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Bird Mortality in the Human Built Environment

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Bird Mortality in the Human-Built Environment

By

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ABSTRACT

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Human development is having a detrimental effect on bird populations around the world. One hundred million to one billion birds are killed every year from colliding with human-built structures. I explored factors influencing the inability of birds to avoid man-made structures. If we can better understand these reasons, we can find solutions to this problem. After a known bird avoidance method, fritted glass, was installed in the Wold building, I investigated whether this glass actually deters birds from striking windows. Strikes on windows were noted daily through observation of specific windows on campus. Results show that vegetation outside of windows has the biggest influence strike frequency. An analysis of the fritted glass windows on campus versus windows of similar size and vegetation showed that fritted glass windows received half the number of strikes as non-fritted windows. I also studied wind turbines, which cause 100,000 bird mortalities annually. The on-campus vertical turbines are known to be much more "bird friendly" but also much less power than large horizontal turbines. A cost analysis was conducted to see if these smaller turbines could ever replace larger industrial turbines and this idea proved unsuccessful. Bird friendly window options and turbine structures must be considered as we continue to build up our infrastructure around the world.

ACKNOWLEDGEMENTS

I would like to acknowledge and thank my advisor Kathleen LoGiudice for providing me with her support, recommendations, and advice this past year. I would also like to thank Kaleigh Ahern and the students who conducted the campus walks this past spring and summer. I would also like to thank Kaleigh Ahern for her collaboration in our grant proposal to install fritted glass windows on Union's campus.

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INTRODUCTION

North American bird populations are in decline. The "Common Birds in Decline" list published by the National Audubon Society contains 20 bird species that have all lost at least half their populations in the past 40 years, and these species are not the only ones in danger (National Audubon Society 2013, Klinkenborg 2007). A study conducted by Stanford University found that ten percent of all bird populations around the world are likely to go extinct by the year 2100 (Stanford 2004). Unfortunately, the main cause of bird population declines has to do with human development. Agricultural, industrial, and suburban developments have all contributed to population drops (National Audubon Society 2013). This growth around the country shows no signs of slowing down and will continue to harm many bird populations if solutions are not found.

Bird-window and wind turbine collisions are a serious issue that must be considered as human development continues to increase and take over the world. Bird habitats are pushed aside forcing these animals to adapt to the world we have created (Klinkenborg 2007). Birds hitting windows, wind turbines and airplanes have become an increasing issue of concern as these structures continue to cover the planet. In North America there are four major migratory pathways that are used by birds to migrate North and South (National Audubon Society 2013). As birds use these flyways to travel, they are more often met with unfamiliar structures, which can ultimately result in a collision. The four migratory pathways are the Atlantic Flyway, the Mississippi Flyway, the Central Flyway, and the Pacific Flyway and the two main migration seasons are spring and fall (FLAP 2013, Hager et. al 2008). The fall is the beginning of the journey South and spring is the return migration in which birds have made it all the way South and are returning to breeding grounds (Klem 1990). Different migrating species follow similar paths every year that are increasingly interrupted by growing urbanization and wind farm development. This problem is becoming more common in the Atlantic Flyway as development grows. I am looking to find a solution to this problem, so bird strikes were monitored at Union College in Schenectady, NY in an attempt to understand why birds strike buildings and where specifically birds strike the most. After fritted glass was installed to prevent strikes in the new Peter Irving Wold Center on campus, I also wanted to explore the efficiency of this glass in preventing bird strikes. Wind turbines and urban windows are different structures but have very noticeable similarities in terms of why birds hit these structures. By observing bird strikes on a college campus, I predict that the trends and similarities present in previous research of urban window collisions and wind turbine collisions will also be present on this urban campus.

Birds and Wind Turbine Strikes

There must be a shift from fossil fuels to renewable energy, but we must also realize that not every solution is perfect. Bird collisions with wind turbines are not uncommon and are a serious issue of concern as these strikes result in thousands of bird mortalities every year (Smallwood and Karas 2009, Smallwood et. al 2009). Although we look to wind farms to take the load off of fossil fuels, we must also consider bird mortalities as an issue so this energy source can work to produce clean power and animal safety can be addressed. Wind energy is in its infancy and has the potential to greatly increase in energy production and grow into a major energy supplier. If bird strikes are taken into consideration now, this problem can be correctly addressed before wind energy production increases.

Birds striking wind turbines first caught people's attention in the 1980's when large raptors were found under turbines in California (Kunz et al. 2007). Researchers have difficulty tracking the exact number of birds that die every year from turbine fatality because scavengers remove many carcasses before researchers can get to the birds (Kunz et al. 2007). The Altamont Pass Wind Resource Area in California is one of the largest wind farms in the United States, once the largest in the world, with a generating capacity of 580 megawatts and approximately 4,800 small turbines (Smallwood et. al 2009, Lowitz 2011). Though the exact number of birds killed by turbines is not fully known it was estimated that 2,710 birds a year were killed at the Altamont Pass Wind Resource Area alone (Smallwood et. al 2009). The number of birds killed every year by wind farms is estimated to be in the hundred of thousands (Kunz et al. 2007, U.S Fish and Wildlife Service 2002) and is certain to rise as wind power becomes more ubiquitous. Some generalizations about bird strikes and wind turbines can be made but many instances are site and wind farm specific (Hoover and Morrison 2005). After a large number of golden eagle deaths and bird strikes on the turbines in the Altamont Pass Wind Farm caught the attention of many in California, taller turbines were brought in to replace the lower turbines that were killing many low flying raptors (Sahagun 2011).

