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The Effects of Soil pH and Composition on Blacklegged Tick Molting Success Avian Window Strike Mortality on Union College Campus

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The Effects of Soil pH and Composition on Blacklegged Tick Molting Success

By

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ABSTRACT

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ADVISOR: Kathleen LoGiudice

The blacklegged tick (*Ixodes scapularis)* is the one of the most significant vectors of infectious disease in the world and most notorious for its ability to transmit *Borrelia burgdorferi*, the bacteria that causes Lyme disease. Because both the range of the blacklegged tick and the annual incidence of Lyme disease have been increasing in North America over the past several decades, it is becoming increasingly important to better understand how environmental factors contribute to blacklegged tick survival. Past studies have shown that these factors include precipitation levels, extent of groundcover, plant and animal community composition, temperature, and soil type. Because blacklegged ticks spend much of their lives in contact with the soil, it is not unreasonable to assume that soil texture and pH can have significant impacts on tick development and reproduction. However, this interaction is arguably one of the most poorly understood. The Albany Pine Bush Preserve in Albany, New York, is an ecosystem that supports very high blacklegged tick densities and is characterized by loamy-sandy soils with very low pH (approximately 4.7). In order to test the effects of soil composition and pH on blacklegged ticks, engorged nymphal ticks were collected from chipmunks trapped in the Pine Bush. The ticks were distributed through 4 soil treatments: acidic playground sand, basic playground sand, acidic unaltered Pine Bush soil, and basic (altered with $CaCO_3$) organic Pine Bush soil. Results suggest that tick molting success was higher in the acidic soils than in basic soils, and higher in the organic Pine Bush soils than in the playground sands. Further research in this area is needed to examine the effects of soil pH and composition on blacklegged ticks as well as give insight into regions of high tick density, future range expansions, increased disease risk, and possible tick control methods.

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INTRODUCTION

Ticks belonging to the *Ixodidae* family are markedly efficient disease vectors due to their long lifespan and relatively long feeding durations (Soneshine, 1991). *Ixodes scapularis,* also known as the hard tick, blacklegged tick, or deer tick, is the second most significant vector of fatal and debilitating diseases in the world (Sonenshine, 1991). This tick is also an important disease vector in the United States, best recognized for its ability to transmit *Borrelia burgdorferi,* the bacteria that causes Lyme disease (Brisson, 2008). The impact of tick-borne diseases is substantial, costing the world-wide economy billions of dollars a year due to human and livestock morbidity and mortality (Sonenshine, 1991). Over the past three decades, a tick range expansion has been observed throughout United States (Madhav et al, 2004) and has been coupled with increasing reports of Lyme disease cases. Although the ecology of tick-borne diseases has been addressed in recent studies, currently the only environmental condition that is consistently associated with high tick densities is forested habitat (Killilea et al, 2008). This emphasizes the need for more in-depth investigations into the abiotic and biotic factors that influence tick distribution and survival.

Tick abundance is indicative of the suitability of an environment for tick development at all life stages (Guerra et al. 2002). The environmental factors that have been shown to influence tick survival include soil composition, plant and animal composition, precipitation, and climatic and microclimatic conditions (Bunnell, 2006; LoGiudice et al, 2002; Ostfeld and Keesing, 2000). Additionally, different species of ticks have varying tolerance levels for each of the aforementioned environmental factors. For example, ticks of the *Ixodidae* family are more vulnerable to desiccation than other families of ticks and require regions that have sufficient moisture levels and ground cover to survive (Soneshine, 1991). This may explain why high tick densities have been associated with forested regions that have sufficient leaf litter and suitable temperature and moisture controlled microclimates near the soil (Guerra et al, 2002; Killilea et al, 2008).

While the relationship between soil composition and tick survival is arguably one of least studied, it is not unreasonable to assume that soil pH and composition could impact tick survival given that ticks spend most of their lives in contact with the soil (Bunnel, 2006). For example, in the Western United States, tick prevalence was negatively associated with clay soil but positively associated with well-drained, loam-sand soil textures (Guerra et al, 2002). Bedrock below a region also influences tick survivability by affecting the soil type and composition and the types of plants and animals that can become established (Guerra et al, 2002). However, it is extremely difficult to separate the wide array of climatic and environmental conditions that can influence tick survival: a region of sandy, well-drained soil may be habitable to ticks when coupled with sufficient rain, vegetation, and leaf litter to keep the soil moist, but this same sandy soil may not be habitable to ticks in more exposed, dryer circumstances (Bunnel, 2006).

Because human activities that impact the environment may also affect tick distribution, it is important to understand how anthropogenic forces alter environmental conditions. Land fragmentation practices have been shown to lower species diversity and increase the prevalence of mammals like the white-footed mouse, eastern chipmunk, and white tailed deer, all of which have been shown to be sufficient hosts for ticks

(LoGiudice et al, 2002; Li et al, 2012; Morlando et al, 2012). With its proximity to a heavily populated urban area, the Albany Pine Preserve in Albany, New York, is a region that has sustained considerable fragmentation as a result of human activities and is also characterized by high blacklegged tick densities.

The native Pine Bush habitat is composed of grasslands, rolling sand dunes, small shrubby plants, and subsequently dry, infertile, acidic soils (Guerra et al, 2002; www.albanypinebush.org; Rittner, 1976). These conditions are not normally associated with high blacklegged tick density (Guerra et al. 2002, Ostfeld et al. 1995). However, as mentioned, over 90% of the Pine Bush has been severely altered by human development, resulting in fire suppression and invasion of non-native plant species like the black locust tree (*Robinia pseudoacacia*). The encroachment of this tree has resulted in an increase in nitrogen fixation in the soils, enriching the native sands and creating a forested canopy that impacts climatic and microclimatic conditions (https://www.albanypinebush.org/pdf/Ecology-Black%20Locust%20Invasive.pdf; www.albanypinebush.org). This dramatic change from a native, dry, and exposed environment to one that is forested has occurred in many regions of the Pine Bush and could partially explain the high tick densities (Li et al, 2012; Civitello et al. 2008; Patz et al. 2004; Morlando et al., 2012).

