strategic plan to monitor bird collisions, to discover where repeated strikes occur, and to modify high-risk areas for the building	None

As previously mentioned, EEEL is a new (2011) LEED platinum certified building; however, it has not been previously evaluated with regards to PC 55. I recommend that, in order for the University of Calgary to be an environmentally progressive establishment, EEEL and all other buildings on the main and satellite campuses be evaluated with regards to PC 55. I strongly advise:

- A three-year monitoring plan for all buildings, including those buildings that satisfy Requirement One (where Requirements Two through Four are not necessary).
- When vegetation is planted around a building, future growth be taken into account.
- Revaluation of vegetation density occur yearly, or less frequently depending on species as different growth rates and patterns of planted materials may provide options for less frequent evaluation.

While I recommend retrofitting the EEEL building to change how birds perceive the glass (by adding decals or etchings), the implementation of this modification is beyond the scope of this research.

5.3 Maximum tolerable vegetation density matrix

In this section, I created a matrix showing all bird-habitat height and distance combinations with maximum tolerable vegetation densities for each potential collision risk. I started by rating the categories by different levels of risk (low, medium, high, and extreme) according to how each may contribute to bird collisions with buildings (Table 5.13). As discussed in Chapter Two, Klem et al. (2004) discovered that when feeders were placed one-to-five metres from a window some birds collided and were unharmed, while some birds were injured. When feeders were placed five-to-10 metres from a window, they noted that more

collisions resulted in injuries and death. I have not found any studies to date on a relationship between height of bird habitat and collision risk. Hence, I assumed that habitat one-to-five metres high present the highest collision risk as most windows are at one metre or higher and birds that forage in this habitat zone (as opposed to sky-zone) tend to have the most collisions.

Table 5.13 Level of collision risk for distance and bird-habitat height surrounding a building

Height (m)	Distance (m)		
	< 1 metre	*1 – 10 metres*	*10 – 20 metres*
<1 metre	Low	High	Low
1 – 5 metres	Low	Extreme	Medium
>5 metres	Medium	High	High

I assigned vegetation located at distances of more than one metre and under 10 metres as low risk, when vegetation is less than one-metre high. Similarly, when vegetation is less than one metre from a building and one-to-five metres high, this also is a low collision risk area. However, when vegetation is 10-to-20 metres distant from a building and from one-to-five metres in height, or when vegetation is more than one metre from a building and more than five metres in height, there is a moderate risk that collisions may occur in this area. If vegetation is located one-to-10 metres from a building and is under one metre or greater than five metres in height, or when vegetation is situated 10-to-20 metres in distance and is more than five metres in height, there is a high risk that collisions may occur at this area of the building. The vegetated area of most concern that presents the most extreme risk of collisions, is that which is one-to-five metres high and located one-to-10 metres from a building.

I propose a realistic vegetation density matrix for landscape architectural design that building property owners and managers could use to understand tolerable vegetation densities surrounding their buildings (in terms of potential for bird collisions). Table 5.14 is a simple matrix that could be used for this purpose. The percentages reflect the maximum vegetation density, in relation to glass in either zone one or zone two, that present a tolerable collision risk. Low-risk areas may have 100-percent vegetation density, medium risk areas may have 50-percent vegetation density, and high and extreme risk areas may have 25 and 0 percent vegetation density (respectively). For example, any vegetation less than one metre distant from a building and one-to-five metres high, is considered a low (tolerable) risk and a 100-percent vegetation density could be planted in this area.

Table 5.14 Level of collision risk for distance and bird habitat height and related tolerable vegetation density (%)

Height (m)	Distance (m)		
	< 1 metre	1-10 metres	*10 – 20 metres*
1 metre	Low/100	High/25	Low/100
1 –5 metres	Low/100	Extreme/0	Medium/50
>5 metres	Medium/50	High/25	High/25

Table 5.15 compares the vegetation densities surrounding the EEEL building to the maximum allowable vegetation densities in order to show the potential low, medium, high, and extreme risk areas. I then calculated the vegetation density (percentage) surrounding EEEL. I used the metric measurements (m^2) in Table 5.8 and divided each measurement by the total metric amount of vegetation in zone one (55.54 m^2) and multiplied by 100.

