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# Habitat Preferences of the Common Nighthawk (Chordeiles Minor) in Cities and Villages in Southeastern Wisconsin

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# HABITAT PREFERENCES OF THE COMMON NIGHTHAWK *(CHORDEILES MINOR)* IN CITIES AND VILLAGES IN SOUTHEASTERN WISCONSIN

by

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ABSTRACT

HABITAT PREFERENCES OF THE COMMON NIGHTHAWK *(CHORDEILES MINOR)* IN CITIES AND VILLAGESIN SOUTHEASTERN WISCONSIN

by

Jana M. Viel

The University of Wisconsin-Milwaukee, 2014
Under the Supervision of Professor Glen Fredlund

Limited survey data and numerous anecdotal accounts indicate that the Common Nighthawk *(Chordeiles minor)* is experiencing population declines in Wisconsin. However, the magnitude of the decline is unclear because current avian monitoring efforts are not conducted at dusk when Common Nighthawks are most active nor do they specifically target urban areas such as cities and villages where Common Nighthawks are known to nest on flat graveled rooftops. New ‘urban’, crepuscular monitoring methods are needed in order to gain a better understanding of current Common Nighthawk demographics in Wisconsin.

The goal of this thesis was to conduct a baseline study using citizen science-based methodology to determine where Common Nighthawks persist in cities and villages in southeastern Wisconsin. The objectives of the study were to collect information on environmental factors, landscape features, and land cover types of potential importance to Common Nighthawks during the breeding season and then analyze the data collected to investigate correlations between each variable and Common Nighthawk occurrence at each survey point. The aim was to use the findings of the baseline study to inform current avian monitoring efforts such as the Wisconsin Nightjar Survey so that adjustments allowing for more effective monitoring of Common Nighthawks could be implemented in survey route placement and survey protocol.

Between June $7^{th}$ and July $18^{th}$ 2013, volunteers conducted 1,412 surveys at 494 points in 82 cities and villages within the Southeast Glacial Plains and Southern Lake Michigan Coastal ecological landscapes of Wisconsin. Common Nighthawks were detected in 98 surveys at 68 points in 32 cities and villages. On three different evenings at each point, volunteers conducted 10-minute point counts in which they counted Common Nighthawks and described their behavior. During surveys, volunteers recorded the temperature (°F), estimated the moon phase, and rated the sky condition, wind speed, noise, light pollution, and insect activity. They also counted the number of potential Common Nighthawk predators (e.g. crows, gulls, raptors, and cats), and the number of Chimney Swifts. Volunteers also counted sources of artificial ambient light (e.g. street lights and stadium lights) and flat rooftops surrounding (100 meter buffer) the survey point.

The land cover surrounding each survey point (500 meter buffer) was analyzed from the National Land Cover Database (NLCD) 2011 using Geographic Information Systems (GIS). The number and total area of flat graveled rooftops surrounding each point (500 meter buffer) were estimated from aerial photos taken in 2011 using GIS. Results from statistical analysis of land cover classes suggests that in cities and villages, Common Nighthawks are more likely to be found in areas with higher percentages of impervious or built-up land cover. Agricultural land cover was the only land cover class that demonstrated a statistically significant negative correlation with Common Nighthawk presence. Strong, statistically significant positive correlations were found between Common Nighthawk presence and both the number of flat graveled rooftops and the total area of flat graveled rooftops.

Mann -Whitney U analysis of environmental variables recorded by volunteers suggests a statistically significant negative correlation between Common Nighthawk presence and percent moon illumination. A statistically significant positive correlation was also found between Chimney Swift (*Chaetura pelagica)* counts and Common Nighthawk presence. A statistically

significant positive correlation was also found between Common Nighthawk presence and the two landscape features measured by volunteers (100 meter buffer)—the number of flat rooftops, and the number of sources of artificial ambient light.

DEDICATION

To Erik, because he is the best

To Tucker, because he is my favorite

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| | |
|---|---|
| CONI: | Common Nighthawk |
| CHSW: | Chimney Swift |
| BBS: | North American Breeding Bird Survey |
| GLM: | Generalized Linear Model |
| WNS: | Wisconsin Nightjar Survey |
| WBBA: | Wisconsin Breeding Bird Atlas |
| ZINB: | Zero – Inflated Negative Binomial |

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## Chapter 1: Introduction

The Common Nighthawk (*Chordeiles minor*), hereafter also referred to by the United State Geological Survey bird banding species alpha code 'CONI' (Gustafson et al, 1997), is experiencing population declines throughout most of its range in North America (Brigham et al., 2011). Data from the North American Breeding Bird Survey (BBS) show CONI populations began to decline roughly 40 years ago (Sauer et al., 2011). Between the years 1966 and 2012 CONI populations declined at an annual rate of 2.1% throughout North America (Figure 1a), at a rate of 1.91% in the United States (Figure 1b), and at a rate of 2.2 % in Wisconsin (Figure 1c) (Sauer et al., 2011). Numerous continent-wide anecdotal accounts support the BBS results (Brigham et al., 2011). Citizens have observed that the species seems to have 'disappeared' from many locations. Its absence is most apparent in urban areas such as cities and villages where CONI are known to nest on flat graveled rooftops (Brady, 2009; Brigham et al., 2011). Years ago, the CONI was a common summer sight in Wisconsin cities and villages. Unfortunately, that is no longer the case.

BBS data are collected following a rigorous scientific protocol (see chapter 2 section on 'Avian Monitoring in Wisconsin' for more detail) and are commonly used by researchers to gauge the status of hundreds of avian species in North America (Nebel et al., 2010; Sauer et al., 2011). However, these declining trends may not be entirely representative of all CONI demographics, as BBS surveys are not conducted at dusk, which is the time of peak nighthawk activity (Brady, 2009; Hunt, 2009). Because of this, the magnitude and geography of CONI population decline remains uncertain (Brady, 2009; Hunt, 2009). BBS is not the only source for CONI demographic information and other efforts such as the Wisconsin Breeding Bird Atlas (WBBA) and the Wisconsin Nightjar Survey (WNS), also indicate that CONI are declining (Brady, 2009; Cutright et al., 2006). However, both the WBBA and the WNS have similar

shortcomings with respect to accurate CONI monitoring in that they are not carried out at dusk nor do they target urban areas where nighthawks may be nesting (Brady, 2009; Cutright et al., 2006).

CONI are notoriously difficult to monitor because of their "secretive" behavior and limited window of observable activity (Brady, 2009; Brigham et al., 2011, Hunt, 2009). Because of this, CONI ecology, biology, and demography are not well understood (Allen and Peters, 2012; Brigham et al., 2011). The reasons for CONI population decline are not fully known, but are likely influenced by a multitude of factors including habitat loss, extreme weather during migration, anthropogenic obstacles, predation, and reduction of their food source, aerial insects (Brigham et al., 2011). The aim of this thesis is to better understand one aspect of CONI population decline by determining where nighthawk persistence remains in cities and villages in southeastern Wisconsin and by measuring environmental factors and landscape features associated with those locations.

The goal of this thesis was to use citizen science-based methodology to conduct a baseline study to determine where CONI populations persist in Wisconsin cities and villages. The intent was to produce results that could be used by organizations such as the WDNR to identify urban areas of importance to CONI conservation, as well as to inform current avian monitoring efforts such as the WNS of potential locations for new urban routes in cities and villages where CONI are known to nest. Both the successes and shortcomings of the baseline study protocol could be used as examples by which a more adequate CONI monitoring protocol could be developed.

In addition to locating CONI in Wisconsin cities and villages, one of the objectives of this thesis was to better understand the habitat preferences in of urban-nesting CONI in Wisconsin. It is well known that CONI are attracted to flat graveled rooftops for nesting in urban areas (Brigham et al., 2011). However, anecdotal accounts from Wisconsin indicate that CONI

are not nesting in all urban areas with flat graveled rooftops (William Mueller, personal communication, November 6, 2012). More research is needed to investigate what other environmental factors and landscape features, in addition to flat graveled rooftops, influence the presence and absence of urban nesting CONI in Wisconsin (Brady, 2009).

In this baseline study, environmental factors, landscape features, and land cover types of potential importance to CONI in Wisconsin urban areas were measured and analyzed. The aim of these analyses was to characterize all sites surveyed in this study to gauge the habitat preferences of urban-nesting CONI in Wisconsin. The underlying assumptions of this study were that a better understanding of the habitat preferences of urban-nesting CONI would enable researchers to better predict which cities and villages would be most conducive to breeding CONI and would allow for more efficient selection of CONI monitoring routes. Also, that the placement of urban CONI monitoring routes would lead to more accurate measurements of CONI demographics which would allow researchers to make more informed and timely decisions regarding the conservation of the species (Brady, 2009).

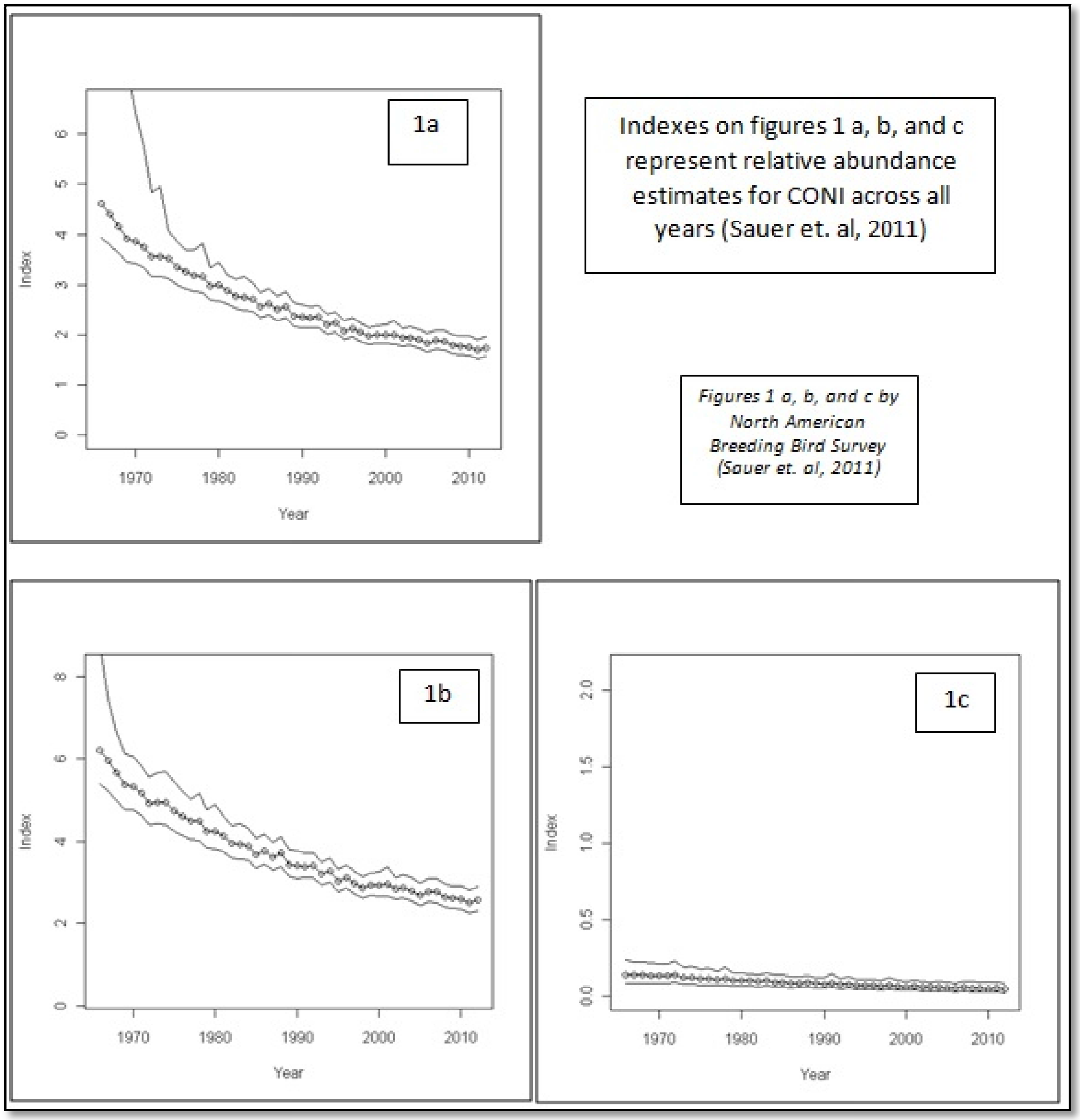



Figure 1: North American Breeding Bird Survey trends for the Common Nighthawk from years (1966 – 2012). a) North America, survey-wide b) United States of America c) Wisconsin

## Chapter 2: Literature Review

### 2.1 Characteristics of the Common Nighthawk

Common Nighthawks are members of the nightjar family Caprimulgidae which includes approximately eighty-nine species worldwide (Brigham, 2006). Eight nightjar species breed in North America, three of which can be found in Wisconsin; the Common Nighthawk, the Eastern Whip-poor-will (*Caprimulgus vociferous*), and on rare occasions, the Chuck will's Widow (*Caprimulgus carolinensis*) (Brady, 2009; Cutright et al., 2006; Temple et al., 2003).

Of the three species found in Wisconsin, the CONI is the only urban dwelling bird. Because CONI often live among humans, they are observed more frequently than both the Whip-poor-will and the Chuck will's Widow, which are found in more rural areas (Brady, 2009; Brigham et al., 2011). When active, CONI are relatively easy to identify by their distinct nasal repeated '*peent*' call, white wing bars (Figure 2), white throat patch (Figure 2), and erratic flight patterns (Brigham et al., 2011).Still, CONI are not as visible as other diurnal avian species and are usually only observed during migration or when they are feeding at dusk. This is because the CONI's primary defense is camouflage and during the day the birds roost or brood motionless on gravel substrate or parallel to tree branches making them less visible to predators (Allen &Peters, 2012; Brigham et al., 2011; Brigham, 1989; Fischer et al., 2004).

Contrary to their name, Common Nighthawks are not hawks nor are they strictly nocturnal (Brigham et al., 2011). They have small feet and fragile beaks that are too weak to grasp and tear prey as hawks do (Brigham, 2006). Unlike other nocturnal nightjars, the CONI is a crepuscular species, meaning it is most active at dawn and dusk (Brigham et al., 2011). CONI are most often observed at dusk just before sunset foraging 'on the wing' collecting masses of small insects in their large gaping mouths while in flight (Brigham, 1990; Brigham et al., 2011; Todd et

al., 1998; Nebel et al., 2011). From a distance, this insectivorous foraging style called 'hawking' resembles the diving predatory behavior of a hawk, and contributes to their ill-suited name (Brigham et, al, 2011).

Male CONI are unmistakable during the breeding season when they are often observed exhibiting distinct territorial behaviors at dusk between bouts of foraging (Armstrong, 1965; Brigham et al., 2011; Cutright et al., 2006). They perform elaborate displays in which they repeatedly dive from tens to hundreds of meters in the sky and pull up abruptly causing the air to flow through their wing feathers in a way that emits a loud 'booming' or 'zooming' noise. This 'booming' behavior likely serves two purposes; it is a territorial warning to other males as well as a breeding display to impress females (Brigham et al., 2011).