While it is important to understand how environmental and anthropogenic factors combine to impact blacklegged tick distribution as it occurs in nature, it is also potentially beneficial and insightful to separate these factors in the lab and investigate them individually. For example, Bunnel (2006) suggested that soil pH could decrease the availability of certain trace metal nutrients to tick eggs in the layer of soil closest to surface (known as the A horizon), but this theory remains to be tested. This study served to remove controllable abiotic and biotic factors that impact tick survival and investigate the extent to which soil pH and composition alone can impact engorged nymphal tick molting success.

METHODS

Tick Collection

A total of 8 chipmunks from the Albany Pine Bush were trapped and held for a 72 hour period. During this time, engorged nymphal and larval ticks that fell off of the chipmunks were collected and placed in vials containing moistened Plaster of Paris. Because the time between the initial collection of the ticks and their placement in the soil was as long as four weeks, the ticks were refrigerated during this time to slow blood meal digestion and development.

Experimental Setup

A factorial design was used to increase potential statistical significance of the experiment. The ticks collected were placed in 1 of 4 differing soil treatments: Pine Bush unaltered soil (acidic), Pine Bush altered soil (basic), playground sand (acidic), playground sand (basic). The usage of two different soil types was to correct for the possible effects of microbes and soil texture on tick molting success.

Creation of Microhabitats

Ticks were distributed equally between 29 Tupperware containers. Each Tupperware contained 1 to 2 nylon mesh bags that held no more than 5 ticks each. The mesh bags were approximately 1.5 in long and 0.5-1.0 in wide. The edges of the bags were hot-glued and folded over twice to be sure ticks could not escape. Reservoirs for liquid were created at the bottom of the containers using ¼ inch wire mesh. Each container had a 100% cotton strip that went from the liquid reservoir to soil sample to act as a wicking agent. The reservoirs were manually replenished with water on a daily basis to maintain a constant level of moisture in the soil.

Soil / Sand Collection and Preparation

Soil was collected from a forested parcel (corner of New Karner Rd. and Washington Ave. Extension) in the Albany Pine Bush Preserve in Albany, New York. This site is known to have a low pH of 4.7 and also harbor high tick densities (LoGiudice personal communication). Twigs, leaves, insects, and other unwanted debris were removed from the soil and it was homogenized. To determine the pH of the soil, 5 g of soil was mixed with 20 mL deionized (DI) water and agitated for approximately 2 minutes. A pH reading was taken once most of the suspended soil particles settled.

The playground sand, also known as silica dioxide, was purchased from a local hardware store. The sand was rinsed 10 times with tap water and the supernatant was poured off to remove fragments of minerals and organic matter that could alter the pH. It was then homogenized, rinsed 10 more times, homogenized again, and rinsed 2 times with deionized (DI) water. The sand was baked in a drying oven at 105°C for 24 hours to control for microbes and burn off any extra organic material. The silica dioxide did not alter the pH of the DI water, indicating that the sand had little to no measurable hydronium or hydroxide ions.

Altering pH of Soil and Sand

Because the pH of the Pine Bush soil sample was already naturally acidic with a pH around 4.5, one half of the Pine Bush soil sample remained unaltered. In order to raise the pH of the other half of the Pine Bush soil, limestone garden fertilizer ($CaCO_3$) was ground up with a mortar and pestle to increase surface area of the particles and increase the extent and speed of dissolution. A predetermined ratio of 1 cup soil to 10-11 g $CaCO_3$ to 50 mL DI water was used to prepare 40 cups of altered soil (Davis, 2012; Hillenbrand, 2012). Contents were mixed thoroughly by hand to be sure the samples were effectively homogenized. The containers were then labeled, covered, and allowed to sit for 3-4 weeks. A pH of approximately 7.2 was achieved after the treated soil was allowed to sit for four weeks

To alter the pH of the playground sand, an aqueous plant extract was prepared (Manadou, 2007) by crudely breaking up dried twigs, leaves, and pine needles and mixing them with water in a blender for approximately 3-5 minutes. The resulting slurry was covered and allowed to sit for 24 hours. The solution was then strained through cheese cloth to remove the large particles and the extract was diluted with DI water.

To lower the pH of the unaltered Pine Bush soil, 4 mL of 1M H_2SO_4 solution was added to one half of the plant extract. To increase the pH of the other half of the plant extract, approximately 136 g of limestone was ground with a mortar and pestle, added to 500mL of water and mixed, and stirred over low heat until most of the solid had dissolved. This solution was then added to approximately 750 mL of the plant extract to raise the pH to 7.3. Approximately 2000 mL of the acidic and 2000 mL of the basic plant extract was made. The solutions were placed in flasks and autoclaved to destroy entomopathogenic microbes. Prior to being autoclaved, the plant extract had a pH of about 4.7. After being autoclaved, the pH increased to roughly 4.9. It is interesting to note that the smell of the diluted plant extract was noticeably different after being autoclaved and the color of the liquid turned to a darker brown.

Distribution of Ticks into Soil / Containers

The distribution of the ticks within the four soil treatments was randomly determined by flipping a coin. Prior to placing the ticks in the mesh bags, the Pine Bush soils and playground sands were wetted with either DI water or one of the pH-altered plant extracts. Approximately 5 g of soil was added to each mesh bag, ticks were randomly selected and delicately placed in the soil, and the bags were sealed with hot glue. The bags were placed in the labeled Tupperware containers and soil/sand was filled in around them so that a small portion of the top of the bag was still visible. The bags were then "watered" with either DI water for the Pine Bush soil or the plant extract for the playground sand. Reservoirs were also filled.

Tick and Soil Maintenance

The completed Tupperware containers were placed on 2 large metal trays lined with Vaseline to reduce the potential of tick escape. Watering frequency was subjectively determined based on a wetness scale of 1 to 4. When soil wetness was considered to be below a rating of 1.5 on the scale, the soil was watered until sufficiently moistened. Notes regarding the wetness of the soil were kept during the first month of watering when moisture levels were not consistent.

Removing Ticks from Soil

All bag numbers were written on pieces of tape and then scrambled in order to randomize the time in which ticks were removed from the soil. A modified Berlese-Tullgren funnel technique (Figure 1) was used to remove the ticks from the soil (Barton 1995). Both the beaker and the large plastic container were filled with a small amount of water to prevent tick escape. A bright light was placed above the apparatus to dry the soil and encourage ticks to move away from the heat, down the funnel, and into the water. A Petri dish was taped in the center of the funnel so that the sides of the dish did not touch the edges of the funnel. The outer container was lined with Vaseline.