Table 5.15 Vegetation density (m^2) surrounding EEEL and tolerable vegetation density (%)

Height	Distance		
	<1 metre	*1 –10 metres*	*10–20 metres*
<1 metre	25.48 / 100	2.45 / 25	1.04 / 100
1 – 5 metres	53.64 / 100	**12.35 / 0 (Extreme)**	5.04 / 50
>5 metres	0 / 50	0 / 25	0 / 25

* Bold indicates value that exceeds acceptable range

All the vegetation surrounding the EEEL building calculates as low risk for bird collisions with the exception of the extreme category (1-10 metres distance x 1-5 metres in height) where 12.35 percent vegetation density exists. Beneficially, the lack of tall and dense vegetation at EEEL is most likely due to it being a new building. The entire property area was excavated prior to construction and new vegetation was planted in 2011 when the building was completed. Admittedly, the vegetation in the extreme-risk category is low, although this should be noted and minimized, particularly because all four sides of the building contain vegetation in this category. Minimization might include addition of more vegetation between the building and the vegetation in the extreme category or altering the building envelope, such as adding decals to the windows.

5.4 Summary

The current PC 55 is a very useful tool for building and property managers to assess whether their buildings are bird collision threats and to install selected mitigation measures. The additions I recommend in this chapter (glass type, window morphology and bird habitat) will evolve PC 55 into a more powerful tool. The changes I recommend, in combination with the existing PC 55 criteria, will help managers understand the specific areas of most concern in order

to direct funds and mitigation measures to these specific areas. Mitigation strategies could include changing glass material, adding decals or etchings to clear glass, closing blinds and shutters during migration seasons, planting trees and bird feeders closer to (within one metre) or away from (further than 10 metres) buildings, as well as keeping branches trimmed when they grow into the high-risk zones to reduce glass reflections.

The maximum tolerable vegetation density matrix is another tool that could be used by building and property managers to evaluate current bird collision risk due to the vegetation density on their properties. When building property owners and managers plant vegetation around a building, future growth should be taken into account and revaluation of vegetation density should occur every one-to-three years.

The University of Calgary currently is striving to certify all new buildings with minimum silver LEED certification. I advocate for PC 55 and the maximum tolerable vegetation density matrix to be a part of the University of Calgary LEED certification process in order to be a leader in bird collision deterrence.

Chapter Six: Discussion and Recommendations

6.1 Discussion

This exploratory research appears to be the first investigation into bird-building collisions at the University of Calgary and, to my knowledge, is the first study designed to monitor bird-building collisions at a Canadian university campus. While a rigorous data collection protocol resulted in a small sample size this does not diminish the value of the approach used. While the dataset resulting from this investigation was too small to perform statistical analysis, it is apparent that diverse species of birds (albeit few in numbers) collide with a variety of University of Calgary building structure types during spring and fall migration.

While this study confirms collisions do occur on campus, the small dataset indicates there may not currently be an excessive problem with collisions in the area. However future confirmatory may find this is not the case. A number of limitations likely impacted my ability to gather a dataset that was of a statistically significant size. Carcass removal rate – which I did not measure – may have been one of the main inhibitors to documenting all collisions on campus. There is a possibility, if the extent of carcass removal is great enough, that a larger collision issue could exist on the University of Calgary campus. As the University of Calgary continues to build more structures to accommodate a larger student body, and as existing vegetation matures, the continuing concern of bird-building collisions should be addressed.

6.2 Recommendations

This study may assist future researchers in designing confirmatory studies on bird-building collision research at the University of Calgary campus. One approach might be to conduct an analysis of general patterns of collisions with regard to building morphology. Hypotheses could

stem from initial assumptions of building and site design influence on collision data (from a thorough literature review) and discussion of the data could then be directly related to accuracy of these predictions. This study could also be a starting point for a more expansive study in Calgary, such as comparing collisions in northwest Calgary with collisions in other quadrants. A comparison of residential and institutional buildings would be useful, as would a comparison of campus buildings to the numerous residential buildings surrounding the campus[5].