To a person who has never seen a wind turbine in person, it is understandable why one would not think it was possible for bird strikes to be so common. Seemingly small in pictures, a single GE 1.5 MW turbine is 120 meters (394 feet) tall when its blade is at its highest position. There are also turbines that stand 150 meters (492 feet) tall (GE

Energy). Wind farms may have hundreds of these turbines, and wind farms are built in areas that are local habitats for birds as well as migratory paths. The rotor zone of a turbine is the area that the blade sweeps through and is a large area in which birds can potentially strike. On average, the rotor zone is extends approximately 50 meters depending on the turbine. Contributing to the problem, birds are invited to these dangerous rotor zones by the turbines as they become perch sites by large raptors and small birds if a turbine is out of service or not moving (Smallwood et. al 2009). At a typical wind farm there will be hundreds of turbines, which means that there are hundreds of these massive structures for a bird to strike. Additional fatalities at wind farms result from electrocution and line collisions although this number is small in comparison to strikes with the turbines themselves (Keil 2005). High mortality rates occur as well when there is a continuous rotor zone, which means that the turbines are placed close together and birds do not have a safe zone to fly through. Another factor that increases the number of strikes is bird behavior and bird interactions on wind farms.

Bird behavior is an important factor in determining why bird strikes are so common on wind farms. One of the behaviors that have been monitored by researchers in the past has been the utilization rate. This is the time that a species uses a wind farm as a habitat, breeding ground or feeding zone. Some species will spend more time on wind farms than others. On that note, every species will also have different responses around wind turbines. Many fatalities occur when birds interact with each other in the rotor zone (Smallwood et. al 2009). Many birds unfortunately strike turbines during the breeding season as bird strikes are amongst their highest during this time. (Keil 2005, Eichhorn et al. 2012). This may be because birds become territorial during this time or because birds have greater flight activity during breeding season. Only a few adults lost in a small population can seriously influence the breeding season and greatly hurt the future of the population (Keil 2005).

Raptors and large predatory birds are common victims of wind turbines for many reasons including collision while trying to catch prey (Eichhorn et al. 2012). Weather can also influence strikes as well flight patterns of certain birds. The red tailed hawk is a bird that many scientists have observed as a high risk raptor in terms of wind turbine collisions due to their foraging and flight behavior in response to wind conditions and topography (Hoover and Morrison 2005). Raptors have also been known to lose track of where they are flying while in pursuit of prey. Many small birds and rodents that live on the floor of wind farms attract larger raptors to wind farms to feed; this raises their risk for collision (Smallwood & Thelander 2004). While large birds get distracted while attempting to catch their prey, smaller birds have the issue of trying to avoid large raptors and other predators. Small birds may alter their flight pattern while trying to avoid a perched raptor that may ultimately result in a collision (Smallwood et. al 2009). Many older turbines are constructed on lattice towers instead of large cylindrical structures. These lattice towers provide perching opportunities for large raptors as well as small birds (Barclay et. al 2007). The more perching opportunities available for birds, the more time birds will spend by the wind turbines, which therefore will increase their risk for collision. More perch sites increase the risk of bird fatality. Many raptors will perch on out-of service turbines adjacent to operating turbines and will collide with a turbine either during take-off or landing. Birds tend to spend more time on wind farms that have a greater amount of turbines out of service and perching sites; this increased amount of time spent on these wind farms also increases collisions (Smallwood et. al 2009).

Nighttime migrants are also a source of concern on many wind farms. The majority of birds killed during the night are killed during the fall migration (Barclay et. al 2007). Lighted towers and lights on wind farms are distractions for birds as lights sidetrack birds during the night and in foggy and rainy weather. While birds are attracted to lights at night, this is also known to disorient them. The most appropriate lighting on wind turbines to keep birds away is flashing red lights which Kerlinger et.al found did not contribute to multi bird deaths. In this same study, white lights and non-flashing red lights contributed to four documented incidents of multi bird death (2010).

Two wind farms in the Atlantic Flyway are the Fenner Wind Farm in Morrisville, NY and the Maple Ridge Wind Farm in Lewis County, New York. The Fenner Wind Farm produced 28.5 MW of energy from 19 wind turbines. The turbines are 328 ft (~100 meters) including the blade at the highest position and the diameter of the tower is 13.5 ft (4.11 meters) at the base of the tower (Fenner Renewable Energy Education 2011). The Maple Ridge Wind Farm is a 321 MW farm that has 195 turbines and each turbine is 260 ft tall with 130 ft blades. The Maple Ridge Farm conducted a study that revealed that wind turbine collisions with birds were small in comparison to the, "guyed communication towers in the Midwestern and eastern United States, where fatalities sometimes involve hundreds or even thousands of birds in a single night or migration season" (Iberdrola Renewable's and Maple Ridge Wind Farm 2007). There are 84,000 communication towers in the United States and a tower can stand almost 2,000 feet tall. It is not just the towers that kill these birds but the wires that hold up the towers as well. A recent study estimated that approximately 6.8 million birds in the U.S and Canada die every year due to collisions with these towers (Longcore et. al 2012).

Offshore wind energy has great potential in the Atlantic flyway zone. Offshore wind energy has the potential to seriously reduce the need for fossil fuel energy since wind potential is very high off the Atlantic coast. This area however, is also in a highly trafficked portion of the Atlantic flyway, especially to the 164 species of water birds that use this corridor. Although no large farm has been constructed yet, offshore wind farms are already been documented to kill migrating birds (Desholm 2009). This is an area of concern as many states have encouraged the idea of building these massive farms. If these farms are to be built, it must be noted that many birds that use the Atlantic flyway are endangered water birds (Watts 2010).

Turbines with rotors that move slowly and are spaced out from each other are believed to have the smallest number of bird strikes (Smallwood et. al 2009). There have been some positive cases where birds have changed their migration patterns in order to avoid turbines such has the Green Mountain Wind Farm in Vermont. This farm had fewer hawks and songbirds fly over the wind farm once the site was erected. Birds may have learned to alter their course of migration when these large structures were put up (Kerlinger 2002). Although it is estimated that bird deaths from turbines are in the hundreds of thousands annually, this number pales when compared with mortalities from strikes on window glass (Klem 1990).