Individual tick bags were placed on a Petri dish inside the funnel and carefully cut open with scissors. Because most of the live, molted adult ticks were located along the inside edges of the mesh, it was easy to spot and remove them before they fell in the water. If not all ticks were claimed in the initial inspection of the bags, the soil was spread out inside the Petri dish and allowed to dry underneath the heat lamps. Once the soil was sufficiently dried, it was carefully inspected to search for dead, unmolted, or live ticks for a standardized period of 10 minutes. It took 5 days to remove all of thel ticks from their bags.

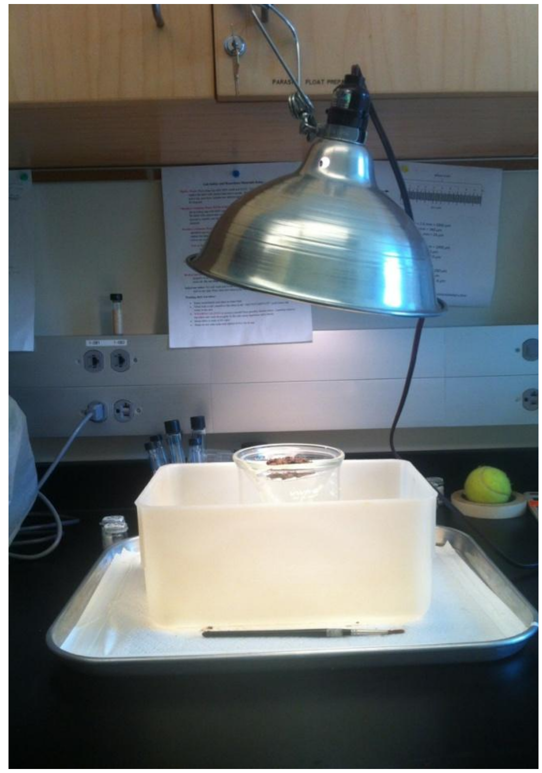

Figure 1: Modified Berlese-Tullgren technique used to remove ticks from soil (Barton, 1995).

RESULTS

Out of the 203 ticks that were collected and placed in the various soil treatments, 37 individuals molted, giving an overall molting percentage of 19.2%. The molting percentage per soil treatment was calculated by dividing the number of ticks molted per treatment by the total number of ticks placed in that treatment: 35.1% ticks molted in the acidic Pine Bush soil, 14.4% molted in the basic Pine Bush soil, 19.9% molted in the acidic playground sand, and 5.6% molted in the basic playground sand (Table 1). An ANOVA was used to calculate any significance between molting success and soil pH and type. The effects of soil type and soil pH were both significant ($p=0.03$ and $p=0.003$

respectively) (Figure 2). Because the number of ticks that were exposed to each treatment was not of normal distribution, a non-parametric Kruskal-Wallace ANOVA was done to further test the significance of these results. The differences between soil type were found to be significant (p=0.02) and the differences between soil pH were very significant (p=0.004). There was no significant difference between numbers of males molted and numbers of females molted (p=0.72).

Although the ticks were removed from their soil treatments over the course of 5 days, no significant differences were found between number of molted ticks and the day they were removed from the soil (p=0.15). Similarly, no significant differences were found in molting probabilities based on which host each tick fed on (p=0.43).

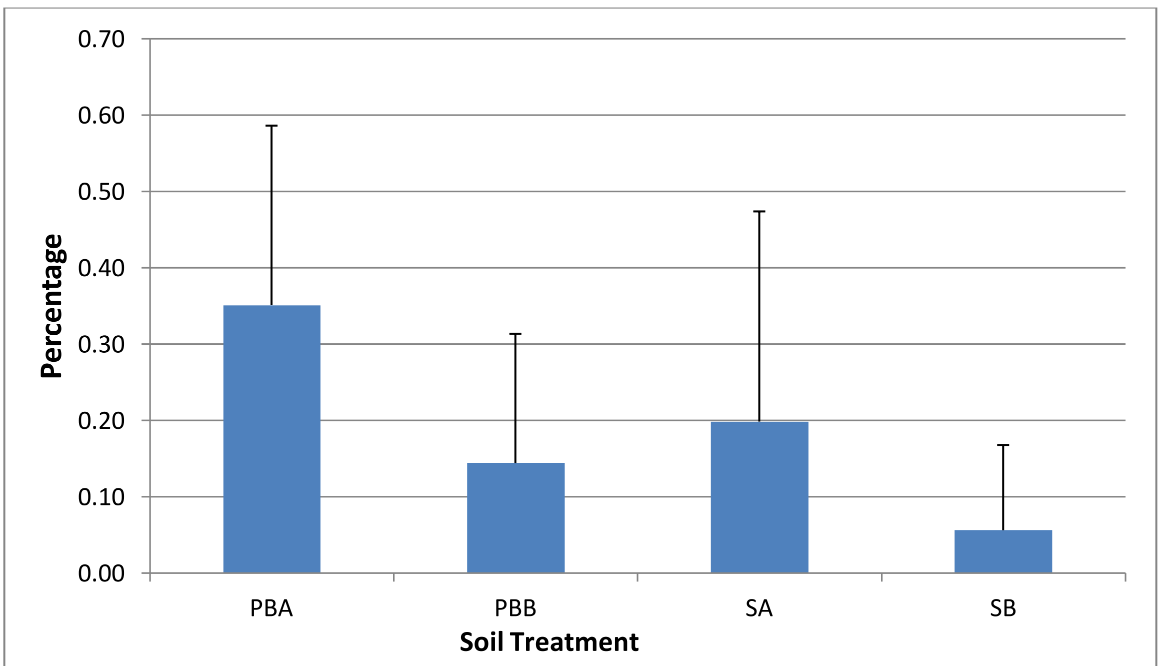

Figure 2: Percentage of molted ticks per soil treatment. PBA = Pine Bush acidic; PBB = Pine Bush basic; SA = playground sand acidic; SB = playground sand basic.