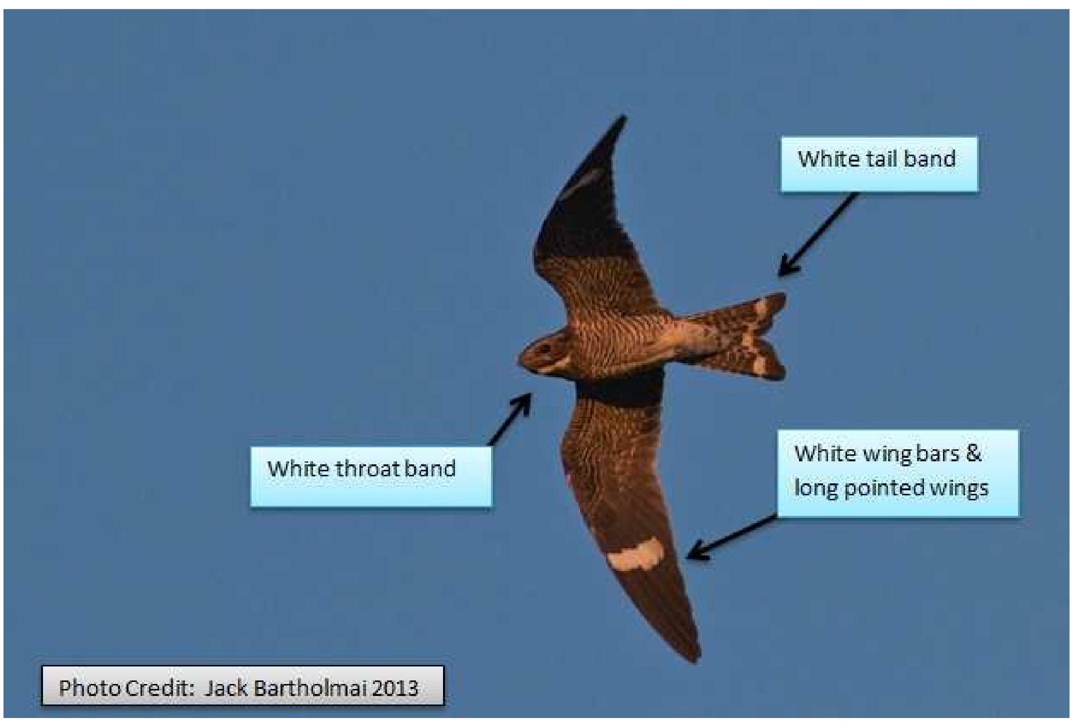



Figure 2: A male Common Nighthawk (*Chordeiles minor*) in flight.

## 2.2 Common Nighthawk Migration

Common Nighthawks are neotropical migrants that travel thousands of miles from their wintering grounds in the southern hemisphere to breed in the northern hemisphere each summer (Figure 3) (Brigham et al., 2011). The birds are known to migrate in large flocks or 'kettles' and are particularly gregarious during fall migration as they return to wintering grounds. Typically, the birds arrive in late May in Wisconsin, and are generally still migrating during early June. They settle to breed, nest, and fledge young between mid-June and early August. They begin to migrate back to their wintering grounds from mid-August through early September (Brady, 2009; Brigham et al., 2011).

## 2.3 Common Nighthawk Range and Distribution

Common Nighthawks have a wide-spread breeding range throughout North America (Figure 3 & 4). They are thought to breed in parts of Central Americas well, however, it is difficult to determine their exact breeding range in Central America because of the presence of the very similar Lesser Nighthawk (*Chordeiles acutipennis*) (Brigham et al., 2011). Very little is documented on the ecology of CONI in their wintering habitat, which is primarily the northern half of South America (Brigham et al., 2011).CONI breed throughout the conterminous United Sates (Figure 3 & 4) and most of Canada. BBS results show that the birds are more common and that populations are more stable in central US and Florida than in the rest of the country (Figure 5) (Sauer et al., 2011).

Results from the WBBA indicated that CONI nest throughout the state of Wisconsin with higher concentrations of confirmed breeding birds in the southern region (Figure 6). However, both confirmed breeding observations and probable breeding observations were scarce. A confirmed observation meant that the surveyor either discovered a nest or witnessed a breeding display. A probable observation meant that the surveyor observed the species in a suitable or ideal

nesting habitat during its breeding season. A significant number of both confirmed and probable CONI observations occurred in urban areas (Cutright et al., 2011).


Figure 3: Common Nighthawk range map in the western hemisphere

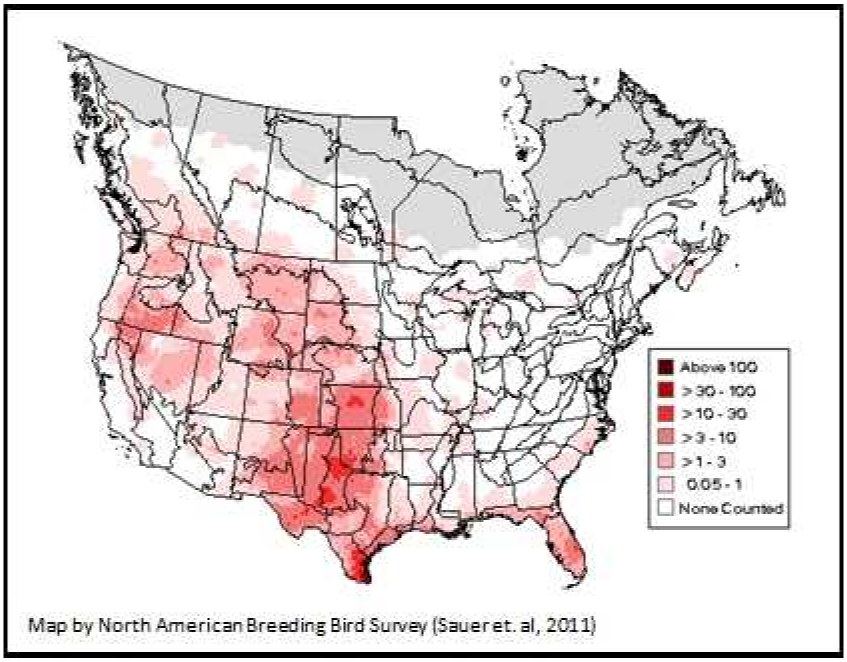



Figure 4: Common Nighthawk distribution map for the conterminous United States based on North American Breeding Bird Survey results for the years (2006 – 2012)

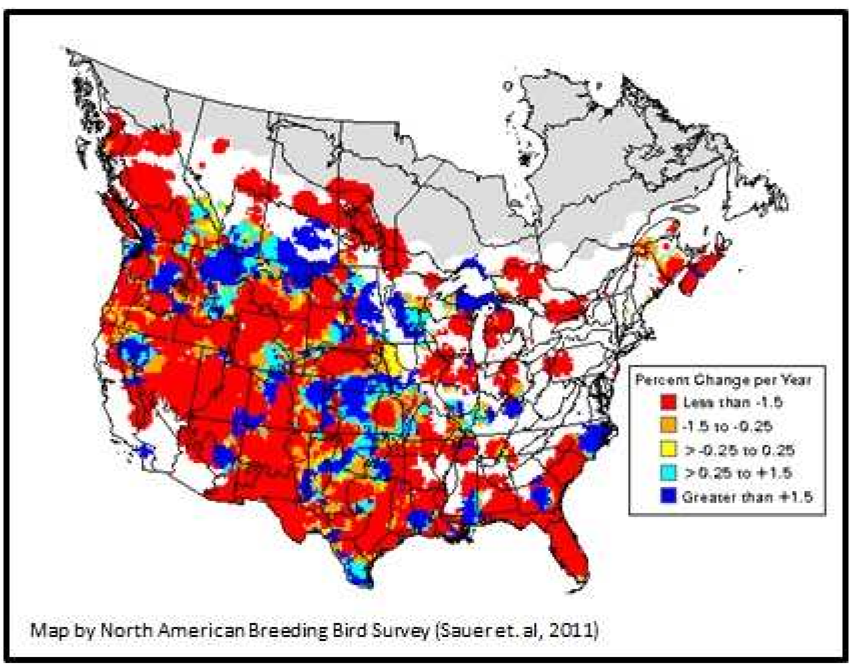



Figure 5: Common Nighthawk trend map for the conterminous United States based on North American Breeding Bird Survey results for the years (2006 – 2012)

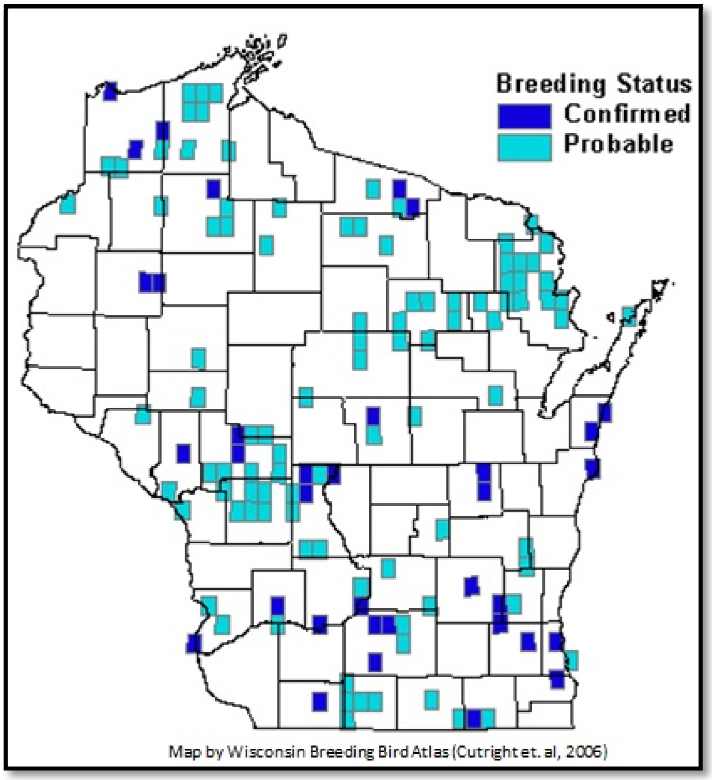



Figure 6: Common Nighthawk distribution in Wisconsin based on results from the Wisconsin Breeding Bird Atlas (1995 – 2000)

**2.4 Common Nighthawk Habitat**

Like many bird species, Common Nighthawks require a range of different habitat types and landscape features for roosting, foraging, and nesting. In North America, they inhabit a variety of open habitat types, including but not limited to grasslands, prairies, fields and meadows, sand dunes and beaches, rocky out-crops, forest clearings, pine and oak barrens, croplands, and cities (Cutright et al., 2006; Brigham et al., 2011). CONI are adaptable and capable of living in a variety of different landscapes as long as they find features that meet their specific needs. For example, CONI need roosting habitat where they will remain cool, protected, and camouflaged during day (Brigham, 1989). They find these characteristics in tree branches, fence posts, logs, among gravel and shrub on the ground or on rooftops (Brigham et.al, 2011). CONI need graveled or shrub vegetated areas that provide camouflage for nesting. The birds find

these characteristics on the ground in a variety of open-areas or on top of flat graveled roofs in cities. CONI require open areas capable of supporting large insect populations for foraging. This requirement can be satisfied in a number of habitats including rivers and ponds, grassland prairies and meadows, and in cities where insects are drawn to artificial light sources such as street lights and stadium lights (Brigham et al., 2011; Ingels et al., 1999).

### *Roosting Habitat*

Researchers suspect that reliable, relatively stable and unchanging night and day-roost sites are important to CONI (Fischer et al., 2004). Fischer et al, 2004 conducted a study in Saskatchewan, Canada and observed that individual birds consistently returned to the same branch in a given roost tree suggesting that the birds do not waste energy searching for new suitable roost sites (Fischer et al., 2004). The preferred roosting branches were primarily on trees on north facing slopes which likely provided a cooler microclimate. This observed loyalty to roosting spots with cooler microclimate could potentially decrease thermoregulatory costs and minimize the need for movement (Fischer et al., 2004).

Bioenergetic conservation is important for nighthawks, making reliable roost sites important for their survival. CONI are capable of utilizing torpor, a state of lowered body temperature and heart rate similar to hibernation in mammals (Brigham, 1989; Fischer et al., 2004; Ingels et al., 1999). This behavior serves as an energy saving mechanism to fuel the birds during their intense foraging bouts (Brigham, 1989). Studies conducted in Canada have shown that the birds prefer natural roosting sites when they are available. Studies have found that the birds search for trees with branches that provide adequate camouflage and microclimate for day roosting and remain loyal to their day roosts to avoid unnecessary use of energy (Fischer et al., 2004).

### *Nesting Habitat*

Female Common Nighthawks do not build nests, but typically lay two (or up to three) eggs directly on the ground in areas having a combination of gravel, dead leaves, and sparse vegetation (Brigham, et al., 2011). CONI find these habitat traits in a range of rural areas such as prairies and grasslands. CONI have adapted to live in urban areas by nesting on flat graveled rooftops in cities (Brigham et al., 2011; Carter et al., 2002; Cutright et al., 2006; Hunt, 2009). They were first documented using flat graveled rooftops in the 1860s, but could have been using them even earlier as graveled rooftops were introduced to the United States mid-century (Gross,1940) It is likely that the birds experience fewer disturbances on rooftop nesting sites than they do on the ground. Studies have found that they prefer flat rooftops with peastone gravel substrate and partial parapets, chimneys, or other shade and protection-providing structures (Hunt, 2009; Ingels et al., 1999).

CONI have been observed foraging for insects near artificial light sources such as tall street lights, stadium lights, and bright lights on buildings (Ingels et al., 1999). It is suspected that these two features, flat gravel rooftops and artificial light sources, are the primary factors drawing Nighthawks into cities (Armstrong, 1965; Brigham, 1989; Ingels et al., 1999). It would be expected that a combination of the two, a flat graveled rooftop with lights on or next to a building, would create an ideal habitat for nesting nighthawks (Ingels et al., 1999). The ratio of urban to rural nesting birds is not known, which means that, at present, the relative importance of these habitats is undetermined (Brigham et al., 2011).

In a three-year study carried out by Brigham (1989) in Okanagan Falls, British Columbia, CONI were captured, fitted with radio transmitter 'backpacks', and then tracked to determine the location of roosting and nesting sites. Over the course of the study, 27 birds were tracked (15 females and 12 males) from May to August (Brigham 1989). Brigham (1989, p. 722) predicted that some of the tagged birds would roost or nest of roofs when available, but found that none of the birds tracked ever roosted or nested on flat roofs. Instead, the birds were found to be nesting

and roosting on open ground as well as roosting in ponderosa pines (Brigham 1989).The results of this study indicate that CONI in Okanagan Falls prefer natural nesting and roosting sites over artificial sites (Brigham, 1989).

***Foraging Habitat***

Common Nighthawks are crepuscular and generally forage at dusk in open areas at altitudes ranging from just above the ground or water to over 500 feet in the sky (Brigham et al., 2011). Wide open spaces with large insect populations are ideal for foraging nighthawks that dive to collect insects in their mouths during flight. CONI drink water on the wing as well by diving and skimming the top of the water source, collecting the water in their mouths during flight. At present, it is thought that CONI do not forage or drink water any other way. They rely solely on their ability to eat and drink in flight. Support for this notion comes from wildlife rehabilitators in Wisconsin who explain that CONI are extremely difficult to care for in rehab facilities because they are unable to eat and drink for a stationary position. Because of this, CONI need to be hand fed and watered during the entire rehabilitation process (Yvonne Wallace Blane, Co-founder and Director of Rehabilitation at Fellow Mortals Wildlife Hospital, personal communication, April 4, 2013).

In the wild, Common Nighthawks find suitable foraging habitat in a variety of open spaces where insects are productive. They are often observed foraging over rivers, lakes, ponds, and other similar water sources that support large populations of insects. They are also known to forage over wetlands, at the edges of forests, over fields, grasslands, meadows, prairies, and croplands. As mentioned earlier, CONI are often observed foraging over “urban” areas as well, usually near stadium lights, street lights, or similar artificial light sources that attract large clouds of insects (Brigham et al., 2011).

## 2.5 Common Nighthawk Diet

CONI diet and food preferences are largely dependent on food availability in the vicinity of the nest site (Brigham et al., 2011; Caccamise, 1974). CONI are opportunistic feeders that prefer to feed on large swarms of insects such as flying ants when they are available (Caccamise, 1974). Male CONI actively defend large territories during the breeding season and avoid leaving their territory to seek food (Caccamise, 1974). The CONI diet consists of over 50 insect species (Terres, 1991). CONI eat a variety of insects ranging in size from mosquitoes to large moths (Brigham, 1990; Brigham et al., 2011). Studies of CONI stomach and fecal matter contents suggest that beetles *(Cleoptera*), queen ants (*Hymenoptera*), and true bugs *(Homoptera*) are often the most common staples of the CONI diet (Terres, 1991; Todd et al., 1998).

## 2.6 Potential Factors Influencing Common Nighthawk Population Decline

CONI population decline is a complex issue. At present, researchers do not understand why populations are declining (Brady, 2009; Brigham et al., 2011; Nebel et al., 2011). Some of the factors potentially influencing the decline include loss of natural habitats and urban nesting sites, hazards during migration, anthropogenic obstacles, predation, and food source reduction (Brigham et al., 2011).