Birds and Building Strikes

Windows and buildings are a greater source of mortality than wind turbines and are the second greatest source of mortality for birds after habitat loss (Hager et. al 2008).

According to the U.S Fish and Wildlife service, bird window strikes may account for 97 to 976 million bird deaths every year (U.S Fish and Wildlife Service 2002). To many birds, windows are not seen as a barrier, but as open spaces that they can pass through. As with wind turbines, many scientists have looked for the exact reason birds fly into windows but this is once again dependent on species and location. Through research, we can identify certain characteristics of birds and traits of buildings that increase the risk of birds striking windows. Once we identify these traits we can try to create window avoidance mechanisms to decrease the risk for birds.

Bird window collisions take place in both rural and urban areas. While an urban area was the study of my focus, it is important to note that bird collisions are not specific to any location or window type. There is not one specific structure, time of day, window size or weather condition that will guarantee a strike, although some of these characteristics could greatly increase the chance of a strike (Klem 1989). Window strikes can be random, and are not isolated to any specific age, sex, or type of bird (Klem 1989).

While seemingly noticeable to humans, birds do not see glass (FLAP 2013). Windows that reflect vegetation and a birds surrounding habitat are known to increase strikes and many new building projects are increasing glass area in the façades of buildings. (Klem et. al 2004). More glass increases the area that reflects vegetation back to birds or that birds think that they can fly through. Parallel windows give the illusion that there is a passageway through a building. This illusion is even stronger when there is vegetation outside a window. Birds can easily strike windows when they believe that they can use these windows to pass through the building. A bird can maneuver itself to fly through a very small hole so no matter the size of the window, it can still be viewed as an accessible opening. Indoor plants placed near windows are also sources of concern as birds see this vegetation as accessible (Klem 1990).

One question that has been investigated is whether bird feeders contribute to the increase in bird collisions, especially in the winter when birds are attracted to feeders the most. While bird feeders do draw a crowd and can likely increase the number of birds that can come in contact with the window, it is ultimately the placement of the feeder that contributes to collision risk. It has been noted that bird feeders placed near a window (within 1 m) can actually decrease collision risks. Klem (2004) found that when bird feeders were placed 1m from a window, collisions were rare while collisions increased when feeders were placed 5-10 m from a window. This is possibly because when birds were closer to the glass they were able to register that the glass was there as opposed to when they were further from the glass.

Night migrations and lights are an issue for many migrating birds as lights can easily disorient a bird (Arnold and Zink 2011). Especially in large urban areas, birds can get trapped in a city of reflective windows. Most birds are attracted to light so when skyscrapers are lit up at night and in a migratory pathway, birds can easily get caught and are much more susceptible to collisions (Conservation 2013). As buildings are much more common than wind turbines, lights in urban, suburban, and rural areas are much more detrimental to migrants who frequently pass through areas highly populated with people.

Manhattan is one of the most highly populated cities in the United States and is a large city in the Atlantic flyway that is a source of concern. Between 1997 and 2008 Project Safe Flight participants documented over 5400 bird wind collisions in Manhattan alone. This number is an underestimate of the number of strikes that actually occurred since some sites were not monitored as frequently as others and monitoring was discontinued at some sites at the end of migrant seasons. The highest number of collisions occurred on windows that reflected outside vegetation while some of these buildings also had indoor vegetation visible to birds (Delacretaz and Gelb 2009).

Many groups including the Fatal Light Awareness Program and NYC Audubon have formed education and outreach campaigns to help reduce the number of bird strikes in cities, where humans can actually do their part. Two programs in New York are Project Safe Flight and their affiliate program, Lights Out New York (FLAP 2013). FLAP and Lights Out Toronto also collaborated to release the *Bird Friendly Development Guidelines,* which provides instructions on how to make our cities as bird friendly as possible (FLAP et. al 2007). Many other cities have also contributed to lights out campaigns where people are encouraged to turn out their lights at night to reduce bird attraction while saving energy. The American Bird Conservancy and FLAP have large campaigns to gain awareness for this growing problem (FLAP 2013). Habitat loss increases the risk for wind turbine collisions as well as window collisions. If humans continue to build more structures in natural environments, they are increasingly likely to alter or destroy birds' habitats. While many birds will try to alter their flight patterns to avoid these giant man-made structures, sometimes it is too late**.**

There are some remedies that can contribute to the reduction of bird window collisions. Window angled down that will reflect the ground instead of vegetation and sunlight have been show to significantly reduce the number of collisions. It is also hypothesized that angled windows reduce the impact which birds will hit the windows

(Klem 2004). Other methods to keep birds away from windows are decal stickers and fritted glass. Decal stickers claim to reflect UV lights that birds can see which will help them avoid windows. It is still unclear how effective these stickers actually are and they have also caused some aesthetic and maintenance concerns since the stickers need to be removed every 7 years and are much more visible; some people finding them unattractive (Klem 2009). Stickers are however, are less expensive option and are being installed on many buildings (Flap et. al 2007). Fritted glass is glass that has small dots evenly engraved in glass that is known to decrease the number of strikes and provide energy savings for buildings. It is known to help birds register the fact that there is a window and not an open space. Typically, fritted glass is thought to be effective (Klem 2009, Flap et. al 2007, Lee 2004).