DISCUSSION

Results suggest a relationship between tick molting success and the pH of the soil where tick molting success was higher in the acidic soil treatments (Pine Bush soil and sand). This implies that acidic soil conditions favored engorged nymphal tick molting success. Reasons for this are relatively unclear and further research is necessary to understand what physiological effects soil pH may have on ticks. It is possible that the pH of the soil may impact the water balance of *Ixodidae* ticks, which are more sensitive to water loss than other types of ticks. Ticks absorb water from the atmosphere actively or passively through their mouth parts and spiracles in the cuticle (Sonenshine, 1991) and pH may somehow interfere with this. It is also possible that the method used to raise the pH of the soil ($CaCO_3$ fertilizer) was toxic to some of the engorged nymphs. It would be interesting to see if the Pine Bush soil pH could have been raised using less limestone fertilizer and if this would decrease the mortality in basic soils. Overall, based on the parameters of this experiment, it is difficult to assess whether the limestone fertilizer was toxic to the ticksor if the ticks were actually less tolerant of basic pH.

Molting success was also affected by the composition of the soil, however, the relationship was slightly less significant than the relationship between molting percentage and pH. The ticks had higher molting success in the Pine Bush soils than the sands regardless of pH treatment. This is not a surprising because the Pine Bush soils are of a loam-sand composition that promote sufficient drainage and retain moisture better than purely sandy soils.

Another potential explanation for the significant difference in molting percentages in the soil textures could be the dissimilarity in pH altering methods used for sand samples and Pine Bush soil samples. Because the Pine Bush soil was altered with Limestone fertilizer prior to placement of ticks, both Pine Bush soil treatments were watered with plain DI water. However, the pH of the sand treatments was altered using an aqueous solution that was poured over the ticks whenever they were watered. Exposing the ticks to pH using these different methods may have contributed to differences in molting percentage.

It was important that the ticks were forced to be in contact with the soil during the entire molting process, thus they were placed in the middle of the soil samples in the mesh bags with soil on top and below them. While this method ensured the ticks were constantly exposed to the soils and pH, it may have caused an unsuitable molting habitat for the ticks, restricting their ability to move where they were most comfortable within the bag. Compaction due to watering and gravity may have caused some ticks to suffocate. Ideally, ticks would have been placed on top of the soil with leaf litter to provide the most natural molting habitat, but this was not possible for the purposes of this experiment. A future experiment may have higher molting percentages if the ticks are placed on the surface of the soils within the mesh bags, instead of placed within the soil.

Overall, total tick molting percentage was low at 19.2%. This is likely associated with the difficulties of maintaining suitable microclimates for ticks in an artificially created laboratory environment. While moisture levels were checked consistently throughout the experiment, no quantitative technique was used to determine the exact moisture levels within each Tupperware. According to LoGiudice et al (2002), average molting percentage for ticks that feed on the Eastern Chipmunk is around 41.2%, which is more than double the molting percentage observed in this experiment. Additionally, it has been shown that tick molting percentage can vary based on individual blood meals (Sonenshine, 1991; Brunner et al, 2011), host species (LoGiudice et al, 2002), and intraspecific host differences (Brunner et al, 2011). While there were no significant correlations between molting success and the host, the sample sizes differed greatly for each host, decreasing the statistical power to detect differences if they exist. It has also been suggested that the types of microbes a tick carries may impact its molting success (Samish, 2004).

Further investigation into this topic is necessary to investigate the effects of soil pH and composition on ticks and truly understand any possible relationship. Potential studies for the future include an extenuation of this project by testing molting success and survival rates at different life stages for engorged and flat ticks, performing field tests of tick molting success in naturally occurring basic and acidic soils, and creating soil treatments that incorporate entomopathogenic microbes because soil pH changes can impact microbial community in the soil (O'Donnell, 2001).

Because research regarding vector-borne ecology is only recently becoming a topic of increasing concern, there are countless questions that can be asked, especially those that are very basic and fundamental. This preliminary research suggests that soil pH may impact engorged nymphal tick molting success and supports past research that soil composition impacts tick molting percentage. The current data and future research pertaining to this topic may be helpful in predicting regions of high tick densities, future range expansions, and tick-borne disease exposure based on location. Understanding what environmental conditions support and disrupt blacklegged tick dispersal and survival could also lead to tick control methods that may have helpful implications for public health.

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Avian Window Strike

Mortality on Union College Campus

By

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ABSTRACT

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ADVISOR: Kathleen LoGiudice

Window glass has enriched the lives of humans for decades by encouraging economic development, allowing for aesthetically pleasing architecture, and fueling infrastructural creativity. Unfortunately, it has become apparent in recent years that window glass is also contributing to the deaths of hundreds of thousands of birds throughout the world annually. The widely accepted explanation for this is that birds do not recognize windows as barriers due to glass reflectivity and general transparency. In order to investigate the prevalence of bird-mortality at windows on the Union College campus, a survey was designed to investigate the prevalence of bird-window collisions on campus. Windows were selected based on overall vulnerability to bird strikes, which has been shown to be influenced by proximity to vegetation, overall reflectivity, orientation, and transparency. Results revealed that bird-window collisions and window-related bird deaths are relatively common on campus, with windows from Upper Class Dining in the Reamer Campus Center being the most vulnerable. In an effort to educate the campus community on the scale of this problem and reduce the number of bird strikes at Upper Class Dining, the results of this research were used to develop a $25,000 grant proposal for Union College's first annual Green Fee Grant. This project called for the installation of special bird-friendly fritted glass in Upper Class Dining that would simultaneously reduce bird strike prevalence and energy usage in the building. While the project was not funded, it was a finalist in the selection process, suggesting that this is a recognized problem on campus that may be addressed in the future.

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INTRODUCTION

While window glass has served to enhance the lives of humans and foster economic growth worldwide, it is also a passive killer of birds (Klem, 2006). There is mounting evidence to suggest that bird-window collisions are the second largest killer of birds behind habitat destruction (Klem, 2006), which is based on an estimate that 1 to 10 birds are killed at each building in the United States annually. This figure suggests that bird mortality rates in the United States range anywhere from 97 million to 1 billion deaths per year (Klem, 2008). These harmful and potentially fatal collisions occur because birds do not recognize clear glass as barriers, instead seeing reflections of vegetation, reflections of sky, or seeing straight through (Klem, 2006; Gelb, 2009; Klem 1991). As human societal growth and development increases, it can be expected that bird-window collisions will also increase, emphasizing the need to research possible solutions to this problem.