I recommend that researchers consider the limitations outlined in this thesis when designing their research. Continued research might incorporate adjustments to the methods of this investigation to include all buildings on campus and monitoring for one or more years to ensure that a statistically significant number of collisions are documented. I suggest measuring carcass removal rates, in particular scavenger and predator carcass-removal and continuing to monitor searcher efficiency. As the university grounds staff was an integral part of data collection in the current study, I suggest asking them to assist in any future investigations. Nocturnal collisions are not likely to occur to the extent that diurnal collisions might, but a thorough study might include investigating this, possibly through a three-day intensive study.

If deterrent strategies become a necessary tact, I then recommend that the University of Calgary employ mitigation measures for existing moderate to high collision risk buildings. These measures might include: Relocating bird habitat (perching areas) closer to windows, covering or "decaling" windows to assist birds in detecting the glass as a solid object, and turning off interior and exterior lights at night. The University of Calgary might also consider applying for LEED Pilot Credit PC 55.

[5] One resident living near campus witnesses numerous collisions each year.

I recommend LEED include the three proposed diurnal collision indicators to Pilot Credit 55: Bird Collision Deterrence (PC 55). Through incorporating glass type, window morphology, and bird habitat, PC 55 could become an instrument by which to determine and reduce both the nocturnal and diurnal collision risk of building structures. The proposed maximum tolerable vegetation density matrix would be a valuable instrument, useful in isolating the areas of highest collision risk at a building structure, and in helping to focus resources on implementing mitigation measures (given economic limitations). Both the PC 55 additions and the vegetation density matrix could be important scientific contributions in helping to deter future bird collisions with buildings.

The threat of bird mortality by building (window collisions will likely increase as habitat continues to be destroyed for development of buildings that incorporate sheet glass, and as the human population continues to build infrastructure in urban areas (Klem 1990a). Through continued research, advancements in mitigating controllable risks will, in turn, contribute to conservation of resident and migratory bird populations. Weidensaul (2013 [Internet]) found words to express the inexplicable reason why humans feel the need to conserve birds:

> "For tens of millions of years, birds have blessed the skies with flight and majesty. Now it's time for us to do our part… We have, all of us, been transfigured simply by watching a flying bird… And we've realized that for those moments, we were privileged to experience something beyond ourselves – that older, greater, glorious world that a wild bird inhabits, and which through its very existence embodies and makes vivid to us. Birds matter. Period."

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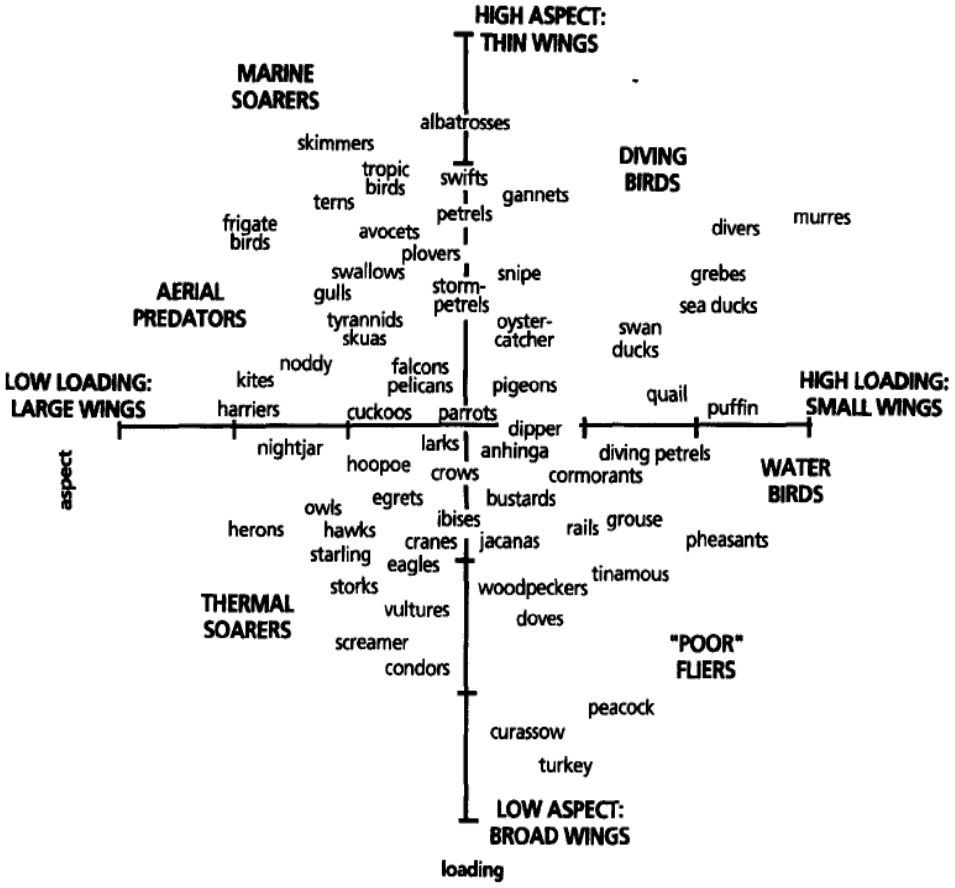
Appendices