Though wind turbines and windows are completely different structures, they both have huge impacts on bird communities for many similar reasons. While renewable energy and sustainability are important and many people have become accustomed to structures that already exist, it is important to be aware of these issues so remediations can be made when possible. Union College has many buildings as well as few small-forested areas around campus and there are many places on campus for local and migratory birds to inhabit. A study was conducted on a college campus similar to Union in Cleveland, OH. In this study, migrant birds were found dead much more frequently than local birds and deaths were observed on buildings that had higher percentages of glass. Another study was conducted on the Northwestern Campus from 2004-2006 and found a high rate of mortality of birds as well as an increased mortality rate for migrants in the spring and fall (Hager et. al 2008). These studies were important to look at before I conducted my study because many urban studies are looking at larger and more populated urban areas such as New York City. Union College is located in Schenectady, a small city, and the campus is filled with vegetation and short buildings, similar to that of the Cleveland and Northwestern campus (Borden et. al 2012).

To see if these trends of bird collisions with turbines and windows were similar on a college campus, walks were completed every day around the campus to look for strike marks on windows and bird carcasses around campus. A specific route was followed every day and strikes as well as carcasses were observed and noted. These walks were able to identify “high strike” windows on this campus. Hopefully these “high strike” windows can be improved to reduce the number of strikes that occur on campus buildings every year. After these locations are identified in this paper, I will propose proper remediation’s to ensure safety for birds on campus. I also monitored the three wind turbines on campus for bird strikes. These turbines are not rotor style turbine but are a cylindrical vertical axis turbine called a Windspire. Through my walks and research, I identified if this style turbine is safer for birds and if it has a comparable energy output and cost to the larger style horizontal axis turbines seen on wind farms. With such a high number of bird deaths each year attributed to human cause, we must work harder to allow animals to occupy their habitats without problems.

METHODS

An examination of window strikes began on April 30th 2012 and continued daily for 10 months to analyze bird window collisions during every season and the two migration periods. During the summer, surveys were conducted once a week and in the month of December the windows were not examined. The study took place at Union

College which is a small urban campus located in the city of Schenectady, NY. Union College has many academic buildings and residence halls but only a few buildings are taller than 2 stories and no buildings are higher than 4 stories.

The campus is surrounded by a city, but is a popular spot for animals since grass, trees and small shrubs cover most of the grounds. There are few roads and the main form of transportation on campus for pedestrians is a sidewalk. There is also a large area set aside as gardens with many trees and flowers and no roads or sidewalks in this area. During the spring and fall migration, the campus is filled with birds that use the trees and bushes around campus as perch sites. There are also local birds that live on campus year round. At the time of the study, there were no mechanisms put in place to divert birds away from windows except on one building. The Peter Irving Wold Center has large windows with fritted glass on the higher parts of these windows (above 11 ft) and not on the windows that are at ground level.

A course around campus buildings was set up to be walked every day to look for indications of bird strikes as well as deceased birds. Indications of bird strikes included feathers stuck to windows; smudge marks that clearly indicated birds had hit the window and bird carcasses below windows. The course that was walked everyday started at the Reamer Campus Center and continued to the Olin Center, the Peter Irving Wold Center, the Science and Engineering Building, the Alumni Gymnasium, and Schaffer library (Figure 1). Pictures of every examined window were taken and smudges were marked on these pictures so a mark would not be noted twice on the strike data sheet. When a carcass was found, this was noted on the strike data sheet as well as on a separate data sheet for witnessed strikes and carcasses.

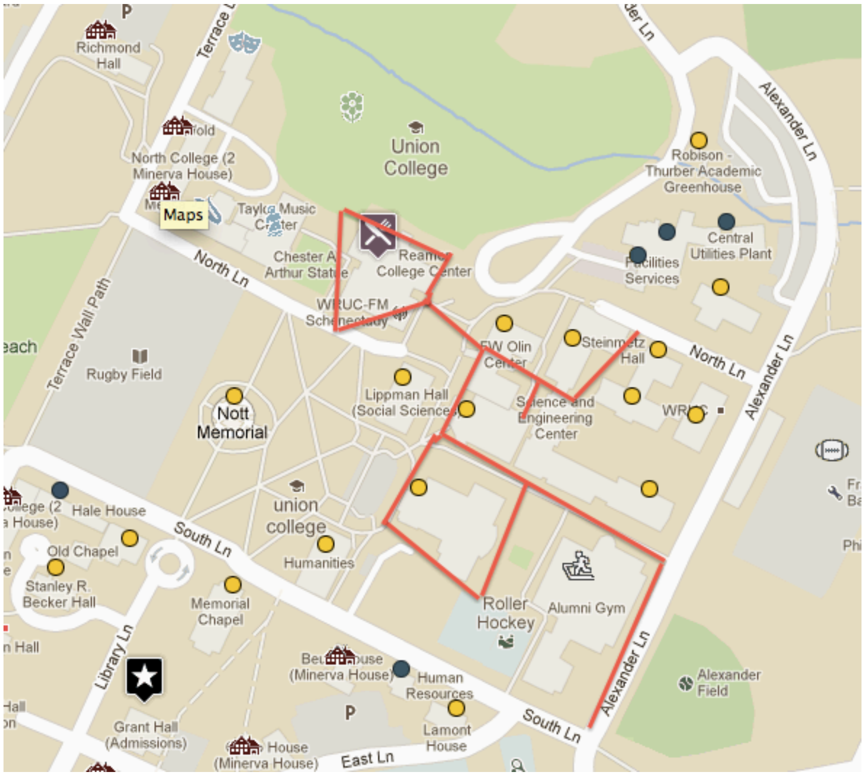

Figure 1: A map of Union College's campus. The red line outlines the course that was walked daily.

While some smudge marks of bird strikes can stay on a window for a long time, other strikes can fade within the hour of a bird strike so many strikes may not have been detected. Additionally, the area below many windows is covered with bushes and the herbaceous ground cover *Pachysandra*. Birds that fell into these bushes and shrubs would be hard to find in these densely packed areas so it is also impossible to tell if all of the bird carcasses were accounted for on the campus walks. When a bird carcass was found, the location, the surrounding vegetation abundance, and the window characteristics were noted. The state of the carcass was also recorded and the species of the bird was documented when possible.