Bird population decreases due to window glass collisions have many negative ecological implications (Klem, 2008). Not only do birds have an inherent right to exist, they are also beautiful animals that pose an aesthetic quality for humans. They are also indispensable aides in controlling insect and rodent populations that are often vectors of infectious disease. While there are currently no universally accepted methods for eliminating bird-window collisions, there are a number of ways that have been shown to limit and even eliminate bird strikes (Klem, 2006). Unfortunately, many of these options sacrifice the artistic and architectural values of buildings and are written-off for these reasons.

One way to decrease bird-window collisions is to install window screens and nettings in front of windows that prevent birds from hitting the hard surface (www.birdscreen.com; Klem, 2006), however this option is inappropriate and unappealing in many architectural situations. Another option is to place sticker decals on the outsides of windows that reduce reflectivity and make the window appear solid to birds. Sticker shapes can range from vertical and horizontal stripes to falcon silhouettes, but in order for this option to work, stickers must be placed no more than 5 to 10 cm apart (Klem, 2006). Other inexpensive and simpler options include hanging vertical strings from windows, white washing windows, and closing blinds. Landscaping can also be modified to discourage bird-window collisions although this option is not fool proof and is best if used in conjunction with clear glass alterations. Fritted glass, as mentioned, is a more permanent solution that has granules fused to the glass surface, making windows appear solid to birds by decreasing transparency and reflectivity (Klem, 2009; www.audobon.org). One major problem that spans all of these solutions is how to mitigate avian mortality at windows without hindering the artistic and aesthetic qualities of buildings.

Union College has addressed the issue of bird-window collisions in its first LEED certified building, the Peter Irving Wold Center, by installing fritted glass in the West and North-facing sides of the building. LEED, which stands for "Leadership in Energy and Environmental Design," is an internationally recognized program that provides a framework for environmentally friendly design, construction, and operation (U.S. Green Building, 2011), although it does not currently have any specific guidelines for preventing bird-window collisions. While fritted glass has been shown to be an effective solution for bird strikes, Union College only installed this glass on the top halves of these large windows, most likely to decrease the visibility of the frits to people inside and outside of the building.

In order to investigate the effectiveness of the “half-fritted” glass windows located in the Wold Building and assess the prevalence of bird-window collisions on campus, I designed a campus survey. Windows were selected based on factors that are known to increase bird strike vulnerability. The goals of this study were to determine windows that are most vulnerable to bird strikes on campus, investigate the effectiveness of the “half-fritted” glass windows of the Wold building, and educate the campus community on avian mortality at Union.

METHODS

A total of 6 buildings were taken into account for the campus bird strike survey: Reamer Campus Center, Peter Irving Wold Center (fritted glass), F.W. Olin Center, Science and Engineering, Alumni Gym, and Schaeffer Library. These buildings were selected based on their overall vulnerability to bird strikes with consideration toward their overall size, vicinity to vegetation, and reflectivity. For this experiment, the Nott was taken to be the center of campus and all labeling directions were relative to the Nott. For example, West College was considered the Western direction, Reamer was considered North, Alumni Gym was considered East, and Old Chapel South. The survey was conducted every day from March until June, then once to twice a week from August to September, and three to four times a week from September to November. While the survey was performed until March, 2013 by another student who extended this research project, for the purposes of this paper October 31st will be considered the last day of the survey. Additionally, it is important to mention a 3 week gap of time from late August to mid-September where the survey was not conducted. Data regarding the discovery of dead birds was collected over the duration of the experiment, but some dead birds found prior to the start of the survey by members of the campus community were also recorded.

There were two ways in which bird mortality was recorded. One was with the discovery of a dead body in the vicinity of glass by either the surveyor or a member of the campus community. The other method was with the walking survey, as mentioned. The Smudge Log, where all bird strikes were recorded, contained photos of each window of interest and when a new smudge appeared, it was marked on the proper photograph with an X and dated.

Smudge Identification

Smudges were identified based on inspection with the naked eye or binoculars. Bird smudges are characterized by grease marks on the outsides of windows and sometimes the outline of a wing or other body part can be seen (Figure 1). Small feathers and other debris could also sometimes be made out in the smudges. If there was any serious doubt about the smudge's bird-origin, it was not recorded in order to limit error.

Figure 1: Example of a bird smudge. Resembles a grease mark; occasionally the shape of a wing can be made out (http://lansingwbu.blogspot.com/2010/09/how-to-prevent-window-strikes-during.html).

CAMPUS SURVEY:

Reamer Campus Center: The survey began at the front entrance of Reamer, with the surveyor checking the large front windows for grease marks indicative of bird strikes. The surveyor continued around the entire perimeter of the building, taking special care to look for bird carcasses underneath windows. Once the perimeter of the building was completely investigated, the surveyor checked the second floor windows of Upper Class Dining for smudges from the inside.

Peter Irving Wold Center and F.W. Olin Center: The surveyor went from Reamer to the North facing fritted glass windows of the Peter Irving Wold Center and the windows of the F.W. Olin Center.

Science and Engineering: The windows within the courtyard between Science and Engineering North and the Steinmetz building were checked from the outside. The "bridge" that connects Steinmetz to Science and Engineering North was analyzed from the outside using binocular because this was determined to be a "hot spot" for bird strikes based on information from facilities and grounds workers. The ground in this area was closely examined window-strike victims.

Alumni Gym: The surveyor checked the front, cylindrical shaped entrance of Alumni Gym that has small square-shaped windows. They then walked to the East facing windows of the Gym that overlook the softball field and checked all of these glass doors and windows for smudges and bodies.

Library: The windows along the foundation of the first floor of the Library were checked from the outside and the second floor windows were checked with either binoculars or from the inside. The large windows on either side of the second floor atrium were examined, as well as the second floor windows in the front of the Library. It was important to check the ground next to the foundation of the Library, including the front walkways and patios, because facilities workers often find dead birds here. Additionally, special care was taken to check the ledges below the large windows of the second floor atrium because (Figure 2).