### *Habitat Loss due to Deforestation and Reforestation*

Since Common Nighthawks rely on a variety of habitat types and landscape features for survival and propagation they likely experience habitat loss from multiple angles that are highly variable and dependent on the geographic location and preference of each individual bird. As mentioned earlier, reliable roosting habitat has been found to be of great importance to CONI. Deforestation could be a serious problem for nighthawks that roost in trees. If the observation that CONI return to the same roost spots when possible holds true for all CONI, then the loss of the chosen roost spot could be detrimental to the birds (Brigham, 1989). Loss of a roost tree or trees

would require the birds to seek new roosting spots, which in turn would require the birds to expend energy that would otherwise be conserved (Brigham, 1989).

Deforestation poses a bit of a conundrum for CONI. On one hand, deforestation can be bad for CONI because it can deprive them of valuable roosting habitat, while on the other hand deforestation could create new open-space habitats for the birds (Lohnes, 2010). It is suspected by some that deforestation in North America during early European settlement could have influenced growth in CONI populations by increasing the amount of open space habitat types preferred by rural nesting CONI (Lohnes, 2010). The subsequent gradual reforestation in some areas of North America could potentially cause reduction CONI populations by decreasing their preferred open nesting habitat (Brigham et al., 2011; Lohnes, 2010).

### *Loss of Urban Nesting Habitat*

Researchers speculate that CONI declines are being caused, at least in part, by a loss of their urban nesting sites (Brady, 2009; Brigham et.al, 2011; Hunt, 2009). In recent years, flat graveled rooftops have been converted to a rubberized or bitumen substrate. The flat graveled rooftops that CONI have adopted as nest sites are slowly being phased out. The new rubberized substrate does not provide nesting nighthawks with adequate camouflage, support, or microclimate needed to successfully reproduce (Brigham et.al, 2011; Carter & Gillette, 2002; Hunt, 2009).

### *Factors on Wintering Grounds*

While the focus of this thesis is on factors influencing the decline of Common Nighthawks in Wisconsin, it is important to keep in mind that factors affecting wintering grounds likely have an equal impact on CONI demographics (Brigham et.al, 2011). The birds spend near half of their lives on wintering grounds primarily in South America where they are likely subject to a range of threats; predation, persecution, food reduction, habitat disturbance, etc. both similar

and different to those experienced on breeding grounds in North America (Brigham et.al, 2011). In addition, to habitat loss on breeding grounds, equally habitat loss in the wintering ground may impact population dynamics in North America. CONI typically overwinter on similar open and forested habitats (Ingels et al., 1999) that may be under threat from human activity. At present, very little information is available to evaluate the condition of these habitats (Brigham et al., 2011).

***Events during Migration***

Common Nighthawks travel thousands of miles to reach their breeding grounds each year (Brigham et al., 2011). The long migration from South and Central America is taxing on the birds. They are forced to contend with unpredictable extreme weather events such as hurricanes, tornados, and bouts of unseasonably cold temperatures along the way. They may also encounter a lack of adequate stop-over habitat along migration routes (Wisconsin Stopover Initiative, 2011). Stop-over habitats are temporary rest stops along migration routes where birds can rest and refuel. Ideal stop-over spots provide shelter and food for the traveling birds. If migrating birds are forced to contend with food and shelter scarcity during migration, they are less likely to make it to their breeding grounds (Brigham et al., 2011; Nebel et al., 2010; Wisconsin Stopover Initiative, 2011).

***Anthropogenic Obstacles***

Common Nighthawks encounter various anthropogenic threats as well. Collisions with automobiles, windows, airplanes, wind turbines, etc. occur on a regular basis during migration. Collisions may be more prevalent during migration, but are still present on breeding and wintering grounds (Brigham et al., 2011). In some locations, male CONI roost on gravel roads where they are often hit by automobiles (Brigham, 1989; Brigham et al., 2011). McConnell Air Force Base (MAF) in Wichita, Kansas has history of CONI colliding with airplanes, which is hazardous to both the birds and the pilots (Cummings et al., 2003). CONI are attracted to MFA

grounds because the area is comprised of large open gravel and vegetated spaces, ideal for roosting and foraging. The majority of collisions occur in August and September during fall migration (Cummings et al., 2003).

### *Predation*

Predation likely contributes to Common Nighthawk declines as well (Allen & Peters, 2012; Brigham et al., 2011).CONI are particularly vulnerable at ground nest sites where they are exposed to snakes, cats, weasels, raccoons and other opportunistic scavengers. Even though the female, eggs, and chicks are well camouflaged, CONI are relatively weak and defenseless birds and once camouflage fails them, they become easy prey (Allen& Peters, 2012). Raptors such as hawks and owls can prey on the adults and chicks in the air and at nest sites in both rural and urban habitats. At rooftop nest sites, CONI may be less likely to experience regular disturbances and may be less accessible to some predators such as snakes, raccoons, and cats depending on the scalability of the building. However, rooftop nest sites attract a different set of predators including crows and gulls that would be less likely to disturb ground nest sites. Rooftop nest sites may be easily detected and accessed by crows and gulls. Crows could potentially prey on both the eggs and the chicks. Gulls pose even more of a problem as they are potential egg predators and rooftop nest site competitors (Brigham, et al., 2011).

### *Food Source Reduction*

Food scarcity may also play a role in Common Nighthawk population decline (Brigham, et al., 2011; Dunn et al., 2011; Nebel et al., 2011). Agricultural pesticide use may have direct and in-direct effects on insectivorous bird species by reducing the amount of available food and contaminating the food and the environment (Nebel et al., 2011). There may also be phenological asynchrony between the timing of peak insect emergence and bird arrival on breeding grounds (Dunn et al., 2011; Nebel et al., 2011). The Miss-match Hypothesis proposes that insects are

emerging earlier with warming climate and the birds have not adjusted their breeding phenology accordingly (Dunn et al., 2011). This may lead to a lack of food availability during the breeding season which would result in increased chick mortality rates (Brigham, et al., 2011; Dunn et al., 2011; Nebel et al., 2011).

### *Avian Aerial Insectivore Declines in North America*

Interestingly, declining trends for many other aerial insectivore species in North America exhibit similar temporal patterns starting in the 1980s (Nebel et al., 2011). The Common Nighthawk belongs to a guild of birds referred to as Avian Aerial Insectivores (hereafter 'AAI'). Members of the AAI guild include species from the swift, swallow, flycatcher, and nightjar families (Nebel et al., 2010).

The AAI guild is incredibly diverse with over 30 species that are not all taxonomically related (Nebel et al., 2010). Species belonging to the guild exhibit great variation in their ecology and life histories. For example, the Least Flycatcher (*Empidonax minimus)* (Table 1) breeds in woodlands of northern North America, weaves clean cup-shaped nests in tree branches, forages from tree branches by hovering over and picking insects off trees branches, a foraging strategy called 'hover-gleaning'(Tarof et al., 2008). The Bank Swallow (*Riparia riparia*) (Table 1) broods in large colonies, builds nests in burrows along bluffs or in quarries, usually near bodies of water, and 'hawks' for insects at about 50 feet above ground (Garrison, 1999). The Chimney Swift (*Chaetura pelagica*) (Table 1), a cavity nester, builds nests using twigs and saliva usually in chimneys or other human-made structures(Cink & Collins, 2002).While commonalities vary from species to species within the AAI guild, and demographic trends vary, most members of the guild appear to be experiencing population declines, which may mean that at least part of the problem lies within their shared food source (Nebel et al., 2010). This suggests that AAI declines are indicative of broader underlying environmental issues (Nebel et al., 2010).

Nebel, Mills, McCracken, and Taylor (2010), conducted a study that analyzed BBS data from 1966 to 2006 to determine if AAI populations were declining more than other passerines. The researchers found that AAIs were in fact declining more than other passerines. They found that the declines exhibited a spatial pattern where declines were most severe in northeastern North America. Also, long-distance migrants, those that winter in primarily in South America, showed more dramatic declines than short-distance migrants, those that winter primarily in Central America (Nebel et al., 2010).

In summary, CONI population decline is likely being influenced by more than one factor. Loss of flat graveled roof nesting habitat seems to be one of the causes of declines of urban populations. It is unclear to what extent deforestation and reforestation may be influencing CONI demographics as the processes could affect CONI roosting, nesting and foraging habitat in both negative and positive ways. Migration, predation, and anthropogenic obstacles and disturbances play a role as well, but the magnitude of the influence of each on CONI populations is unknown. The fact that the majority of other North America AAI species are declining at similar temporal scale suggests that the problem might be related to a reduction in the CONI’s food source, aerial insects.

Table 1: Examples of avian aerial insectivore species population trends from (1966 -2012) in North America based on results from the North American Breeding Bird Survey.

| Bird Species | Nesting Strategy & Habitat | Foraging Strategy | Migration Distance | Annual Trend | Reference |
|---|---|---|---|---|---|
| Common Nighthawk (*Chordeiles minor*) | Ground nester; in open areas with shrub/ gravel or on flat graveled rooftops | Hawker | Long | -2.10% | (Brigham et al., 2011) |
| Eastern Whip-poor-will (*Caprimulgus vociferus)* | Ground nester; in forests on leaf litter | Sallier | Short | -2.85% | (Cink, 2002) |
| Least Flycatcher *(Empidonax minimu)* | Tree nester; branches in woodlands | Hover-gleaner | Short | -1.76% | (Tarof et al., 2008) |
| Willow Flycatcher (*Empidonax traillii)* | Tree nester; Shrubby areas near water | Hawker & Hover-gleaner | Short | -1.59% | (Sedgwick, 2000) |
| Bank Swallow (*Riparia riparia*) | Cavity Nester; Banks, cliffs, and quarries near water | Hawker | Long | -5.65% | (Garrison, 1999) |
| Chimney Swift (*Chaetura pelagica*) | Cavity Nester; Chimneys almost exclusively | Hawker | Long | -2.41% | (Cink, & Collins 2002) |

## 2.7 Urban Common Nighthawk Studies

Studies are needed in Wisconsin and continent-wide to monitor and determine the habitat preferences of Common Nighthawks that nest and breed in urban areas such as cities and villages. At present, relatively few studies have been conducted to monitor and observe CONI in urban areas in North America. In the United States, three different studies in Minnesota (Carter & Gillette, 2002), Michigan (Armstrong, 1965), and New Hampshire (Hunt, 2009) stand out as successful efforts aimed to collect information on urban Common Nighthawk populations.

Concern for Common Nighthawk status in Minnesota arose when it was observed that the birds had disappeared from neighborhoods in Hennepin County (Carter & Gillette, 2002). Volunteers conducted statewide surveys during the summers of 1989, 1990, 1991, and 2001 to determine distribution and abundance of CONI in Minnesota. Studies completed in 1991 and 2001 had a stronger emphasis on urban areas. In the 2001 study, the state was separated into six regions to be surveyed, representing different levels of urbanization; the outer sate, the metro region, the inner metro, the outer metro, Hennepin County, eastern Hennepin County, and western Hennepin County. The objectives of the 2001 study were to compare nighthawk abundance among regions, within regions, and with datasets from the previous decade (only available for certain regions). The results of the study showed CONI populations to be relatively stable in the outstate region while CONI populations in the metro regions declined significantly from 1991 to 2001(Carter & Gillette, 2002).

In another study, Armstrong (1965) looked at Common Nighthawk breeding home range within the center of Detroit, Michigan. A total of 80 surveys were completed in the city during the CONI breeding season. Thirteen males and their corresponding territories were identified based on flight pattern frequency and the location of their characteristic ‘booming’ displays,

which to the trained observer appear slightly different for each male making individual displays unique. Male CONI primarily display over the nest, but they will often ‘boom’ over intruders such as people or predators entering their territory. Once males were identified, individual territory was determined by the range and location at which the males were seen displaying including both mating and territorial displays (Armstrong, 1965). The results of this study did not reveal significant correlations between CONI home range size and the density of any of the measured environmental features which included tree density and an index of photosynthesis (Armstrong, 1965). Home ranges for the 13 males varied in size from 4.14 ha to 22.80 ha with a mean home range size of 10.43 ha. The primary source of variation in home range size was individual aggressiveness. Another contributing factor was the density of flat rooftops; if there were more flat rooftops, there were more birds with smaller home ranges (Armstrong, 1965).

According to the New Hampshire Audubon Society, Concord and Keene are the only two remaining cities that have breeding Common Nighthawks each summer (Hunt, 2009). Project Nighthawk was initiated to monitor urban nighthawk populations and to test conservation strategies through habitat restoration. The habitat being restored in this case is gravel substrate once found on flat rooftops in the area. Gravel patches were installed in corners of two flat roofed buildings with the hope that nighthawks would nest on them. Volunteers observed CONI in the area and recorded their behaviors. During the first years of the study nighthawks did not use the gravel patches but were found nesting in graveled areas on the ground instead. To date, there has been little success attracting CONI to the gravel patches. This study is important because it provides valuable information on urban nighthawk habitat in New Hampshire as well as information on potential conservation strategies (Hunt, 2009).

The three studies discussed in this section demonstrate different methods by which urban Common Nighthawk populations could be monitored. The research in Minnesota is an example of a state-wide urban monitoring project to determine where CONI were declining and where

populations persisted (Carter & Gillette, 2002). The study in Detroit is an example of detailed research on CONI home range size and preferred habitat characteristics (Armstrong, 1965). The study conducted by the New Hampshire Audubon is an example of on-going research to measure the success and test new conservation methods to restore urban nest sites for CONI in New Hampshire (Hunt, 2009). Research is needed to develop new protocols to effectively and efficiently monitor urban populations long-term, to determine the specifics habitat traits required by urban nesting CONI, and to gauge the effectiveness of restoration efforts. These three studies have paved the way for development and improvement of urban CONI studies in other locations in North America.

**2.8 Avian Monitoring in Wisconsin**

In order to adequately study a species, researchers must first locate it (Sauer et al., 2011). Monitoring efforts are crucial to our understanding of avian species distribution, range, habitat preferences, and demographics (Brady, 2009). Common Nighthawks are more difficult to monitor than other birds and because of this, researchers do not have a solid understanding of the severity of nighthawk declines (Brady, 2009). A number of sources show that CONI populations are declining in Wisconsin; however it is not possible to adequately estimate the magnitude and geography of the decline because most monitoring efforts are not conducted at times of peak CONI activity (Brady, 2009; Cutright et al., 2006; Sauer et al., 2011). Currently, most avian monitoring survey efforts are conducted during the day or at night which covers peak activity times for the majority of avian species such as song birds that are diurnal and owls that are nocturnal (Brady, 2009; Sauer et al., 2011). Generally, avian surveys are not conducted at dusk when CONI are most active nor do they specifically target urban areas where a portion of the population is known to dwell (Brady, 2009). At present, CONI declines in Wisconsin are gauged primarily based on results from three monitoring efforts; the North American Breeding Bird

Survey (BBS), the Wisconsin Nightjar Survey (WNS), and the Wisconsin Breeding Bird Atlas (WBBA) (Brady, 2009; Cutright et al., 2006; Sauer et al., 2011) (Table 2).

### ***The North American Breeding Bird Survey (BBS)***

The North American Breeding Bird Survey (BBS) was initiated in 1966 and is conducted on an annual basis (Sauer et al., 2011). It was inspired by Rachel Carson's book "Silent Spring", which discusses the effects of indiscriminant pesticide use and its impact on bird populations in North America (Carson, 1962). Surveys are conducted on over a thousand 24.5 mile roadside survey routes that are randomly distributed throughout North America, with 92 in Wisconsin. Both professional scientists and trained volunteers monitor these routes on an annual basis. Training consists of an online exam and the first survey year as 'practice survey' where data collected are not included in the larger pool of annual results. Surveys begin about 30 minutes before sunrise during June and July when birds are most actively breeding. Surveyors follow the route and stop at 0.5 mile intervals to conduct a 3 minute point count where they look and listen for birds within a .25 mile radius. Each route usually takes about 5 hours to complete (Sauer et al., 2011).