Every Monday and Thursday (during what time period?), the three on-campus wind turbines that are located by Union's soccer field were visited in order to examine the possibility of a bird carcass under this style of turbine. The turbines are further away from the main campus and it would be highly unlikely on these turbines to notice a smudge mark on the blades so the only indication of strikes on these turbines would be a bird carcass.

RESULTS

Window Strike Results

The fifty windows were observed once a day from May 2nd 2012 to February 9th 2013. The total number of strikes was evaluated to see if there were any factors that increased the risk of these birds colliding with windows on campus (Appendix A). To investigate potential causes, every window was placed into descriptive categories: Height, Width, Vegetation Outside and Flythrough Appearance; each descriptive category was divided into number classes for further evaluation (Table 1).

Table 1: Window Descriptive Categories

Category	**Description**
Width	< 4 feet =1 >5 and <10 =2 >10 feet = 3
Height	< 1 story = 1 > 1 story = 3
Fly Through Appearance	Does it appear that you can fly through window 1 get to the other side of window 2? No=1 Yes =3
Vegetation Outside	No vegetation = 1 Some vegetation = 2 A lot of vegetation =3

A correlation analysis was run for all fifty windows to see if total strikes per windows were correlated with any of the window descriptor categories (Table 2). Vegetation Outside and Total Strikes had the largest correlation (r=0.41). The next two strongest correlations were Sum of Categories and Total Strikes(r=0.32) and Window Width and Total Strikes (r=0.31).

Table 2: Correlation of Window Descriptive Categories to the Total Strikes on all 50 Windows.

Correlation Analysis	*Total Strikes*
Total Strikes	**1**
Window Size Height Category	**-0.17**
Window Size Width Category	**0.31**
Vegetation Outside	**0.41**
Fly Through Appearance	**0.25**
Sum of categories	**0.32**

The distribution of the data was non-normal, with many "0" entries, so non-parametric statistics were used to further analyze the data. Spearman Rank Correlation Analyses confirmed the linear correlation results shown in Table 1. The amount of vegetation significantly affected the number of strikes a window received with the most vegetated windows receiving a higher number of bird strikes (Kruskal-Wallis test, p=0.0092). The window width had a marginally significant effect on the number of strikes a window received with the widest windows being hit the most often (Kruskal-Wallis, p=0.075,Figure 2).

A Mann Whitney test was run for Flythrough Appearance and Window Height and there was not a significant difference between the window height categories or the fly through categories. The average number of strikes decreased from 2.5 to 1.5 when the windows were greater than 1 story but this difference was no significant (Figure 2). The average number of strikes increased from 1.4 to 2.8 when adjacent windows gave the appearance of being a fly-through but this difference was no significant (Figure 2).

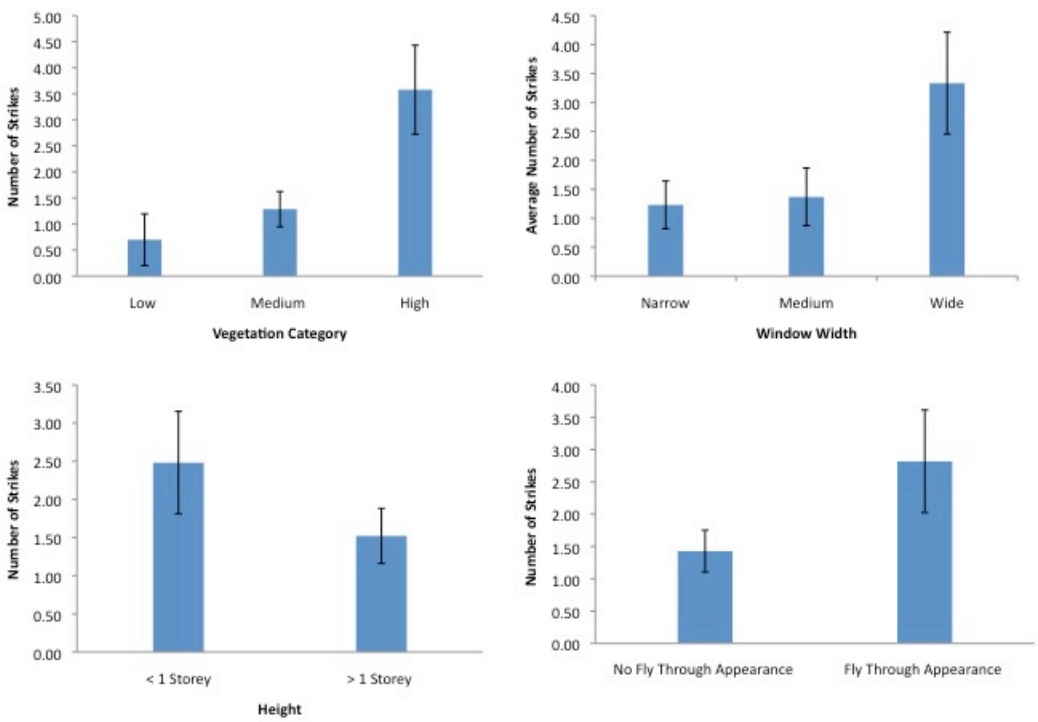

Figure 2: The average number of strikes per window for each specific window descriptive category. Error bars represent error .

To see if the fritted glass is doing its intended job and deters birds from striking windows, I compared these windows to other windows of similar size and vegetation. Although the sample sizes were too small for a meaningful statistical analysis, the mean number of hits for the seven windows without frits was 2.4 while the mean number of hits for the two windows with frits was 1.5 (Figure 3). Furthermore, in the Wold Center where the fritted glass is placed, only the second story of each window facade has fritted glass. Thus, the lower, clear glass windows can be considered a control (n=2) and the upper, fritted glass windows, a treatment (n=2). While the sample sizes are again too small for analysis, the clear glass lower windows sustained twice as many strikes as the upper, fritted glass (3 vs. 1.5, Figure 3).