During the campus survey, special care was taken to check the ground around windows for dead birds. A newspaper article was printed in the campus newspaper to educate the campus community about the research project and encourage students to contact me regarding witnessed bird strikes or bodies. Because dead bodies and bird smudges disappear quickly due to predators, weather, insects, facilities workers, and other factors, it was important that the survey was done as often as possible.

Figure 2: Photo of skeltonized bird carcass on ledge outside large windows of the second floor Library atrium.

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RESULTS

Forty eight windows and 8 buildings were observed for the duration of this experiment. A total of 99 bird strikes were recorded from April 30, 2012 to October 31, 2012. Because of the qualitative nature of this experiment, standard deviations were very high and quantitative statistics were irrelevant. The set of windows that had the most recorded strikes were located within Upper Class Dining, with 44 total strikes, followed by the Schaeffer Library with 18 strikes, and Alumni Gym with 14 strikes (Figure 3). In order to normalize the data, the average number of strikes per window was calculated (Figure 4).

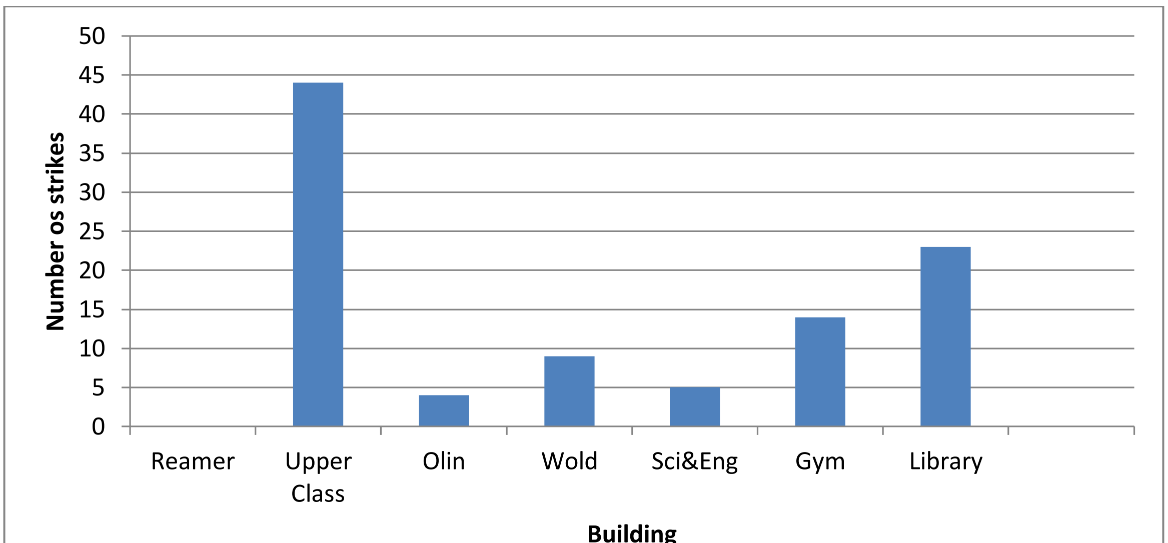

Figure 3: Number of bird strikes per building on Union College campus. Note that Wold building windows are composed of half fritted glass and have clear glass.

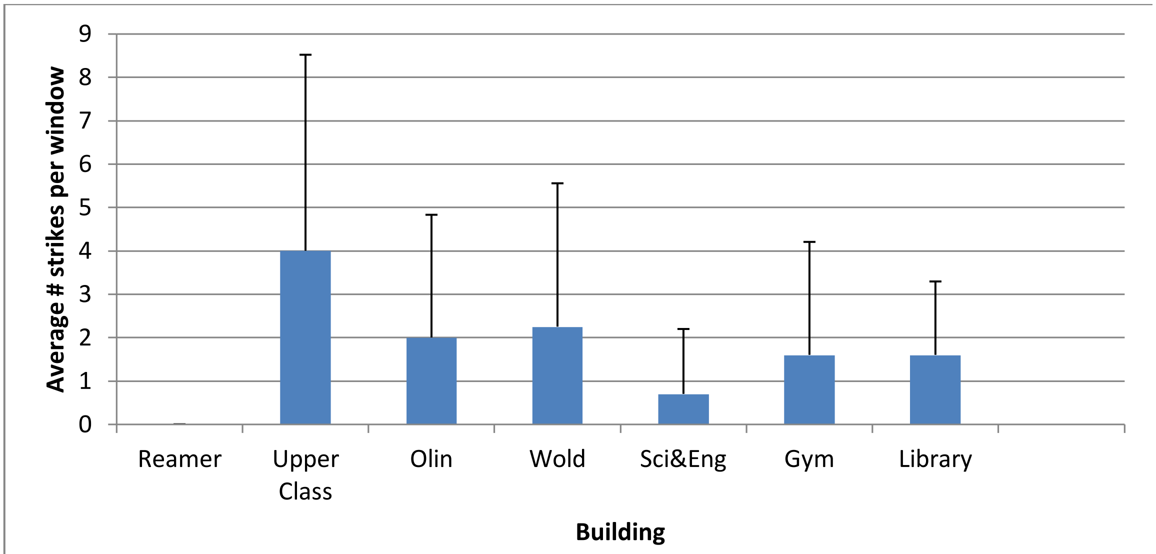

Figure 4: Average number of bird strikes per window per building on Union College Campus. Note that Wold building windows are composed of half fritted glass and half clear glass.

Amongst these heavily hit buildings, there was a total of 8 windows that had a notably high number of strikes (5 or more). Five of these windows were in Upper Class dining, while the remaining 3 were in Wold, Alumni Gym, and Schaeffer Library (Figure 5). It was determined that seasonality did not have any significant impact on the prevalence or consistency of bird strikes at these locations.

Thirty five dead birds were found during this study. The date of discovery was recorded, along with the state of the remains, the location of the bird, and the species. Members of the campus community were very helpful in finding dead birds. Twelve different species were found in the vicinity of the buildings examined in the campus survey (Figure 6). There were 15 birds in which the species was unknown, either due to decomposition or the disappearance of the bird before the species could be identified (Figure 7), but out of those that were identified the majority were American Robins.