### ***The Wisconsin Nightjar Survey (WNS)***

The Wisconsin Nightjar Survey was piloted in 2007 by the Wisconsin Institute for Bird Conservation (partnered with the DNR) and is coordinated on an annual basis by Ryan Brady, WDNR Research Scientist (Brady, 2009). The purpose of the survey is to monitor nocturnal nightjar species such as the Eastern Whip-poor-will, Chuck will's Widow and the Common Nighthawk. Surveys are conducted by volunteers that have been trained using online resources and have passed an online exam. Surveys are conducted between May and July each year. Surveys begin at night, after sunset. The routes used are the same as the BBS routes, but only the

first 6 miles are surveyed along each route. Surveyors conduct a total of ten 6 minute point counts at 1 mile intervals on each route (Brady, 2009).

### *The Wisconsin Breeding Bird Atlas (WBBA)*

The Wisconsin Breeding Bird Atlas is a project that began in 1995 with volunteers collecting data on bird species in WI through the year 2000 (Cutright et al., 2006). Surveys were conducted in 7.5 minute USGS topographic quadrangles divided into six 10 square mile blocks. Trained volunteers conducted surveys during the daytime usually beginning before sunset. The next breeding bird atlas project will begin in 2015 (Cutright et al., 2006).

### *Other Avian Monitoring Efforts*

In addition to these three monitoring schemes, other bird data is collected at a variety of geographic scales from global to the local neighborhood through initiatives such the National Audubon Society's Christmas Bird Count (National Audubon Society, 2014), the Institute for Bird Populations Monitoring Avian Productivity and survivorship program (The Institute for Bird Populations, 2002),Birdlife International (BirdLife International, 2014), etc. While these efforts may gather information on Common Nighthawks, they are not discussed at length here because they do not specifically target CONI and/or do not collect enough incidental information on CONI in Wisconsin to be considered at the same level as BBS, WNS, and WBBA surveys.

## 2.9 Citizen Science in Common Nighthawk Research

Each of the aforementioned avian monitoring projects relies heavily on Citizen-Science based methodology (Brady, 2009; Cutright et al., 2006; Sauer et al., 2011). Citizen science is a term referring to collaboration between scientists and citizens to conduct research and collect

environmental data (Donnelly et al., 2013; Mayer, 2010; Silverton, 2009). While most of these efforts have coordinators and professionals that are paid, the majority of the surveyors are volunteers or citizen scientists. The WNS has approximately 70 to 100 volunteers, the WBBA has hundreds, and The BBS has thousands (Table 2) (Brady, 2009; Cutright et al., 2006; Sauer et al., 2011).

Citizen science-based methodology lends itself well to large scale avian monitoring projects (Donnelly et al., 2013; Sullivan et al., 2009). It is nearly impossible to complete continent-wide, region-wide, or state-wide monitoring projects efficiently without the help of volunteers. Using citizen science, researchers are able to gather information on species in a short period of time across a large geographic range. This saves time, money, and other resources making projects that could not be conducted by one or a few researchers possible. Citizen science is a mutually beneficial process that helps scientists conduct research while educating the community at the same time (Donnelly et al., 2013; Sullivan et al., 2009).

Some question the validity of data collected and produced using citizen science-based methodology (Cohn, 2008). Studies have shown that in order for citizen science to be effective and reliable - appropriate quality assurance methods must be in place at the outset of the project. For focused studies, volunteers should be adequately trained to conduct the tasks asked of them (Donnelly et al., 2013). Necessary training will vary depending on the complexity of the project. As mentioned earlier, training is provided to volunteers collecting data for the BBS, WNS, and WBBA surveys (Brady, 2009; Cutright et al., 2006; Sauer et al., 2011).

For smaller scope studies such as the WNS, less training is needed as volunteers are only collecting information on two nightjar species and owl species (Brady, 2009). For the WNS, volunteers are required to have some experience in nightjar and owl aural and visual identification before they can be recruited as surveyors. Potential volunteers communicate with

the coordinator Ryan Brady in a capacity that allows him to determine the skill level of the volunteer (Brady, 2009).

BBS survey volunteers are required to have good eye sight and hearing and are expected to be able to identify birds by sight and sound (Sauer et al., 2011). They are required to complete the BBS Methodology training program before their observations will be included in BBS analyses. The training program includes an introductory survey year in which the new volunteer's observations are not included in BBS analyses. Only data from an observer's second year and on will be included (Sauer et al., 2011).

Most WBBA volunteers are advanced birders (Cutright et al., 2006). They also go through training and testing processes before they are accepted as surveyors for the project. WBBA data is incredibly detailed as it includes observations on species and their behaviors. The goal of the WBBA is to determine what species are breeding where, which is determined by observing breeding, nesting, and mating behaviors. Surveyors need to be incredibly well versed in ornithology since there are over 200 species of birds that breed in Wisconsin each year. The intensive surveys for the atlas take years to complete, compile, and publish. For this reason, several surveyors are paid to expedite the process. However, for the most part, surveyors volunteer their time (Cutright et al., 2006).

One of the most prominent examples of citizen science in the realm of ornithology is eBird, an online mapping site created and managed by the Cornell Lab of Ornithology where citizens can submit bird observations at any time and from anywhere in the world. Since its launch in 2002, ebird has been a largely successful database and research tool (Sullivan et al., 2009). To effectively use ebird, citizens are required to provide the date, time, and location of the species seen or heard.  This information is stored and archived regularly in a secure database (Sullivan et al., 2009).

EBird data can be used to determine the distribution and abundance of bird species and is available for anyone to view or use for research (ebird, 2012; Sullivan et al., 2009). eBird has features such as interactive maps and charts that allow users to visualize bird data. Many avid birders keep detailed journal records of species observed while birding. Some of these people have several years or even decades of information that can now be entered into the ebird database for the world to view. One criticism of ebird, and other citizen science based research efforts are the issues of observer experience, bias, and error. To reduce some of this type of error, ebird automatically filters every entry and experts review the ones that are flagged (Sullivan et al., 2009).

Citizen science has been successfully utilized by the BBS, WNS, WBBA, and ebird to efficiently and affordably monitor avian species over large geographical areas. Citizen science-based methodologies could be applied similarly to studies focused on monitoring CONI. In order to gauge the severity and causes for CONI declines, both urban and rural populations need to be monitored. It would be inefficient and expensive for a group of professional researchers to monitor CONI given the species' wide-spread breeding range and narrow breeding timeframe. Citizen science offers effective and inexpensive methods by which to monitor CONI over large geographic regions, which would expedite overall understanding of CONI demographics and enable researchers to make more timely decisions regarding the conservation of the species.

Citizen science has become a widely used and accepted method by which to conduct avian monitoring. It is important to note that citizen science-based methodology is subject to flaws. In many cases, citizen scientists are 'amateur experts' with no formal training (Gura, 2013). Also, the dependability of each volunteer will vary from individual to individual, as will the reliability and integrity of the data collected. This is due to varying levels of experience conducting research, varying degrees of commitment to the cause, and varying levels of understanding of the research process and experimental design among volunteers (Chon, 2008).

Not all volunteers are created equal and some are likely to perform better than others for various reasons (Donnelly, 2013; Silverton, 2009).

Based on the information presented in the previous sections, it is clear that while populations of CONI are declining the reason(s) for the decline are not fully understood (Brady 2009, Brigham et al, 2011). It is also clear that at present, understanding of CONI demographics is limited because current avian monitoring efforts are not conducted during times of peak CONI activity and do not target urban areas such as cities and villages where CONI are known to nest (Brady, 2009). In order to address this issue in Wisconsin the first step is to establish a new crepuscular, urban bird survey by which to monitor CONI populations (Brady, 2009).

| Table 2: Summary of details for three avian monitoring efforts in Wisconsin | | | | | |
|---|---|---|---|---|---|
| **Survey Name** | **Initiation Date** | **Frequency** | **Time of Day & Start Time** | **Route Type** | **Number of Volunteers** |
| North American Breeding Bird Survey (BBS) | 1966 | Annual | Daytime, 30 minutes before sunrise | Roadside, 24.5 miles | Thousands |
| Wisconsin Nightjar Survey (WNS) | 2007 | Annual | Daytime, 30 minutes before sunrise | Roadside, 6 miles *(uses BBS routes)* | Approximately 70 to 100 |
| Wisconsin Breeding Bird Atlas (WBBA) | 1995-2000 | Every five years | Nighttime, after sunset | 7.5 minute USGS topographic quadrangles divided into six 10 mile sq. blocks | Hundreds |

## Chapter 3: Methods

In this chapter a number of methods for different aspects of the study are described in detail. First, the study region within Wisconsin is described and reasoning for the selection of the study region is discussed. Second, methodologies for sampling urban landscapes within the study region are explained. Then, methods of volunteer recruitment and training are described. Next, a detailed description of the components of the survey protocol is given. Finally, methods to extract habitat characteristics within a 500 meter buffer of each survey point are explained.

### 3.1 Description of Study Region

This study was conducted within the boundaries of the Southeast Glacial Plains (SEGP) and Southern Lake Michigan Coastal (SLMC) ecological landscapes of Wisconsin (WDNR, 2014). These regions of the State lie adjacent to and encompass the southeastern corner of Wisconsin. The study area was limited to these two ecological landscapes of Wisconsin both to create a manageable study area and to control the range of ecological and climatic variability.

The Southeast Glacial Plains and Southern Lake Michigan Coastal areas are two of the 16 ecological landscapes that constitute Wisconsin (WDNR, 2012). Designated by the Wisconsin Department of Natural Resources, each landscape is defined by the combination of distinct physical characteristics such as climate, landforms, and hydrology. Both the Southeast Glacial Plains and Southern Lake Michigan Coastal landscapes lie south of the upper estimated boundary of the “Tension Zone” (WDNR, 2011), an area that transects the state, separating northern and southern Wisconsin into two major climate zones with different growing seasons, vegetation types, and land use practices (WDNR, 2012).

The Southeast Glacial Plains ecological landscape is highly populated and heavily developed comprising a 7,725 square mile region spanning Calumet, Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Kenosha, Manitowoc, Outagamie, Ozaukee, Racine,

Rock, Sheboygan, Walworth, Washington, Waukesha, Waupaca, Waushara, and Winnebago counties (WDNR, 2014). While dominated by agricultural cropland (58%), the Southeast Glacial Plains landscape retains a variety of natural landforms created during the Wisconsin ice age including glacial till plains, moraines, drumlins, eskers, outwash plains, kames, and kettles. The landscape is speckled with several highly productive lakes including Lake Winnebago and the Yahara Chain of Lakes, and intersects a number of large river systems including the Bark, Fox, Rock, Wolf, Milwaukee, Mukwonago, Sheboygan, Sugar, and Rock rivers. Large wetlands and forested lowlands are also prevalent in the landscape, and while there has been some degradation from anthropogenic activities such as the introduction of invasive plant species, significant portions are maintained and protected in public areas such as the Southern and Northern units of the Kettle Moraine State Forest, the Horicon National and State Wildlife Areas, and the Cedarburg Bog (WDNR, 2014).

The Southern Lake Michigan Coastal landscape is an 843 square mile region encompassing portions of Kenosha, Milwaukee, and Racine counties (WDNR, 2014). It abuts the western border of Lake Michigan and lies adjacent to the southeastern corner of the Southeast Glacial Plains. Similar to the Southeast Glacial Plains, the Southern Lake Michigan Coastal landscape is dominated by agriculture (39%). Twenty four percent of the Southern Lake Michigan Coastal landscape is urbanized, making it the most heavily urbanized landscape in the state. Landforms such as sand dunes and clay bluffs are prominent near Lake Michigan, and rolling ground moraine is prominent inland. The Southern Lake Michigan Coastal area has a small percentage of wetland and is intersected by the Milwaukee, Menomonee, Kinnickinnic, Des Plaines, Southeast Fox, and Pike rivers (WDNR, 2014).

### 3.2 City and Village Selection – Sampling Urban Landscapes

Since the goal of the study was to better understand the habitat preferences of urban nesting nighthawks, only urban areas were surveyed. A number of steps were required to determine the location of the urban areas within the study region since this was the focus of the research. Cities and villages were randomly selected from the study region to create an unbiased sample of locations to be surveyed in the study.

The Wisconsin Ecological Landscapes shapefile from the WDNR was viewed in Arc Map 10.1 (ESRI, 2012) and clipped the file to the size of the study area containing only the Southeast Glacial Plains and Southern Lake Michigan Coastal Regions (WDNR, 2012). Next, the US Census Bureau Tiger/Line: 2010 Census WI Municipal Civil Division (MCD) Boundary shapefile was added (Census, 2010) and clipped to the extent of the study region, which yielded 473 cities, villages, and townships. In most cities and villages the human population increased as the physical area of the city or village increased. In townships, which incorporate large areas of agricultural lands, geographic area was much larger than human population size. Because the aim of this study was to characterize the habitat preferences of urban-nesting CONI, only cities and villages were used. In three cases, cities that resembled townships by their incorporation of large areas of agricultural landscapes were also omitted from the sample. Finally, cities and villages whose boundaries fell less than 50% inside the study region were omitted. This process yielded a total of 159 cities and villages within the study region. A random stratified sampling method was utilized to select 94 cities and villages to survey for CONI to produce an unbiased random sample of cities and villages representative of a range of levels of urbanization from heavily developed large cities to less developed small villages. The sample was stratified by separating the 159 cities and villages into 4 different classes based on human population from the US 2010 Census. The method of classification used was Geometrical Intervals (ESRI, 2012) and the number of classes was set to four. The resultant classes were the following; Class 1: 161 – 1,303 people (40 cities

and villages), Class 2: 1,304 – 10,073 people (80 cities and villages), Class 3: 10,074 – 77,434 people (35 cities ), and Class 4: 77,435 – 594, 833 people (4 cities) (Table 3) (ESRI, 2012). Once each class was identified, the data was exported into Microsoft Excel and 30 cities and villages from classes 1 through 3 were randomly selected using the =rand( ) function (Microsoft, 2010). Later on, two of the four cities from Class 4 were removed from the list. The two that were removed, Milwaukee and Madison, were significantly larger both in geographic size and human population than the other two cities in Class 4. Milwaukee and Madison were extreme outliers in the random sample and did not fit with the study design. This process yielded a new list of 90 randomly selected cities and villages from Classes 1 through 3 and two cities from class 4. The 92 randomly selected cities and village constituted the final list of survey locations for this study (Figure 7).

Table 3: City and Village Classes based on geometric interval breaks in human population size from the US Census 2010.

| **Class** | **Human Population Range (2010 Census)** | **Number of locations in Random Sample** | **Average Number of Points in each Location** |
|---|---|---|---|
| **1** | 161 - 1,172 people | 30 | 4 |
| **2** | 1,173 - 5,435 people | 30 | 6 |
| **3** | 5,436 – 23,411 people | 30 | 8 |
| **4** | 23,412 – 99,218 people | 2 | 8 |

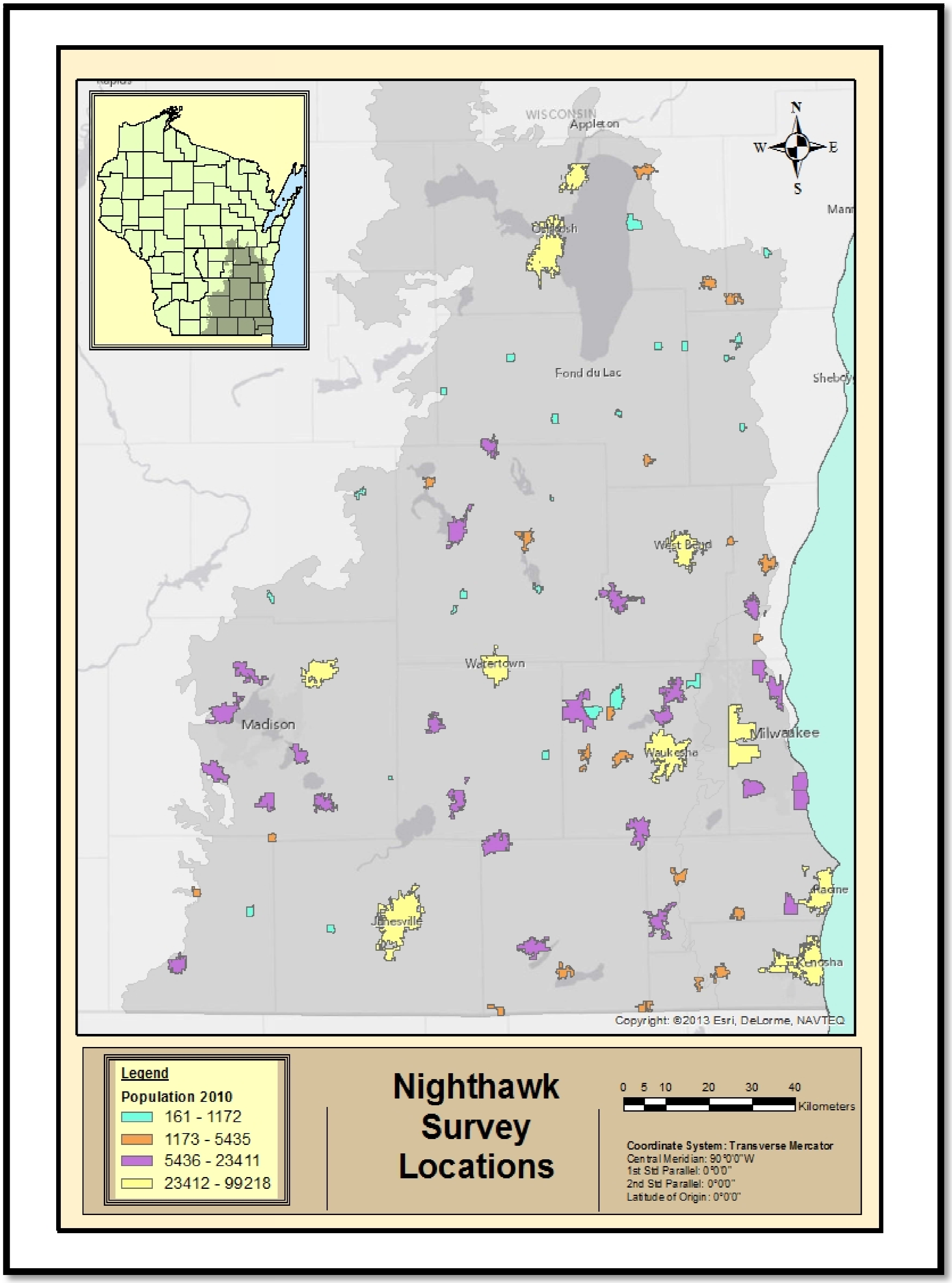



Figure 7: Map of Common Nighthawk survey locations. These are the 92 cities and villages that were randomly selected from the study region.