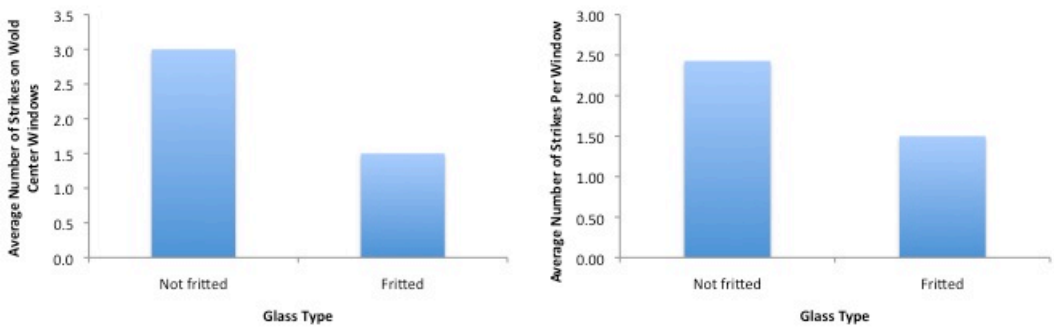

Figure 3: The average number of strikes between fritted glass and non-fritted glass. The left graph compares the Wold Center's first story non-fritted glass to the >1 story fritted glass. The right graph compares the Wold Center's fritted glass to all non-fritted glass on campus of a similar size and vegetation-outside amount.

Wind Turbine Results

I investigated the power generating capacity of horizontal axis wind turbines and vertical axis wind turbines and determined the relative bird killing capacity. On campus there was no evidence of the three vertical axis wind turbines killing any birds. In addition, Quinnipiac University in Hamden, CT has not reported any strikes on their 25 vertical axis Windspire turbines and Maria Power, the manufacturer of Windspire turbines, has claimed on their website that the Windspire product is actually "bird friendly" and has never harmed a bird (Terry 2012, www.windspireenergy.com) Previous evidence, as detailed earlier, proves that horizontal axis wind turbines contribute to many bird and bat deaths. To compare the other aspects of these two styles of turbines, I evaluated the cost and power generating capacity of both Horizontal Axis Wind Turbines (HAWTs) and Vertical Axis Wind Turbines (VAWTs)(Table 3).

Table 3: Comparison of energy and cost on vertical axis wind turbines and horizontal axis wind turbines.

Turbine Style	kWh	Number of annual kWh produced	Known wildlife impact	Cost per turbine	Number of turbines per 1.5 mWh	Cost of 1.5 mWh
VAWT (Windspire)	1.2[1]	2000[1]	Low [1]	~$5,000[1]	1,643	~$8,215,000
HAWT (GE Standard Turbine)	1500[2]	3,285,000[2]	High[3]	~2,000,000[3]	1[3]	~$2,000,000

1. *Windspire Wind Turbines by Windspire Energy* 2013
2. GE Energy Report: Wind 2009
3. Sahagun 2011, Smallwood 2007, Smallwood et. al 2009, Smallwood and Thelander 2004

DISCUSSION

Window Strike Discussion

While many factors contribute to a bird strike, my results revealed that certain window characteristics had stronger correlations with the number window strikes. The strongest correlation I found was between Vegetation Outside and Number of Strikes and this correlation indicated that high vegetation windows on average had the greatest number of strikes (Table 2, Figure 2). This finding is consistent with previous bird collision research. On the urban Ohio college campus that conducted research of bird strikes, sites with high vegetation close to windows were known as “migrant traps”, luring birds in and hurting or killing them (Borden et. al 2010). Findings in the New York City study explained that high collision sites were where “large glass exteriors [are] opposite abundant vegetation" (Delacretaz and Gelb 2009). This is also consistent with my findings that the number of strikes and window width were positively correlated. The Kruskal-Wallis test indicated that the number of strikes for the Window Width category were significantly different between the small, medium, and large window widths (Figure 2). Further break down of the window width groups showed that high strike windows were generally wider windows. Previous studies have also shown that larger windows contribute to the possibility of a bird strike (Borden et. al 2010, Hager et. al 2013). Although some of the carcasses found could be identified as a local or migrant, the sample size of carcasses found was too small to identify whether local or migrant birds struck windows more often. Over the course of 10 months, 102 strike marks were observed and 38 carcasses were found below windows. When a carcass was found it was counted as a strike (Figure 4).

Figure 4: Examples of bird carcasses found on Union's campus.

The fritted glass window analysis supports previous results that this type of glass deters birds from flying into windows (Klem 2009, Flap et. al 2007, Lee 2004). This solution does not completely prevent strikes, but strikes were cut in half compared to windows of a similar size and vegetation level**.** Installing fritted glass in areas that were found to be high-risk will most likely reduce the number of strikes in these locations greatly. My findings were consistent with previous findings that stated that ceramic fritted glass is effective in making birds aware that there is a barrier preventing them from entering the building (Klem 2009). Buildings at Swarthmore College in Swarthmore, PA and Muhlenberg College in Allentown, PA have both provided extremely successful results of lowering strikes on these buildings since installation. Muhlenberg College has reported no known collisions on the fritted glass since installation while a similar window on the same building had reported 12 collisions in the same time (Klem 2009).