Appendix One: Bevanger's wing loading and aspect ratio axis
(Bevanger 1998 p 69)



Appendix Two: Organizational bird collision mitigation efforts

FEDERAL ORGANIZATIONS
Government of Canada Migratory Bird Convention Acts of 1917 and 1994 (last amended Dec 10, 2010) • "Insur[es] the preservation of" and reduces the likelihood of "extermination through adequate protection" of all shorebirds, migratory birds, and some granivorous and insectivorous songbirds (other song-bird protection falls under provincial governance) (Ecojustice 2012, Government of Canada 2013).
United States Federal Government Federal Bird-Safe Buildings Act of 2011 • Requires all General Services Administration (GSA) contracts to employ bird-friendly practices on new and existing buildings (United States Government 2011).
PROVINCIAL/STATE ORGANIZATIONS
Government of Ontario The Endangered Species Act of Ontario (2007) Fish and Wildlife Conservation Act of Ontario (1997) • Protects 11 endangered bird species and habitats as well as common species in Ontario (Government of Ontario 1997, Government of Ontario 2007).
State of New York Bird-Friendly Building Design • Requires new and existing buildings to be bird-friendly by January 2012, inclusive of the Twin Towers (Shepard 2011).
MUNICIPAL ORGANIZATIONS
City of Calgary Bird-Friendly Urban Design Guidelines • Recommends all new buildings, plus-15 glass walkways and urban vegetation to be built/planted bird-friendly in order to "protect and enhance the environment" (Calgary Land Use Planning and Policy 2011).
City of Toronto Bird-Friendly Development Guidelines • Requires all new buildings to be built bird-friendly (City of Toronto 2007).
NON-GOVERNMENTAL ORGANIZATIONS
Leadership in Energy and Environmental Design (LEED) US Green Building Council (this organization developed LEED in the United States) NC-2009 SSpc55: Bird Collision Deterrence LEED Pilot Credit 55: Bird Collision Deterrence • Offers LEED credits for human-made structures that are built and operated bird-friendly (USGBC 2011, LEEDuser 2013b).

*Adapted from references cited (listed in References section on page 94)

Appendix Three: Fieldwork data collection sheet

Fieldwork data collection sheet		**Name & Date:**
Personal Bird ID	*(i.e. VL-001)*	
Date & time of collection		
Bird size	*(S - Chickade M - Robin L – Magpie)*	
Bird colour		
Strike aspect	*(From map i.e. BI - W)*	
Strike height	*If collision seen or evidence on window*	
Band #	*(If present)*	
Result	*(Dead/injured)*	
Delivered to	*(Jessica, CWRS, Biology freezer)*	
Date of delivery		
Additional details	*(imprint on window, injured bird)*	