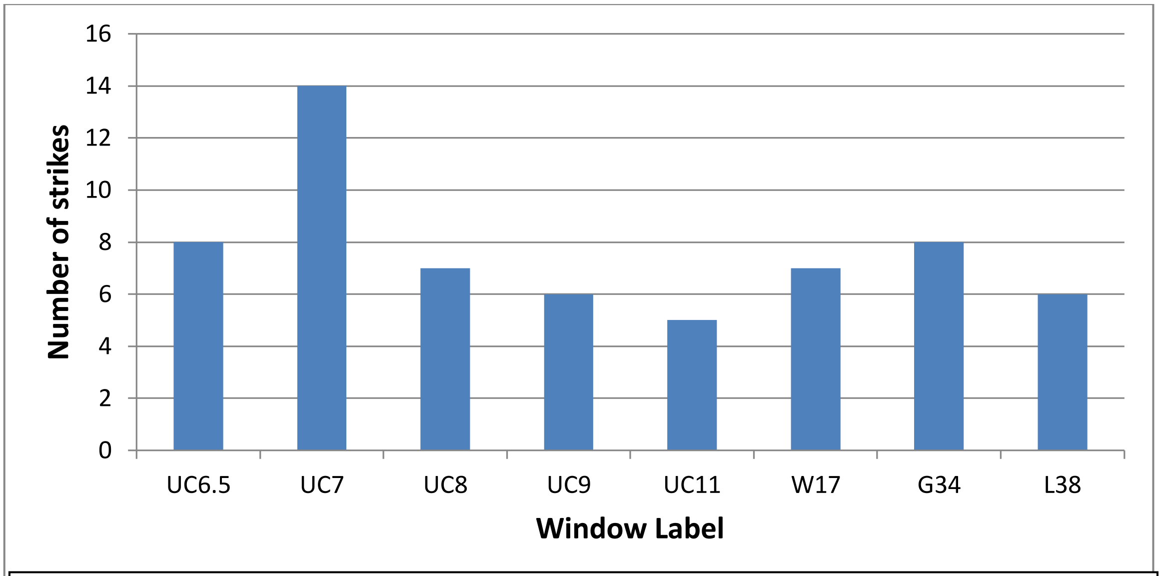

Figure 5: Number of bird strikes on most heavily hit windows on campus. Note that 4 of these windows are from Upper Class Dining (UC) and the remaining 3 are from Wold (W), Alumni Gym (G), and Schaeffer Library (L) respectively.

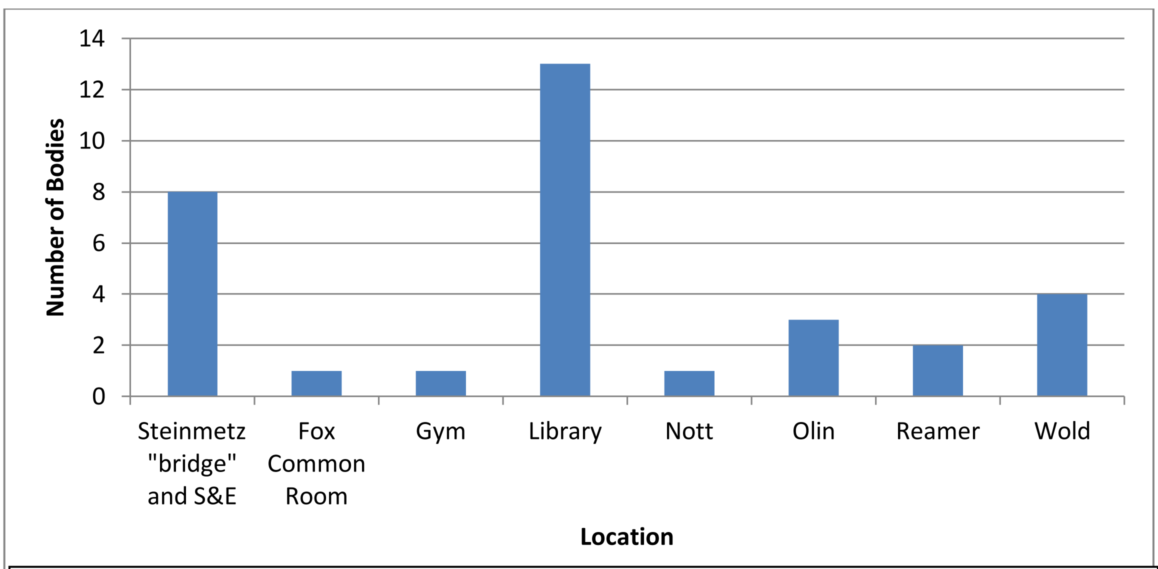

Figure 6: Sum of dead birds and remains found in close proximity to buildings included in campus survey. Note that Wold windows are half fritted glass and half clear glass.