Fritted glass is not only safer for birds but also contributes to energy savings by diffusing the light coming in to a building, reducing cooling costs in the summer and heating costs in the winter (Milano 2012). Typically the more glass on a building, the more you will spend on heating and cooling costs. Fritted glass is popularly known as a "light filtering material" that will control solar radiation. To make the windows even more efficient, builders can purchase fritted glass that also has a low-e coating that will absorb more long wave radiation heat rays than windows without low-e coating. (Lee et. al 2002) While fritted glass is clearly safe for birds, in the long run it will also reduce energy costs. This feature should make fritted glass more enticing for architects to include into new building designs (Jonsson et al. 2009, Milano 2012) The other results that did not yield statistically significant results still showed interesting outcomes, especially when the buildings were broken down by high and low strikes. Most of the "high strike windows" were also windows that were described as having a fly through appearance. In Upper Class dining, one of the windows that had the most strikes recorded was a corner window that was adjacent to another window, creating a fly through appearance. Another window area that I reported having a lot of strikes were the windows on the Science and Engineering "Bridge" that were parallel to each other which created another appearance to birds that they could fly through this area.

It is important to note that many factors go into a bird perceiving a window as a passage that they can fly through. The factors that I chose to identify will only explain some of the reasoning as to why birds strike certain windows more than others; there were some previously found explanations that were not examined in my study. It is also important to note that some bird strikes may have gone unreported due to smudges on the windows disappearing or animals removing carcasses before they were found (Borden et. al 2010, Klem 1989, Hager et. al 2008). This was proven to be the case in one noted strike where only feathers were found after a scavenger most likely picked this bird apart before I was able to properly record it. The strikes that were reported however still give an accurate representation of high-risk windows on campus.

Wind Turbine Discussion

Industrial size turbines on wind farms are threatening the lives of many local and migrant birds. The two main styles of wind turbines are Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT, Figure 5). HAWTs are the standard wind turbines that come to mind when a person thinks of a wind farm; they are the large industrial turbines with sweeping blades. The horizontal blades of a HAWT face the wind while the main rotor shaft and blades of a VAWT is perpendicular to the ground (Ke et. al 2012). The three VAWTs on campus are manufactured by Maria Power (Reedsburg, WI) and are called Windspire turbines. To date there have been no recorded strikes on the Windspires on Union's campus and Quinnipiac has not reported any strikes on their 25 Windspire turbines (Terry 2012). Maria Power has stated on their website the Windspire product has never had a strike and are actually "bird friendly" (windspireenergy.com). HAWTs are the turbines that have been under scrutiny for bird collisions and are known to be dangerous for many species. Since VAWTs are clearly the safer turbine for birds, I investigated whether VAWT farms could ever replace HAWT farms altogether and be the safe new wind farm of the future.

HAWT **VAWT**

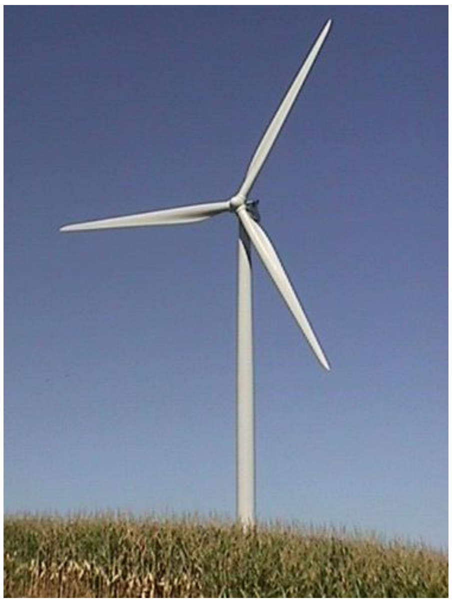

Figure 5: Horizontal Axis Wind Turbine (left); Verticle Axis Wind Turbine (right). Heinz 2012 *(Windspire Wind Turbines*

The Windspire vertical turbines are 30 feet tall and 4 feet wide and due to their vertical presentation, can be placed much closer to each other than standard HAWTs. A standard HAWT is much larger and can generate a lot more energy. A typical turbine produced by General Electric will stand 394 feet at tip height. Table 3 explains the pricing and kWh produced for both styles of turbines. It would take thousands of Windspire turbines to generate the power of one industrial HAWT so while VAWTs are clearly safer for birds; the technology is clearly not there yet to replace HAWTs.

Typical high wind power farms cannot be replaced with VAWTs just yet, but there are certain situations where VAWTS are preferable to HAWTS and should still be used. Although some turbines are dangerous to birds, wind energy is still necessary to the growth and change in our infrastructure as we slowly make the move away from "dirty" fossil fuels to replace them with "clean" alternatives. Our grid is extremely dirty in the sense that the majority of the grid is fueled by coal and natural gas (Fox-Penner 2010). The world is starting to make changes to shift to a Smart Grid as it would reduce the amount of energy needed and imported from around the world. Smart grid technology would also remove the need for fossil fuel driven "peaking plants" which are turned on during high-energy use times. This grid would increase the practicality of renewables such as wind, solar, and geothermal energy (Fox-Penner 2010).

An aspect of the smart grid that is encouraging the growth of renewable power is the concept of the micro-grid. A micro-grid is essentially the transmission grid on a smaller scale. The generating facilities are built specifically for local communities including hospitals, colleges, and suburban areas. A micro-grid in a small community will involve small generating units such as small wind turbines and solar panels providing energy for the community with a fossil fuel generating facility still connected for times when the renewable energy is not providing enough energy (Fox-Penner 2010). If implemented, micro-grids will improve the support of renewables as source of power for many communities, creating a new era of self-sufficiency. Large HAWTs are inefficient in the fact that they require a lot of space and you cannot place many turbines near each other to maximize their efficiency (Dabiri 2011). While VAWTS may not be able to replace industrial large wind farms, they can be very beneficial on the smaller scale where more turbines can fit in a smaller space. Quinnipiac is the first college to incorporate a micro grid or "wind garden" onto their campus where 25 Windspire turbines now power more than 50% of the exterior lights on the 250 acre campus (Environmental News Service, U.S. Climate Action Network). A benefit in having a VAWT on a micro-grid wind farm is that a VAWT is designed to pick up wind from any direction. This is important especially if micro-grids are to become more popular because this means that they can pick up more wind if they are placed in areas of the state that are not known to be particularly windy (Saeidi et. al 2013).