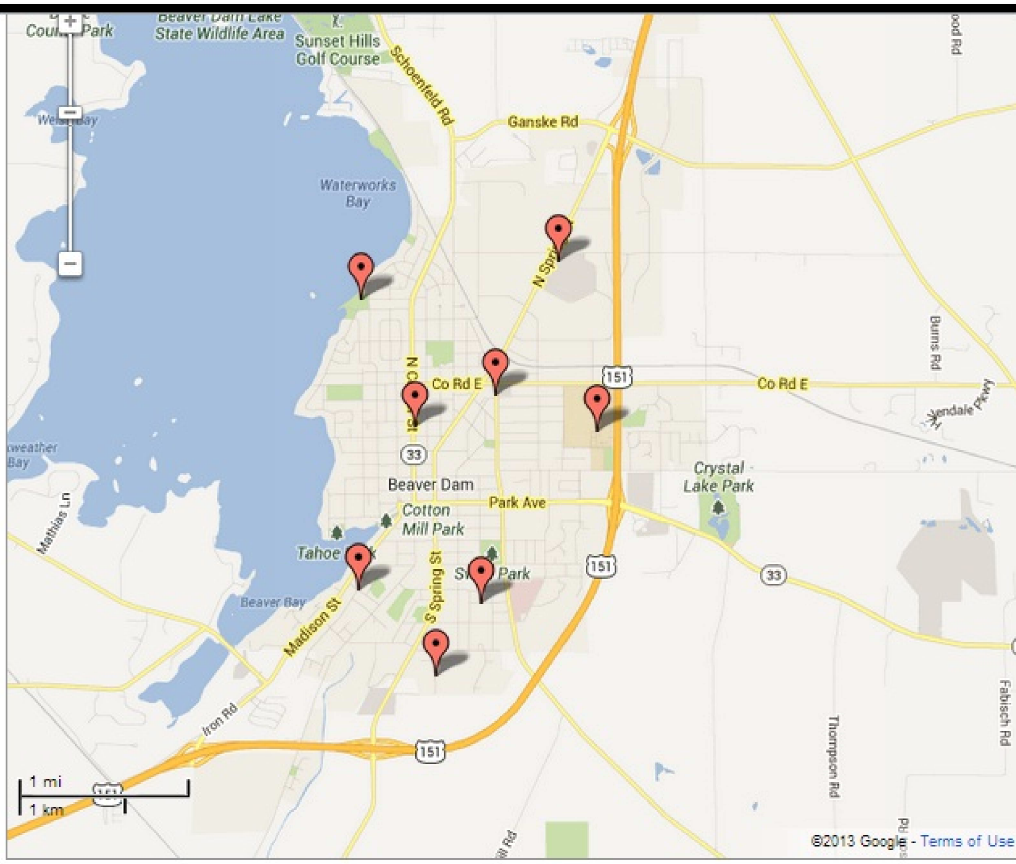
### 3.3 Survey Point Selection within Urban Areas

Since urban landscapes were the focus of the study, survey points were only generated within the cities and villages in the random sample. Survey locations within each city and village were determined using a randomized point distribution. The aim of this approach was to produce an unbiased set of survey points within each city and village. The study would be unlikely to yield any new information if all points were placed in locations known to have CONI based on past observations or in locations having similar habitat characteristics to sites known to have CONI.

Random point coordinates for each survey location were generated at a minimum buffer distance of 500 meters within the boundaries of each city and village in the random sample. All water bodies were removed from the map before generating points to avoid placing points in water. The number of points within each city or village was roughly proportional to the size of the municipality. Specific point selection within a city or village varied based on the geographic area of the location which restricted the number of points that could be placed at a 500 meter radial distance from each other. The minimum number of points placed in a village was 2 and the maximum number of points placed in a city was 8. Once random points were generated, their placements were evaluated using the WI roads shapefile and aerial imagery from Arc GIS 10 online (ESRI, 2012). All points were moved to the most reasonable survey location e.g. on the side of the road, on a sidewalk, in a parking lot, etc. within 100 meters of the original point. This was done so that points were located in easily accessible public areas where volunteers could survey safely.

Separate point shapefiles were created for each of the 92 cities and villages. Each of the 92 new city and village point shapefiles was converted to KML files and uploaded into Google Maps. This produced 92 Google maps, one for each city and village to be surveyed. Google Maps

was chosen over other mapping programs or output forms, e.g. ArcMap or PDF static maps, because of its familiar graphical user interface and because its interactive direction functions provided volunteers with various means by which to view point coordinates and plan respective routes (Figure 8) (Google, 2013).




**Beaver Dam City**

Nighthawk Survey Points for Beaver Dam City

Unlisted · 2 Collaborators · 10 views
Created on May 31 · By Jana · Updated 2 hours ago

Point# BD1
Point# BD1 @43.441764,-88.836855

Point# BD2
Point# BD2 @43.476484,-88.822332

Point# BD3
Point# BD3 @43.448903,-88.846013

Point# BD4
Point# BD4 @43.447748,-88.83149

Point# BD5
Point# BD5 @43.465275,-88.829749

Point# BD6
Point# BD6 @43.462156,-88.817764

Point# BD7
Point# BD7 @43.46253,-88.839365

Point# BD8
Point# BD8 @43.473217,-88.845708

Figure 8: Example of Google Map showing survey points in Beaver Dam (Google, 2013)

### 3.4 Volunteer Recruitment and Training

In order to collect data on Nighthawk activity it was necessary to engage the help of volunteers since it would not be possible for one person to cover all sampling points. Therefore, volunteers were recruited for data collection through a number of social networks using a targeted and focused approach. Noel J. Cutright, Ph.D. and William Mueller, M.S. of the Western Great Lakes Bird and Bat Observatory (WGLBBO) and Ryan Brady, M.S. from the WDNR WNS played crucial roles in recruiting volunteers. Flyers (Figure 9 &10) and announcements were handed out and sent via email to the Birdnet list-serve, bird clubs, Audubon chapters, and other organizations with avian conservation-oriented goals. Volunteers were also recruited through networks created at WDNR 2013 Citizen Based Monitoring Conference (CBMC) and through organizations such as the Urban Ecology Center, the Wildlife in Need Center in Oconomowoc, and the Wildlife Rehab Center at the Wisconsin Humane Society, and the University of Wisconsin – Milwaukee (Table 4). The study was further promoted and coordinated via the WGLBBO website and 'Help Conserve Nighthawks' Facebook page where resources, links to pictures, video, and other related websites dealing with CONI identification and surveying techniques were posted.

Volunteers were screened either in-person, over the phone, or via email. In most cases, informal 'interviews' were conducted to gauge each volunteer's birding experience and physical ability to see and hear birds. Individuals with less experience were referred to training resources on the WGLBBO website and were paired with an experienced birder for surveys. Two training sessions were held, one at the Urban Ecology Center and one at the Horicon Marsh Education Center. Nighthawk ID and the survey methods were reviewed and demonstrated at these sessions. About 20 volunteers attended each session. It is important to note that CONI are a great 'beginner

bird' and very easy to identify once one knows what to look for. Minimal training is required to accurately ID this species.

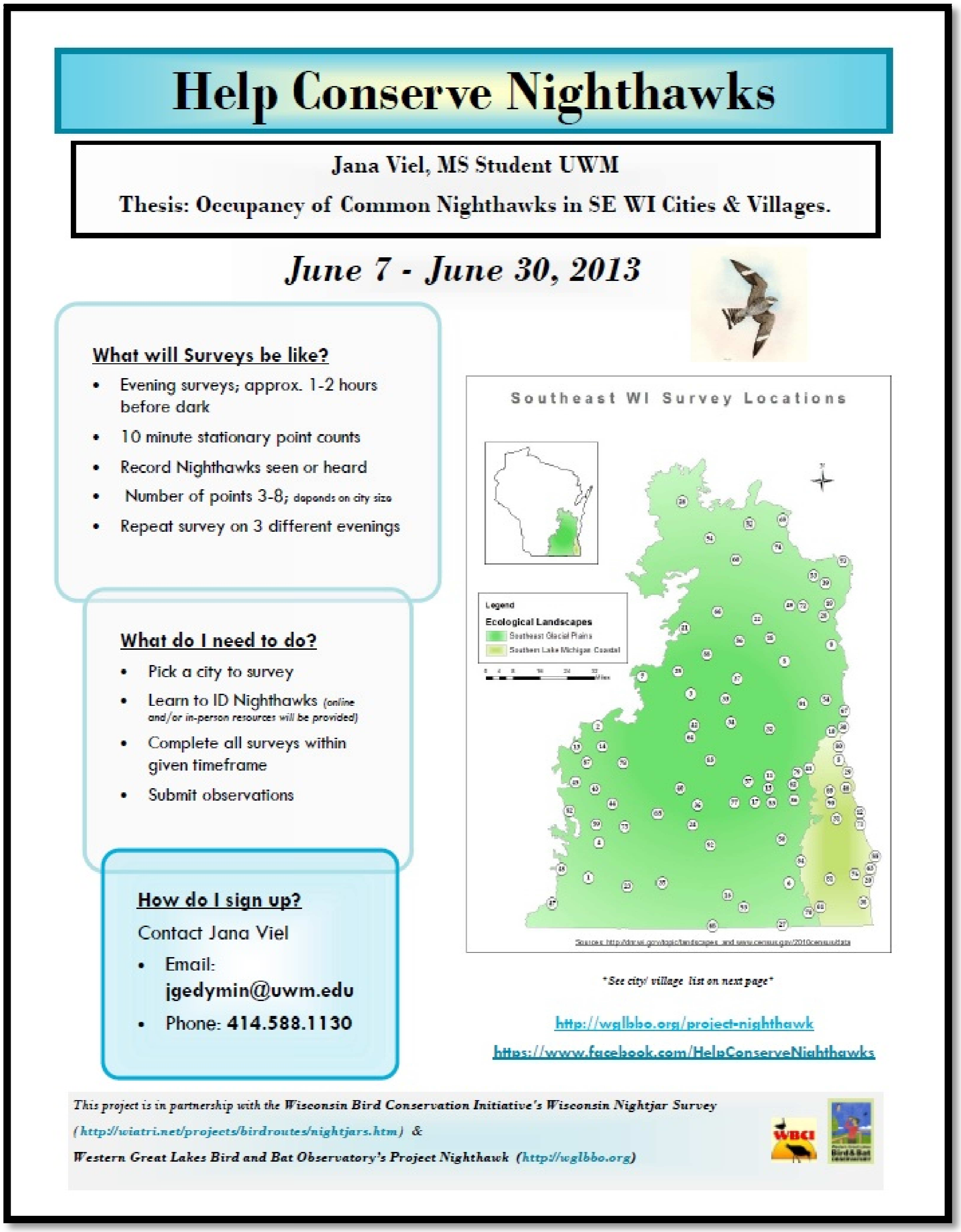



Figure 9: Flyer used to recruit volunteers for CONI surveys

## Survey Locations

| Map# | City / Village Name | Map# | City / Village Name | Map# | City / Village Name |
|---|---|---|---|---|---|
| 1 | Albany village | 34 | Hustisford village | 67 | Saukville village |
| 2 | Arlington village | 35 | Janesville city | 68 | Sharon village |
| 3 | Beaver Dam city | 36 | Jefferson city | 69 | Sherwood village |
| 4 | Brooklyn village | 37 | Kekoskee village | 70 | Silver Lake village |
| 5 | Brown Deer village | 38 | Kenosha city | 71 | South Milwaukee city |
| 6 | Burlington city | 39 | Kiel city | 72 | St. Cloud village |
| 7 | Cambria village | 40 | Lake Mills city | 73 | St. Nazianz village |
| 8 | Campbellsport village | 41 | Lannon village | 74 | Stockbridge village |
| 9 | Cascade village | 42 | Lowell village | 75 | Stoughton city |
| 10 | Cedarburg city | 43 | Madison city | 76 | Sturtevant village |
| 11 | Chenequa village | 44 | McFarland village | 77 | Sullivan village |
| 12 | Cudahy city | 45 | Middleton city | 78 | Sun Prairie city |
| 13 | Dane village | 46 | Milwaukee city | 79 | Sussex village |
| 14 | DeForest village | 47 | Monroe city | 80 | Thiensville village |
| 15 | Delafield city | 48 | Monticello village | 81 | Union Grove village |
| 16 | Delavan city | 49 | Mount Calvary village | 82 | Verona city |
| 17 | Dousman village | 50 | Mukwonago village | 83 | Wales village |
| 18 | Eden village | 51 | Nashotah village | 84 | Waterford village |
| 19 | Elkhart Lake village | 52 | Neenah city | 85 | Watertown city |
| 20 | Elmwood Park village | 53 | New Holstein city | 86 | Waukesha city |
| 21 | Fairwater village | 54 | Newburg village | 87 | Waunakee village |
| 22 | Fond du Lac city | 55 | North Bay village | 88 | Waupun city |
| 23 | Footville village | 56 | Oakfield village | 89 | Wauwatosa city |
| 24 | Fort Atkinson city | 57 | Oconomowoc city | 90 | West Allis city |
| 25 | Fox Lake city | 58 | Oconomowoc Lake village | 91 | West Bend city |
| 26 | Fremont village | 59 | Oregon village | 92 | Whitewater city |
| 27 | Genoa City village | 60 | Oshkosh city | 93 | Williams Bay village |
| 28 | Glenbeulah village | 61 | Paddock Lake village | 94 | Winneconne village |
| 29 | Glendale city | 62 | Pewaukee village | | |
| 30 | Grafton village | 63 | Racine city | | |
| 31 | Greendale village | 64 | Reeseville village | | |
| 32 | Hartford city | 65 | Rockdale village | | |
| 33 | Horicon city | 66 | Rosendale village | | |

Figure 10: The back-side of the flyer used to recruit volunteers to conduct surveys. *It contains a numbered list of cities and villages to be surveyed. The numbers listed correspond with the numbers on the map on the front of the flyer. Note there are 94 survey locations listed on the flyer. This is because the flyer was produced and distributed before Madison (#43) and Milwaukee (#46) were removed from the sample.*

Table 4: Number of volunteers recruited from various organizations

| Number of Volunteers (Total =95) | Organization | Method |
|---|---|---|
| 2 | B.F. Gross Bird Club Waukesha | Email |
| 5 | Bird Net List serve | Email |
| 3 | Green- Rock Audubon | Email |
| 10 | Horicon Marsh Bird Club | Presentation |
| 4 | Hoy Audubon | Email |
| 3 | Madison Audubon | Email |
| 4 | Milwaukee Journal Sentinel | Announcement at the end of article on Mr. Mueller's 2013 'Long Walk For Birds' |
| 1 | Retzer Nature Center | Email |
| 6 | Riveredge Nature Center | Presentation |
| 8 | Urban Ecology Center | Email & personal communication at bird banding sessions |
| 4 | University of Wisconsin - Milwaukee | Personal Communication |
| 6 | WDNR | Announcement on website & list serve via Mr. Brady |
| 8 | WDNR Citizen Based Monitoring Conference | Personal Communication |
| 8 | WGLBBO | Website & Word-of-mouth via William Mueller &Noel Cutright |
| 2 | Wisconsin Humane Society | Personal Communication |
| 9 | Wisconsin Nightjar Survey | Email sent to volunteers from Mr. Ryan Brady |
| 12 | Other | e.g. word of mouth, random flyer, etc. |

## 3.5 Survey Protocol

The survey protocol used in this study was derived from the Wisconsin Nightjar Survey and the New Hampshire Audubon's Project Nighthawk survey protocols (Brady, 2009; Hunt, 2009). Aspects of the survey such as the weather rating system and point count methodology were taken from the Wisconsin Nightjar Survey (Brady, 2009). Codes to describe nighthawk behavior were borrowed from the New Hampshire Audubon's Project Nighthawk protocol (Hunt, 2009).