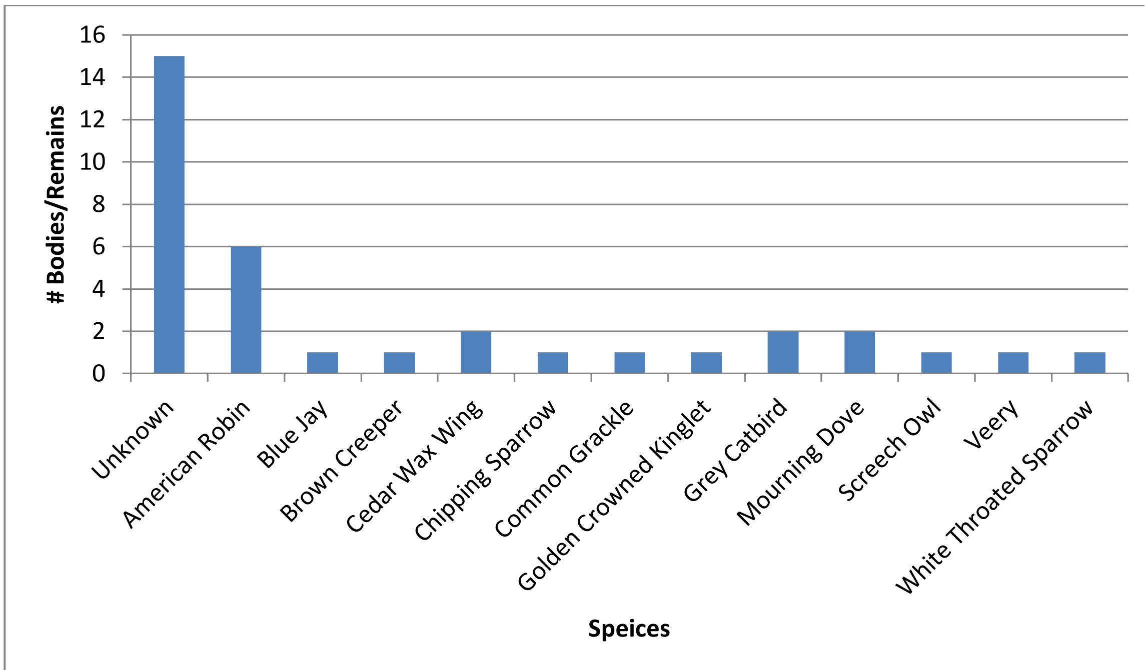

Figure 7: Number of dead bodies/remains found per species.

DISCUSSION

It is difficult to quantitatively assess bird-window collisions, largely because 1 in 4 bird strikes leave no evidence of a collision after 24 hours and up to 25% of bird strikes go unnoticed (Klem, 2009). Additionally, bodies may become hidden in vegetation below windows and quickly disappear due to the elements, decomposition, facilities workers, or predators. Based on Daniel Klem's (2006) assumption that 1 to 10 birds are killed at each building in the United States annually, it can be estimated that the number of bird deaths on Union College campus ranges anywhere from 75 to 750 deaths per year. The lower end of this spectrum is likely a more accurate assumption because Union College is not in line with any significant migration patterns.

The installation of fritted glass on the large windows in the Peter Irving Wold Center did not eliminate the incidence of bird strikes when compared to other windows on campus. This is most likely because the large windows in this building are only half fritted: the top halves of the windows have fritted glass, but the bottom halves at eye level are clear glass (Figure 8). This was most likely done for aesthetic purposes in an effort to limit the appearance of the fritted glass to people inside and outside of the building. However, from an ecological point of view, this is a significant design flaw that only limits bird strikes for a portion of the window. This study suggests that in order to increase the environmentally friendly aspect of the Wold building, fritted glass or a fritted glass alternative should be installed on these lower windows that are still vulnerable to bird strikes. This building cannot be considered entirely Green and "bird friendly" until modifications occur.

The windows of Upper Class Dining, located on the second floor of the Reamer Campus Center, had the highest number of recorded bird strikes. This is most likely because the area below the window is part of Jackon's Garden, which supports high levels of vegetation and wildlife. This idea is supported by the theory that the best predictor of bird strike prevalence is the density of birds within close proximity to a window and the best indicators of high bird densities are vegetation, water sources, and food sources (Klem, 2009; Hager, 2008).

Figure 8: West facing windows in Peter Irving Wold Center. Note that only the top portion of the window is fritted.

While the windows of Upper Class Dining were of the most heavily struck by birds, (see Figure 3), one window had almost twice as many strikes as the second-most-struck window, which may be due to its close proximity to trees located approximately 5 to 10 ft away. Because the area underneath these trees is near a commonly used path behind Reamer Campus Center, it is possible that birds perched in the tree may be startled by people walking by, attempt to flee, and strike the window.

Thirty five dead birds of 12 different species were recorded during this study. The majority of dead birds recorded were of unknown species. This was due to either the decomposition of the bird or news of the dead bird from a second party who did not identify the species. The most commonly found dead bird was the American Robin, which may be because Robins are year-round residents in Schenectady, thus increasing their overall chance of hitting a window on campus. Further research is necessary to determine what other possible factors may contribute to a bird species' vulnerability to striking a window.

The building around which the most bodies were found was Schaeffer Library. Thirteen dead birds were found at this location from April 30 to October 30. This may be because the Library is a very central building on campus that students often walk by during the day, increasing the chances of a dead bird spotting. Additionally, there is a large amount of pavement surrounding the front entrance of the Library, which may explain why 6 of the 13 birds were found around the front of the building.

Another possible explanation for the high prevalence of bird mortality around Schaeffer Library may be the vegetation located sporadically around the building. It has been shown that fatalities occur more frequently when bird feeders are placed within 5 to 10 m of glass and fatalities decrease dramatically when feeders are placed approximately 1 m from a window (Klem et al. 2004) This is based on the idea that if a bird is startled at a bird feeder that is only 1 m away from window glass, it will not be able to gain enough velocity to injure itself if it runs into a window, but the further the feeder is from the window, the more time the bird has to build up speed. This phenomenon may be occurring at the windows around the Library, where the trees are analogous to bird feeders and most are 5 to 10 m away.

Eight bodies were found in the vicinity of the Science and Engineering building, giving it the second largest number of recorded dead birds. Exactly half of these bodies were found within immediate proximity to the “bridge” that connects Science and Engineering North to Steinmetz. This bridge may be especially vulnerable to bird strikes because birds can see straight through the windows located on each side, possibly mistaking them for passageways (Figure 9). Additionally, there are numerous trees that are more than 5 to 10 m away from the windows, and the angle of these windows may cause reflections of the sky and vegetation (Klem, 2006).

Although the Peter Irving Wold Center is outfitted with bird-friendly fritted glass, it was ranked third in terms of the number of dead birds recorded. As mentioned earlier, this result is not surprising considering only the top half of these large windows are outfitted with fritted glass.

Figure 9: “Bridge” connecting Science and Engineering North to Steinmetz. Note the trees and vegetation around windows, as well as the fact that one can see from one window through the parallel window.

It was difficult to compare bird strike prevalence between seasons due to uneven survey frequency during each season. The Spring surveys were conducted almost every day of the week, whereas Summer and Fall surveys were conducted 2-3 times per week.

The results of this study suggest that the fritted glass in the Peter Irving Wold Center is inadequate at preventing bird-window collisions. This study also suggests the need to install fritted glass windows or stickers on the most vulnerable windows of Upper Class Dining and the Steinmetz to eliminate the high incidence of bird strikes. Not only will this option reduce bird strike prevalence, but it can also reduce the amount of sunlight that penetrates the windows, possibly decreasing cooling costs during the Spring and Summer seasons.

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