Proposed Solutions

Currently there are no plans to install any more wind turbines on campus or turn the existing turbines on campus into a mini micro-grid to support Union's electricity need. In terms of installing bird friendly turbines on a college campus, Union College met that objective. In the future, hopefully Union will install more Windspires to support other areas on campus that use a lot of energy. One area on campus that could benefit greatly from Windspire turbines could be the football field, where large energy wasting lights are kept on all night to keep that area of campus safer. Other institutions should follow by example and install these bird friendly turbines and move towards cleaner power.

On a larger level, there must be continuous research to explore how we can improve turbine technology to make wind farms a safer environment for all animals. While bird safety is visibly an issue on many wind farms, there is also a high rate of bat mortality as well (Smallwood and Karas 2009). The following improvements should be included when wind farms are modified and when new wind farms are built. Birds hardly ever perch on active turbines, so we must improve measures around turbines that are inactive (Smallwood et. al 2009). Lattice towers are extremely harmful because they provide additional perching sites for birds and invite them towards turbines. Additionally, broken turbines that are left in active rows could attract birds and raptors to attempt to pass through this area, which could result in additional strikes (Smalwood and Karas 2009). If turbines need to be shut down, they could be turned off at certain times of the day, during certain seasons or wind conditions to reduce the amount of fatalities on wind farms. It may also be beneficial to synchronize when turbines are shut down since fatalities have occurred when birds have attempted to pass through an area that has one or two inactive turbines (Smalwood and Karas 2009, Smallwood et. al 2009). While small VAWTS are known to be safer for birds, one report of recommendations to make wind farm safer proposed replacing small HAWTs with much larger HAWTS as a safer wind farm for birds. The same report also proposed retrofitting tower pads to prevent small rodents from burrowing under these turbines. Retrofitting these pads could make the area around turbines less attractive for raptors which currently forage close to turbines looking for small rodents (Smallwood and Thelander 2004). Since there are some HAWTs that are clearly more "bird friendly" than older models, these turbines should be installed and proper practices followed when building new farms and updating older ones.

For windows on Union's campus, it is clear that there are certain windows that are high-risk windows for birds. While replacing all windows on campus is too expensive, it is important that the college consider fritted glass when renovating buildings or building new structures on campus. This will not only save many birds lives on campus, but will also help the college reduce energy costs and move towards the goal of reducing their carbon footprint. Union College recently began funding one large student initiated sustainability project a year for up to $25,000. Because of the high cost of replacing windows with fritted glass, I proposed with fellow student, Kaleigh Ahern that we replace the windows in Upper Class Dining, which we believe is in the most dire need of improvements. This project was selected as a finalist for the $25,000 grant, but ultimately did not receive funding. The facilities department at the college however did request a copy of this report so that they could allocate future funds towards this cause as well as apply less expensive solutions: by purchasing decal stickers that can be placed on the exteriors of windows. While less expensive, these stickers have to be replaced approximately every seven years (Flap et. al 2007).

On an industrial level, all new building models should include at least one bird avoidance tactic whether it be installing energy efficient fritted glass, bird avoidance stickers, or proper vegetation placement. We must turn off the lights at night to avoid disorienting birds, keep indoor vegetation away from windows and avoid using reflective glass on new structures (Klem 2004, Lights Out Toronto, Klem et. al 2009). As we continue to build up our cities and infrastructure, using more glass in the process, we must take into consideration the many bird species that are affected by our infrastructure intruding on their habitat.

CONCLUSION

The human built environment is infringing upon bird habitats across the world. As our cities and renewable grid expands, we must take into consideration the livelihood of the wildlife we cohabitate with. There are many bird strike prevention tactics that can be practiced on wind farms and on buildings that must be considered in order to minimize wildlife destruction.

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Appendix:

Window	Total Strikes	Window Size Height Category	Window Size Width Category	Vegetation Outside	Fly through appearance
1	0	3	2	1	1
2	1	1	2	3	1
3	0	1	2	2	1
4	0	1	2	1	1
5	0	1	1	1	3
6	0	1	1	3	3
6.5	11	1	3	3	3
7	13	1	3	3	3
8	7	1	2	3	3
9	6	1	3	3	3
10	3	1	1	2	3
11	5	1	3	2	3
12	1	1	2	2	1
13	0	3	2	2	1
14	5	3	2	1	1
15	0	1	1	2	1
16	0	3	3	2	1
16.5	2	3	3	2	1
17	4	3	3	2	3
17.5	3	1	3	2	1
18	0	3	2	1	3
19	0	1	3	1	1
20	0	1	3	3	3
21	0	1	2	2	1
22	0	1	2	2	1
23	5	1	1	3	3
25	1	1	3	3	1
26	1	3	3	2	3
27	0	1	2	2	3
28	0	3	2	2	3
29	0	3	2	2	3
30	0	3	2	2	3
31	1	3	2	1	3
32	3	1	2	3	1
33	1	1	1	3	1
34	5	1	2	3	1
35	3	3	2	2	1
36	2	3	1	2	1

37	2	3	1	3	1
38	6	3	3	3	1
39	2	3	3	3	1
40	0	3	1	3	1
41	1	3	1	3	1
42	1	1	1	3	1
43	0	1	1	1	1
44	1	1	1	1	1
45	2	3	3	2	3
46	0	3	3	1	3
47	3	3	3	3	3
48	1	3	3	2	3

Appendix A: Total number of strikes for each window and the rating for each descriptive category.