The original survey window was June 7th through June 30th, 2013. This window was extended by two weeks to accommodate for many lost survey days due to poor weather conditions. Surveys were conducted between June 7th and July 8th, 2013. This window increases the likelihood of observing breeding and nesting Nighthawks while avoiding those still migrating through Wisconsin. Surveys were not conducted in precipitation stronger than an intermediate light drizzle, or if average wind speed was above 8 miles per hour as per the instructions in the Wisconsin Nightjar Survey (Brady, 2009).

### *Survey Logistics*

Volunteers received an email containing a list of survey point coordinates and a link to a Google map of the points (Figure 8). The points were numbered, but volunteers were not required to visit points in any particular order or in the same order every time. In fact, they were encouraged to visit points in a different order each evening to increase the likelihood of detecting Nighthawks at each point by varying the time of the survey for each point.

Volunteers were asked to conduct surveys on three different evenings, beginning each evening approximately 20 to 30 minutes before sunset, or around 8 pm. In an optimal study, surveys would be spread across the timeframe so that one survey would be completed in the

beginning, middle, and end of the survey window. This spacing would allow for detection of Nighthawks at different stages of the nesting cycle.

In some cities, points were spread far enough apart that volunteers were unable to reach all points before the sun had set completely. In these circumstances, volunteers were advised to split the points into different evenings if possible. Volunteers were advised not to survey points after dark because doing so would decrease their ability to detect Common Nighthawks. Ideally, volunteers should have finished surveying their last point around 9:45 pm, but they were asked to use their best judgment and do what they could.

Volunteers were asked to scout points prior to conducting surveys. If the survey point was not favorable for some reason(inaccessible, unsafe, excessive noise at location), they were instructed to move in increments of 0.1 miles or about 190 meters in a direction of their choosing until arriving at a more reasonable survey location. Survey volunteers were asked to record the exact coordinates of the location to which they moved to be submitted with their data.

At the conclusion of each survey volunteers were asked to make electronic or paper copies of their datasheets to keep as back-up records. They were asked to keep all back-up copies for at least one year (Brady, 2009). Volunteers were asked to submit the completed original datasheets via US postal mail to be collected and complied for data entry.

***Data Collected to Characterize Each Point***

Volunteers were asked to collect information on flat rooftops and tall street lights at each point, since these are two structures have features of possible importance to Nighthawk occupancy in urban areas. The objective of this was to collect data at a finer scale. This was particularly important for street lights that were too small to be identified in aerial images. They were instructed to count the number of flat rooftops within their field of view or within a 100

meter radius. They were also asked to count the number of tall street lights, baseball/football field lights, or bright lights mounted high on buildings within their field of view (Figure 10).

Volunteers were provided with a second data sheet and were given the option of drawing a sketch to characterize the observation point within an approximate 100 meter radius (Figure 11). They were asked to draw the location of street lights and flat rooftops around them to the best of their ability. This was optional because it required that volunteers spend more time in the field outside of survey hours. The objective was to obtain as much detail as possible to help characterize the point.

### *Data Collected on Each Survey Evening*

On each survey evening, volunteers recorded the name(s) of the observer(s) conducting the survey, city or village name, and the date of the survey. They also recorded the start time and end time, and start temperature (°F) and end temperature (°F) at the beginning and end of the evening. They recorded notes to describe overall weather conditions for the evening and estimated the moon phase. Volunteers also logged travel time, total mileage, and total time invested in surveys, survey preparation, survey related travel, etc. (Figure 10).

### *Data Collected at During Each Point Survey*

At each survey point, volunteers provided the point name and/or coordinates of the point. They recorded the start time and end time of the survey. They also recorded 6 environmental variables; temperature (°F), wind speed, sky condition, the amount of light pollution, insect activity, and the noise level at the start of each survey. Wind speed, sky condition, insect activity, light pollution, and noise level variables were measured based on a scale that ranged from zero to three (Brady, 2009). The ratings for these variables were copied directly from the Wisconsin Nightjar Survey for the sake of consistency. The variables are loosely based on the Beaufort scale (Brady, 2009) (Figure 10).

For wind speed, a rating of zero indicated calm wind less than 1 mph where smoke rises vertically. A rating of one indicated light wind 1 – 7 mph where smoke drifts, weather vanes are active, leaves rustle, and wind can be felt on the face. A rating of two indicated moderate wind 8-18 mph where leaves, twigs, and thin branches move around and small flags extend. A rating of three indicated strong wind 19 mph or greater where small trees begin to sway. Volunteers were asked not to conduct surveys under wind conditions two and three, because CONI may be less likely to venture out in harsher weather, and therefore would not be counted and/or the wind conditions could impair their ability to detect CONI due to noise, flying debris, etc. (Brady, 2009) (Figure 10).

For sky condition, a rating of zero indicated clear skies with almost no cloud cover or less than 20% cloud cover. A rating of one indicated mostly clear skies with more open sky than clouds, or 25 – 40% cloud cover. A rating of two indicated mostly cloudy, with skies at least half cloudy, and about 20 – 40% open sky visible. A rating of three indicated more than 50 % cloud cover (Brady, 2009) (Figure 10).

For insect activity, a rating of zero indicated that there was no insect activity. A rating of one indicated that some flying insects were detected. A rating of two indicated a moderate amount of insect activity with many flying insects and a few biting mosquitoes. A rating of three indicated a large amount of insect activity with many flying insects, swarms, and/or many biting mosquitoes (Figure 10).

Some studies suggest the possibility that light pollution from artificial light sources could be a factor influencing Nighthawk occupancy (Armstrong, 1965; Brigham et al., 2011). The lights attract insects, which in turn attract foraging Nighthawks. It is also possible that the light extends the Nighthawk foraging window (Brigham et al., 2011). Surveyors were asked to describe the amount of light pollution at each point based on artificial light produced from streetlights and the

like. A rating of zero meant that there was no illumination from streetlights at the survey point. A rating of one indicated one or a few streetlights producing only a small amount of artificial light. A rating of two indicated a significant amount of illumination from artificial light, but not exceedingly bright. A rating of three indicated that artificial light was very bright, either due to many lights and/or very bright lights, such as sport field spotlights (Figure 10).

The noise rating system used in the Wisconsin Nightjar Survey was employed as a guideline to help surveyors gauge the effect of noise on their ability to detect Nighthawks aurally. A rating of zero indicated noise had no appreciable effect on the observer's ability to hear Nighthawks. A rating of one indicated that noise had a slight effect on the observer's ability to hear Nighthawks. Some examples of a noise rating of one are distant traffic, a dog barking, or 1 – 2 cars passing during the survey. A rating of two indicated that noise had a moderate effect on the observer's ability to hear Nighthawks. Some examples of a rating of two are nearby traffic, 3-6 cars passing, or an airplane overhead. A noise rating of three indicated that noise had a serious effect on the observer's ability to hear Nighthawks. A noise rating of three could be due to continuous nearby traffic, construction noise, a loud spring peeper chorus, or more than 6 cars passing by during the time spent at the point (Brady, 2009) (Figure 10).

Information on Common Nighthawk predators was collect during each survey. At the end of each 10 minute point count, volunteers were asked to estimate the number of crows, gulls, raptors or owls, and cats observed during the survey. Volunteers were also asked to estimate the number of Chimney Swifts (CHSW) during each survey. A table of ranges for CHSW counts was provided and the options were (1 to 5), (6 to 10), (11 to 15), (16 to 20), and (25+). Volunteers were advised to simply check the corresponding box with their CHSW estimate or write in the exact count in the box if possible. While not the primary subject of the study, these birds are another species of urban dwelling aerial insectivores. Numbers of Chimney Swifts could provide

insight into Common Nighthawk presence/absence and will serve as 'backup species' survey data (Figure 10).

***Common Nighthawk Point Counts***

At each point, each observer spent 10 minutes looking and listening for Nighthawks, with each one-minute period treated independently. What this meant in practice is that volunteers marked the number of birds detected each minute. Since birds often move during surveys, volunteers were instructed to use their best judgment when deciding if a "new" detection was an additional bird or simply an already-counted bird that had moved. Volunteers were instructed to count repeat birds from minute to minute. This meant that if a bird was present in minute one and also in minute two, it would be counted as one bird separately in each minute (Brady, 2009).

Volunteers were asked to describe Nighthawk behavior by assigning codes to the birds detected in each minute. The aim of this was to use the code to get an overall idea of what types of behaviors Nighthawks are engaging in at each location. The codes were as follows: F meant bird flying overhead and could be further described as soaring or erratic flight. B meant that a bird was exhibiting the territorial 'booming' or diving behavior. P indicated that the bird was calling in it characteristic 'peent' call. R meant that the bird was observed roosting. Volunteers were asked to indicate the senses used, aural, visual, or both, to identify the behaviors observed which was obvious for most behaviors except the 'booming' behavior which can be detected visual and/or aurally (Hunt, 2009). At the end of the 10 minutes, volunteers were asked to give their best estimate of the total number of Nighthawks observed through the entire survey (Figure 10).

*(Sample)*

Data Sheet I: Nighthawk Surveys

| | | |
|---|---|---|
| City/ Village: Milwaukee City | | |
| Observer(s): Jana Viel | | |
| Date: June 7, 2013 | Start time: 8:00 pm | End time: 9:30 pm |
| | Start temp: 78 F | End temp: 76 F |
| Travel time: 15 min | Total time: 1 hour 45 min | Mileage: 6.26 miles |
| General Weather: Clear, sunny, calm | Moon Phase: | |

| Codes: | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Wind | none | slight | moderate | strong |
| Sky | clear | m clear | m cloudy | cloudy |
| Insects | none | light | medium | heavy |
| Light Pol. | none | dim | medium | bright |
| Noise | none | slight | medium | excessive |
| Behavior | F | B | P | R |
| | Flying | Booming | Peenting | Roosting |

Point#/Loc: (#1) Intersection of N Murray Ave and E Newport Ave; NW corner Start time: 8:10 pm End time: 8:20 pm .

| Minute | # of Nighthawks | Activity | Method of Detection: aural (A) , visual (V), or both( B) |
|---|---|---|---|
| 1 | 1 | F | V |
| 2 | 2 | F& P | B |
| 3 | 1 | P | A |
| 4 | None | | |
| 5 | None | | |
| 6 | 1 | B & P | B |
| 7 | None | | |
| 8 | None | | |
| 9 | 2 | F& P & B | B |
| 10 | 1 | R | V |

Environmental Variables

| Temp (F) | Wind | Sky | Insects | Light Pol. | Noise | Cars (#) |
|---|---|---|---|---|---|---|
| 76 F | 0 | 0 | 1 | 0 | 1 | 10 |

Chimney Swifts

| 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26+ |
|---|---|---|---|---|---|
| | x | | | | |

Predators

| Crows | Gulls | Raptors | Cats |
|---|---|---|---|
| 4 | 1 | 0 | 1 |

| Flat Rooftops | Tall Street Lights |
|---|---|
| 4 | 11 |

Figure 10: Example of a completed Datasheet 1

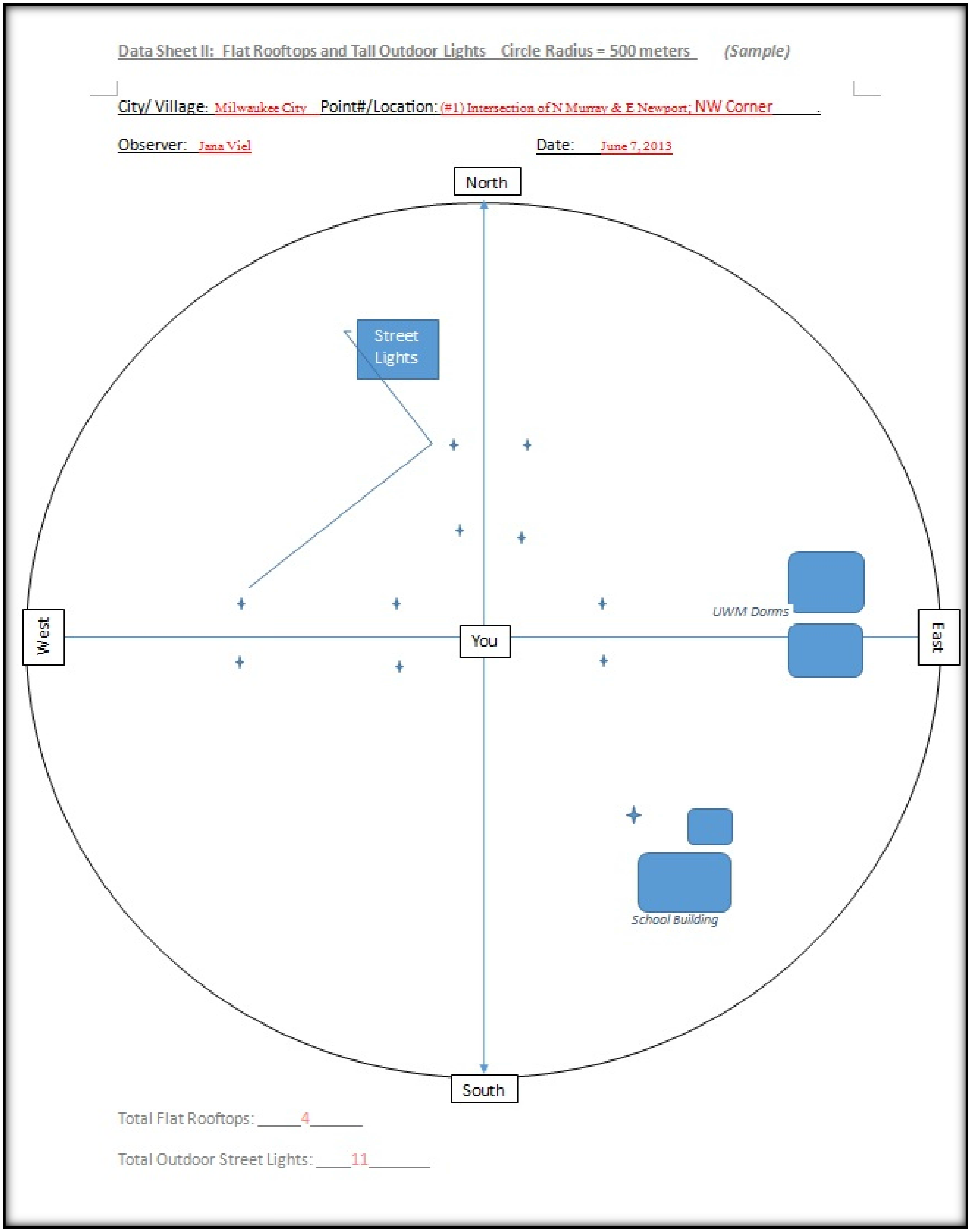



Figure 11: Example of a completed Datasheet 2

### 3.6 Extraction of Land Cover Percentages to Characterize Point Survey Sites

In order to determine the relationship, if any, between land cover and Nighthawk activity it was necessary to explore the land cover types in the vicinity of the survey points. Land cover and land use at each survey point were examined using the National Land Cover Dataset from 2011, which was the most recent available version (Jin etal., 2011). There were 15 different land cover classes within the study region (Jin et al., 2011) (Table 5). A model was created to extract land cover percentages within a 500 meter buffer surrounding each point. The model extracted each of the 500 meter buffers from the NLCD raster and calculated the percentage of each land cover type in a new field (Figure 12). This process yielded a new dataset containing percentages of each land cover class within a 500 meter buffer of each point.

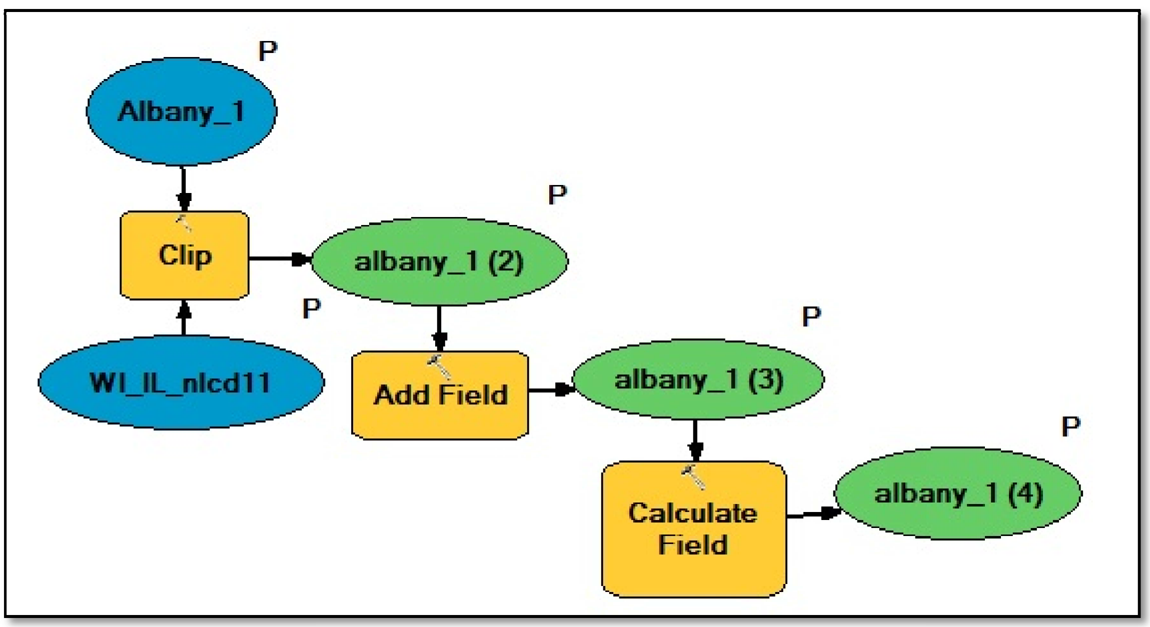



Figure 12: GIS Model to extract land cover class percentages from 500 meter buffer surrounding each point

Table 5: Land Cover Class Descriptions (15), from NLCD 2011 (Jin et al., 2013)

| **Land Cover Class** | **Description** | **Nighthawk Habitat** |
|---|---|---|
| Open Water | – Areas of open water with <25% vegetation or soil cover | Drinking, Foraging |
| Developed, Open Space | – Mostly lawn grasses with some constructed materials vegetation.<br>– Impervious surfaces<20%<br>– large-lots, parks, golf courses, | Foraging |
| Developed, Low Intensity | – Mix of constructed materials and vegetation.<br>– Impervious surfaces 20% to 49% | Nesting |
| Developed, Medium Intensity | – Mix of constructed materials and vegetation.<br>– Impervious surfaces 50% to 79% | Nesting |
| Developed High Intensity | – areas where people live/work in high numbers<br>– Impervious surfaces 80% to 100% | Nesting |
| Barren Land | - areas of rock/sand/clay<br>- Vegetation <15% | Roosting, Nesting |
| Deciduous Forest | - Trees > 5 m tall are > 20% total vegetation cover<br>- > 75% of tree species seasonal foliage | Roosting, Foraging |
| Evergreen Forest | - Trees > 5 meters tall are > 20% total vegetation cover<br>- > 75% of tree species retain leaves year-round | Roosting, Foraging |
| Mixed Forest | - Trees > 5 meters tall are > 20% total vegetation cover<br>- Neither deciduous nor evergreen > 75% | Roosting, Foraging |
| Shrub/Scrub | - Shrubs < 5 meters tall with shrub canopy typically > 20% | Foraging |
| Grassland/Herbaceous | - > 80% Gramanoid /herb. vegetation<br>- NO intensive management<br>- Can be utilized for grazing | Foraging, Nesting |
| Pasture/Hay | – Pasture/Hay vegetation >20% | Foraging |
| Cultivated Crops | – >20% crop vegetation | Foraging |
| Woody Wetlands | – Forest or shrubland >20%<br>– Soil periodically covered with water | Foraging, Drinking |

| | | |
|---|---|---|
| Emergent Herbaceous Wetlands | – Perennial herb. vegetation >80%<br>– Soil periodically covered with water | Foraging, Drinking |

**3.7 Measurements of Flat Graveled Rooftops to Characterize Point Survey Sites**

The number of flat graveled rooftops and the area of flat graveled rooftops were estimated within a 500 meter buffer around each point using aerial photos from Arc GIS online world imagery (ESRI, 2012). The photos were from 2011 and had spatial resolution of 0.3 meters and an accuracy of 2.72 meters (ESRI, 2012) (Figure 13). A number of buildings known to have flat graveled rooftops, such at the Northwest Quadrant and Bolton Hall at the University of Wisconsin—Milwaukee, were identified in the aerial photos to determine what flat graveled rooftops looked like in aerial photos. The buildings known to have flat graveled rooftops were used as a guide in identifying other flat graveled rooftops based on similarities in color, shape, and texture of the roof surface in the photos. Flat graveled rooftops in the aerial imagery are flat and light in color ranging from off-white to a medium gray tone, with most falling somewhere in the middle of the spectrum. All flat rooftops that were black to dark grey in tone were excluded as they were more likely to be rubberized or tar substrate. Rooftops that appeared to have pitch as well as those with riveting were excluded as this was often indicative of an aluminum or similar substrate based on verified observations of similar buildings.

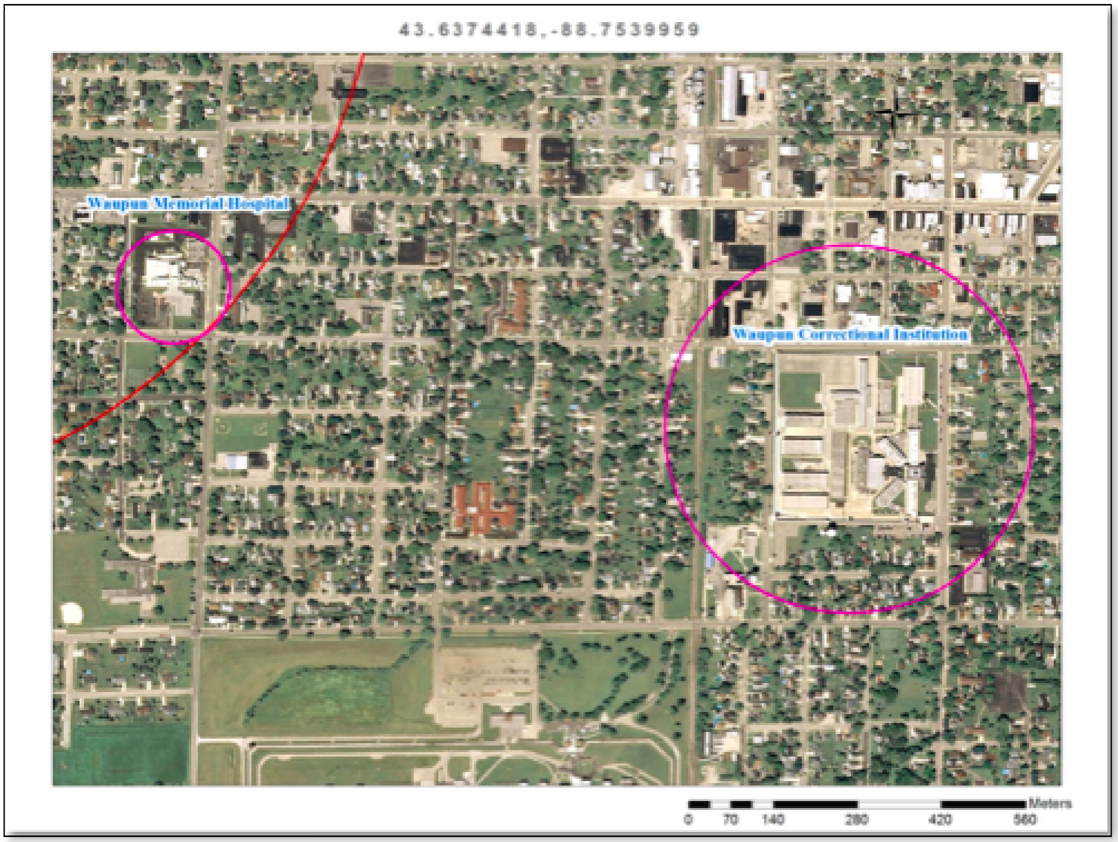



Figure 13: Example of aerial photo of Waupun used to estimate number and area of flat graveled rooftops. Items circled in pink are the Waupun Memorial Hospital (smaller circle) and the Waupun Correctional Institution (larger circle), two buildings with flat graveled rooftops. The red line in the top left corner is the edge of the 500 meter buffer around Waupun survey point #4.

### 3.8 Methods of Statistical Analysis

***Survey Summaries***

At the conclusion of the study a summary of survey results including descriptive statistics on volunteer investment and survey location coverage was produced. The frequencies of Common Nighthawk detection and Common Nighthawk counts were described at both the survey and the point level. Instances having non-zero count values were also analyzed at both the survey and point level.

***Explanation of Common Nighthawk Count and Presence/Absence Data Classification***

Common Nighthawk presence/absence data were collected during surveys. If a CONI was observed during a survey then it was considered present or detected (Gu & Swihart, 2004). If a CONI was not observed during a survey then it was considered absent or not detected. Presence/absence data were analyzed across all surveys and were also aggregated at the point/site level. If a CONI was present at a site in one survey, then the site was included in the present category regardless of the number of surveys in which CONI were absent for the same site. For example, if site A was surveyed on three different evenings and CONI were detected on evening 1, but not on evenings 2 and 3, site A was still included in the present category. The literature suggests that if a bird is detected at a site within the appropriate time frame, e.g. the Common Nighthawk breeding season, it can be considered present, but not detected in all surveys in which it was recorded as absent (Gu & Swihart, 2004; Lasiewski & Dawson, 1964; Royle & Nichols, 2003).

Common Nighthawk count data was collected during surveys. CONI count data from surveys were translated to count data at point level by taking the maximum count value from all surveys of the site. The maximum CONI count was taken instead of the mean because animal count values need to be whole integers. For the purposes of this study, one cannot observe a fraction of a CONI. For example, if site A was surveyed on three different evenings with 1 CONI detected on evening 1, 2 CONI detected on evening 2, and 1 CONI detected on evening 3, the aggregated CONI count for site A was 2 CONI, not 2.5 CONI. Additionally, since the maximum number of total CONI across all points did not exceed 4 individuals in any survey, it is reasonable to assume that the birds were breeding pairs and their young as opposed to migrants, in which case there would be a larger number of birds in one survey (Brady, 2009; Brigham et al.,

2011).Aggregation at the site level was necessary to analyze CONI count and presence/absence with landscape features and land cover classes that did not change from survey to survey.

***Explanation of Environmental Factor and Landscape Feature Groupings for Analysis***

Environmental factor and landscape feature data collected in this study were analyzed in groups based on the method and scale at which they were collected. There were three different groups defined by the scale of data collection. The three groups were: environmental factors recorded by volunteers during surveys, landscape features recorded at the survey point at an estimated 100 meter radius around the observer, and landscape features measured remotely at a 500 meter buffer surrounding each point.

Unchanging landscape features and land cover classes were not analyzed with data collected on environmental factors during surveys.  In an ideal occupancy study, all environmental factors and landscape features would be analyzed together with a parameter included for repeated measures of a site (Bailey et al., 2013).  Ideally, each site would have three surveys so that surveys could be coded as survey 1 of site 1, survey 2 of site 1, and survey 3 of site 1. Unfortunately, not all sites in this study were surveyed three times. In order to properly apply an occupancy model, the data set would have needed to be reduced so that all sites had the same number of surveys. Doing this would have reduced the size of the data set significantly and would have required the removal of a number of surveys in which CONI were present. It was determined that too much information would be lost using this method since the data set was already inflated with non-detection zeros.

***Explanation of New Land Cover Classes used in Analyses***

The 12 land cover classes included in the analysis were derived from the original 15 based on their similarities, potential importance and significance to Common Nighthawks (Table 6). The classes deciduous forest, evergreen forest, mixed forest, and shrub/scrub were combined into one category called forest because they represented potential roosting habitat for CONI. The

classes pasture/hay and cultivated crops were combined into one category called agriculture. Grassland/herbaceous was kept separate from the agriculture class because the description clearly states that this land cover type could be used for grazing, but is not managed, which means there is less likelihood that this land cover type is treated with pesticides, whereas pasture/hay and cultivated crops are more likely to be treated with pesticides. Also, CONI are known to nest in grassland areas, but not in agricultural areas, which means that grassland habitats could be of greater importance to the birds.

The classes developed low intensity, developed medium intensity, and developed high intensity were analyzed individually and in a combined class called urban. This was done to determine if CONI were more likely to be present in particular types of urban areas or built-up areas and to determine if they were more likely to be found in urban habitats in general. The class developed open space was initially analyzed individually because it represented a managed type of vegetated habitat that could potentially be periodically treated with pesticides, making it different from the forest and wetland classes.

The class barren was not combined with any other classes because it represented unique habitat characteristics that were unlike those in other classes. The class open water was not combined with other classes because it was distinctly different from the other classes. Both wetland classes were combined into one class called wetland because there was not a distinguishable difference between the two with respect to CONI habitat use. The land cover classes wetland, grassland/herbaceous, and developed open space were also analyzed in combination with the class Forest in order to investigate the significance of all types of vegetated space. This new category containing all classes with large amounts of vegetation was called Green Space (Table 6).

Table 6: Land cover classification used in analysis. See Table 5 for detailed land cover class descriptions.

| **Land Cover Class** | **Description** | **CONI Habitat** |
|---|---|---|
| Open Water | *See Table 5* | Drinking, Foraging |
| Developed, Open Space | *See Table 5* | Foraging |
| Developed, Low Intensity | *See Table 5* | Nesting |
| Developed, Medium Intensity | *See Table 5* | Nesting |
| Developed High Intensity | *See Table 5* | Nesting |
| Barren Land | *See Table 5* | Roosting, Nesting |
| Forest | Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub | Roosting, Foraging |
| Grassland/Herbaceous | *See Table 5* | Nesting, Foraging |
| Agriculture | Pasture/Hay & Cultivated Crops | Foraging |
| Wetlands | Woody Wetlands, Emergent Herbaceous Wetlands | Foraging |
| Green Space | Forest, Developed Open Space, Wetlands, Grassland/Herbaceous | Roosting, Foraging, Nesting |
| Built-up Space | Developed Low, Medium, and High Intensity | Nesting |

### ***Test for Differences between Means of Variables Grouped by Common Nighthawk Presence/Absence***

Differences between environmental factors, landscape features, and land cover classes at sites where CONI were present vs. those where CONI were absent were analyzed. These analyses were calculated using the Mann-Whitney U test in SPSS (IBM, 2013). The Mann-Whitney U test was the best choice for this dataset because it is a non-parametric test that does not require the assumption of normality or equal variance between groups.

### ***Environmental Factors Recorded by Volunteers during Surveys***

The Mann-Whitney U test was first used to compare the nine environmental factors recorded by volunteers during surveys which included: percent moon illumination, temperature (°F), wind speed, sky condition, insect activity, light pollution, noise, Chimney Swifts (CHSW), and predators. Originally, this group consisted of 12 variables. Because counts were low, the variables crows, gulls, raptors, and cats were combined into one group called predators.

### ***Landscape Features Recorded by Volunteers at the Survey Point***

The Mann-Whitney U test was then applied to the landscape features recorded at the survey point at an estimated 100 meter radius around the observer. This group included two variables, the number of flat rooftops and the number of tall street lights. These two variables remained in a separate group and were not combined with environmental factors measured during surveys for the reasons explained previously. They were not analyzed in combination with land cover classes or landscape features measured within a 500 meter buffer because of differences in scale.

***Landscape Features and Land Cover Classes Examined Remotely within a 500 meter Buffer of Each Point***

The Mann-Whitney U test was applied to a third group of variables, those that were measured remotely using GIS at a 500 meter buffer surrounding each point. This third group of variables included the total number of flat graveled rooftops, the total area ($m^2$) of flat graveled rooftops, and 12 land cover classes. The aim of analyzing the landscape features and land cover types within a 500 meter buffer at each point was to investigate correlation between land cover and CONI occupancy.

***Statistical Modeling of Common Nighthawk Count Data***

Two different statistical regression models were applied to the CONI data collected in this study to determine the correlation, if any, between landscape features and land cover classes measured remotely within a 500 meter buffer around each point. Calculations were carried out in the program R (R Core Team, 2013) using the package 'AER' (Kleiber & Zeileis, 2008) and the package 'pscl' (Jackman, 2013). The count data were modeled using a negative binomial generalized linear model (GLM) and also using a zero inflated negative binomial (ZINB) GLM.

Count data in avian surveys are often skewed (Martin et al., 2005; Min & Agresti, 2005). Because of this, count data are often modeled using distributions that do not require the assumption of normality. Two of these GLMs are the Poisson distribution and the negative binomial distribution (Min & Agresti, 2005). Both distributions were applied to the count data in this study, but only the negative binomial models were pursued. This is because the Common Nighthawk count data exhibited overdispersion. The negative binomial distribution was chosen because it allows for overdispersion whereas the Poisson distribution does not (Sokal & Rohlf, 1995).

**Negative Binomial Distribution Equation :***( Equation 1)*

$$f(y;k,\mu) = \frac{\Gamma(y+k)}{\Gamma(k) \times \Gamma(y+1)} \times \left(\frac{k}{\mu+k}\right)^k \times \left(1 - \frac{k}{\mu+k}\right)^y$$

Where;*(Equation 2)*

$$\Gamma(y+1) = (y+1)!$$

And the mean and variance are given by; *(Equation(s) 3)*

$$E(Y) = \mu \qquad \text{var}(Y) = \mu + \frac{\mu^2}{k}$$

Overdispersion in the CONI count data occurred in two ways. There was overdispersion in the non-zero counts and there was overdispersion caused by an excessive number of zero counts in the data. Count data sets that contain an excessive number of zeros are often referred to as ‘zero inflated datasets’. Failing to differentiate between the two types of overdispersion in zero inflated datasets; overdispersion in the non-zero counts and overdispersion from the excessive zeros can lead to biased results (Min & Agresti, 2005; Zuur et al., 2008). Zeros in avian count data can be generated in a number of different ways. First, there are true zeros, zero counts where the observer did not detect the bird because the bird was not there (Zuur et al., 2008). Then there are false zeros, instances in which the bird was there, but was not detected for some reason. False zeros could be generated in a number of ways. For example, the observer could mistake a CONI for a gull species, leading to misidentification and non-detection. Or, an observer could simply not be able to see the bird because it was flying out of view or was masked by clouds or maybe it was too dark to see a bird that was not calling. Or maybe the bird was present, but resting out of sight (Zuurr et al., 2008).

Researchers have found ways to analyze zero inflated data sets using mixed models called ‘zero inflated models’ (Kleiber & Zeiles, 2008; Martin et al., 2005; Min & Agresti, 2005; Zuur et al., 2008). The Zero-Inflated Negative Binomial (ZINB) model was chosen to analyze the CONI count data because it allows for overdispersion in the zeros and in the non-zeros (Jackman, 2013; Zuur et al., 2008). ZINB is a mixture model with two equations that can have the same or different covariates. One equation is a binomial GLM that estimates the probability of measuring a false zero. The other equation is a negative binomial GLM that models the non-zero count data, which may also contain zeros (Figure 14) (Zuur et al., 2008). In the ZINB model, Pr (Yi) is the probability that a CONI is detected at site i. The first set of equations written in ‘laymen’s terms’ by Zuur et al., (2008) below demonstrate the meaning of the each model in the ZINB mixed model. The first line states that the probability of obtaining a zero is equal to the probability of obtaining a false zero plus the probability of not obtaining a false zero times the probability that the count process produces a zero. The second line states that the probability of obtaining a non-zero is equal to the probability of not obtaining a false zero plus the probability of the count process (Zuur et al., 2008).

**Zero-Inflated Negative Binomial Mixed Model Equations:**

**In layman’s terms:***(Equation(s) 4)*

$$\Pr(Yi = 0) = \Pr(FlaseZeros) + (1 - \Pr(Falsezeros)) \times (\Pr\ (Countprocessproducesazero)$$

$$\Pr(Yi = yi) = (1 - \Pr(Falsezeros)) \times (\Pr\ (Countprocess)$$

**Formal Equations:** *(Equation(s) 5)*

$$f(y_i = 0) \quad = \pi_i + (1 - \pi_i) \times \left(\frac{k}{\mu_i + k}\right)^k$$
$$f(y_i | y_i > 0) = (1 - \pi_i) \times f_{NB}(y)$$

Where; *(Equation 6)*

$$\mu_i = e^{\alpha + \beta_1 \times X_{i1} + \cdots + \beta_q \times X_{iq}}$$

And the probability of obtaining a false zero is given by; *(Equation 7)*

$$\pi_i = \frac{e^{\nu}}{1+e^{\nu}}$$

And *fNB*(*y*) = *(Equation 1)*

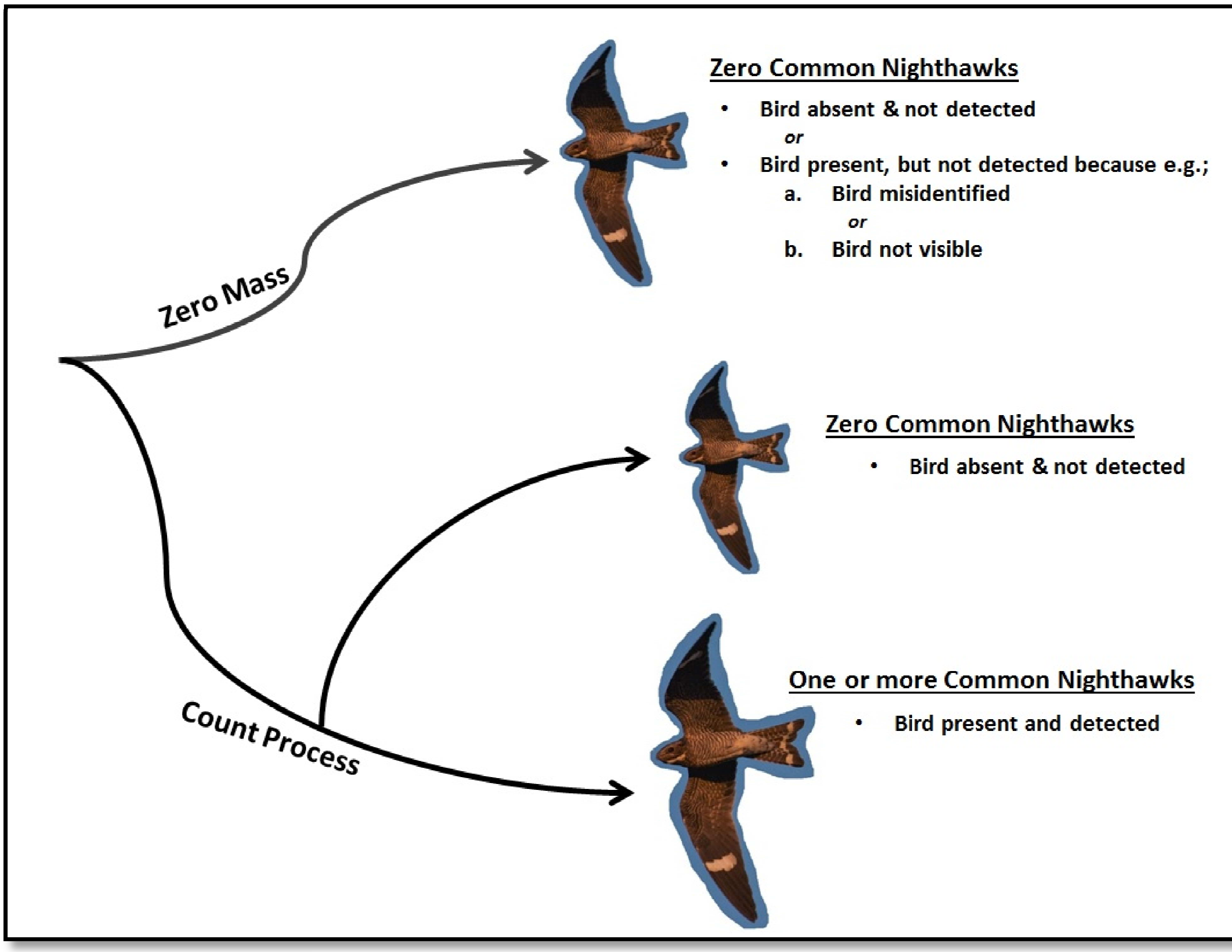



Figure 14: Visual conceptualization of Zero-Inflated Negative Binomial (ZINB) mixture model. The diagram shows how zeros are grouped in the model. The zero mass are the zeros modeled by the binomial distribution. The count process is modeled by the negative binomial distribution. (*This figure was modeled after a similar figure by Zuur et al., (2008).)*

### 3.9 Comparison of Survey Results with ebird Entries

The website ebird was used to compare data collected in the survey to that documented in ebird during the same time frame (see chapter 2 for detailed discussion of ebird). The aim of this process was to identify any locations in the survey with observations that conflicted with those on ebird. The ebird database is searchable by species, location, and time frame (ebird, 2012; Sullivan et al., 2009).It allows a search of all dates for a given time frame for a given species. It is possible to examine ebird entries for the breeding season at a given location. The survey window, June 7$^{th}$ – July 7$^{th}$, was analyzed for the survey year 2013 and then for all years available at each of the 82 cities and villages surveyed.

This was a method by which to check for possible observer error. This applied primarily to locations that did not have CONI sightings during surveys. If a survey result indicated that CONI were absent at a site and an ebird observation of a CONI was discovered for the same date, the survey result could be less credible. However, ebird entries could also be wrong. Observations entered in ebird are posted by a variety of citizens from different backgrounds that are not disclosed on the website. Also, data collection for ebird does not follow a specific protocol. Still, ebird submissions are screened by professional ornithologists making their accuracy more plausible (Sullivan et al., 2009). The observations on ebird and those recorded in this study probably have about the same degree of credibility. Observer error would seem more likely if there were many observations of CONI on ebird at or near a point that was surveyed and had zero CONI.

### 3.10 Analysis Common Nighthawk Occurrences and Behavior Observations

A non-statistical approach was used to characterize the points at which CONI were detected. Frequency of CONI occurrence was used to characterize the likelihood of consistent CONI occupancy at a given location throughout the breeding season (Appendix E, F, & G).

Points with non-zero CONI counts were characterized by the number of surveys in which CONI were detected and by the dates on which the observations occurred. The points were further characterized based on the CONI behavior codes recorded during each time a CONI was observed in a survey.

CONI behaviors can give clues to where the birds forage, nest, and roost, and can aid in characterization of corresponding habitats. Since the aim of this study was to determine habitat preferences of urban-nesting CONI, four distinct CONI behaviors were documented during surveys. The behaviors were defined and assigned codes to simplify the data collection process and to standardize data reporting. The behaviors recorded were booming (B), flying (F), peenting (P), and roosting (R) (for more detail see Chapter 2 ‘conducting the surveys’). These codes helped to characterize each point based on CONI activity.

The behaviors flying and peenting had less specific meanings in this study and were more or less a measurement of the presence of CONI. CONI peenting behavior alone is an indicator that a CONI is nearby and not much more. For many of the points that had CONI observations, the behaviors were either flying or peenting (Appendix A, B, & C). In some cases all or almost all observations were of peenting, which means the bird was heard, but not seen. Consistent observations of peenting and nothing more at a point were likely indicative of CONI activity nearby, but not near enough that the bird could been seen. Or it is possible that at peenting bird was near enough to be observed, but was not seen because of tree cover or obstacles obstructing the view of the observer.

Flying could be further characterized by the type of flight observed, whether it was erratic or soaring flight and whether the bird seemed to be passing through or circling. Erratic flight is often observed when CONI are foraging. If a bird was circling or returning to the same area it would be more likely that is was occupying the area, meaning its presence was not coincidental and was likely associated with a nearby nest site. However, this may not hold true in

all cases. While studies have shown that CONI tend to forage within or in close proximity to their home range (Armstrong, 1965), other studies have shown CONI will travel much further to forage if food is not abundant in the vicinity of the home range (Caccamise, 1974). Detailed research involving telemetry or other tracking methods would be the best way to determine how far CONI travel to forage, and detailed analysis of insect abundance would allow for estimations of the relationship between food availability and foraging distance from the boundaries of the home range (Armstrong, 1965; Caccamise, 1974).

If roosting behavior was recorded it meant that a bird was observed resting or sitting perched in some capacity. It was expected that this behavior would not be observed very often if at all since roosting CONI are often camouflaged and very difficult to detect. CONI usually roost during the day or at night between bouts of foraging (Brigham et al., 2011). Roosting was only observed on three occasions, twice in Wauwatosa and once in Union Grove (Appendix F).

CONI booming behavior was the most telling of all the behaviors recorded in this study. A CONI observed booming or diving was likely defending its territory, displaying to a female, or both (Armstrong, 1965; Brigham et al., 2011). Male CONI usually boom in the vicinity of a nesting female, therefore, if a booming male was observed, it was likely that an active nest was nearby (Armstrong, 1965).

# Chapter 4: Results

## 4.1 Survey Results Summary

One thousand four hundred and thirty one surveys were conducted between June 7th and July 18th 2013. As mentioned previously, the survey window was extended from June 30th to July 7th because of poor weather conditions. Two sets of surveys were conducted outside of the designated time frame, one in Dousman on July 8th and another in Stoughton on July 18th. The data collected for these dates were included in the larger dataset because both were technically conducted within the CONI breeding season. Volunteers covered 83 cities and villages and surveyed a total of 500 points within those locations. CONI were detected in 33 cities and villages, at 72 of the points, and in 107 of the surveys (Table 7). These totals include data from Beloit, which was not one of the randomly selected locations. A volunteer residing in Beloit was interested in surveying points known to have CONI. The volunteer choose six points spaced at least 500 meters apart and surveyed them with the knowledge that they would not be treated as 'controls' and would not be included in the initial analysis. Excluding Beloit, a total of 1,412 surveys were conducted at 494 points within 82 cities and villages. CONI were detected in 32 of the cities and villages, at 68 of the points, and in 98 surveys (Table 7 and Figure 15).

Table 7: The total number of cities and villages surveyed, the total number of points surveyed, and the total number of surveys conducted for the randomly selected sites and for the randomly selected sites including Beloit.
The percentages of cities & villages, points, and surveys that had Common Nighthawk observations are also shown.

| | **Including Beloit** | | **Random Only** | |
|---|---|---|---|---|
| | **Total** | **CONI Detected** | **Total** | **CONI Detected** |
| **Cities & Villages** | 83 | 33 (40% of total) | 82 | 32 (39% of total) |
| **Points** | 500 | 72 (14%) | 494 | 68 (14%) |
| **Surveys** | 1,431 | 107 (7%) | 1,412 | 98 (7%) |

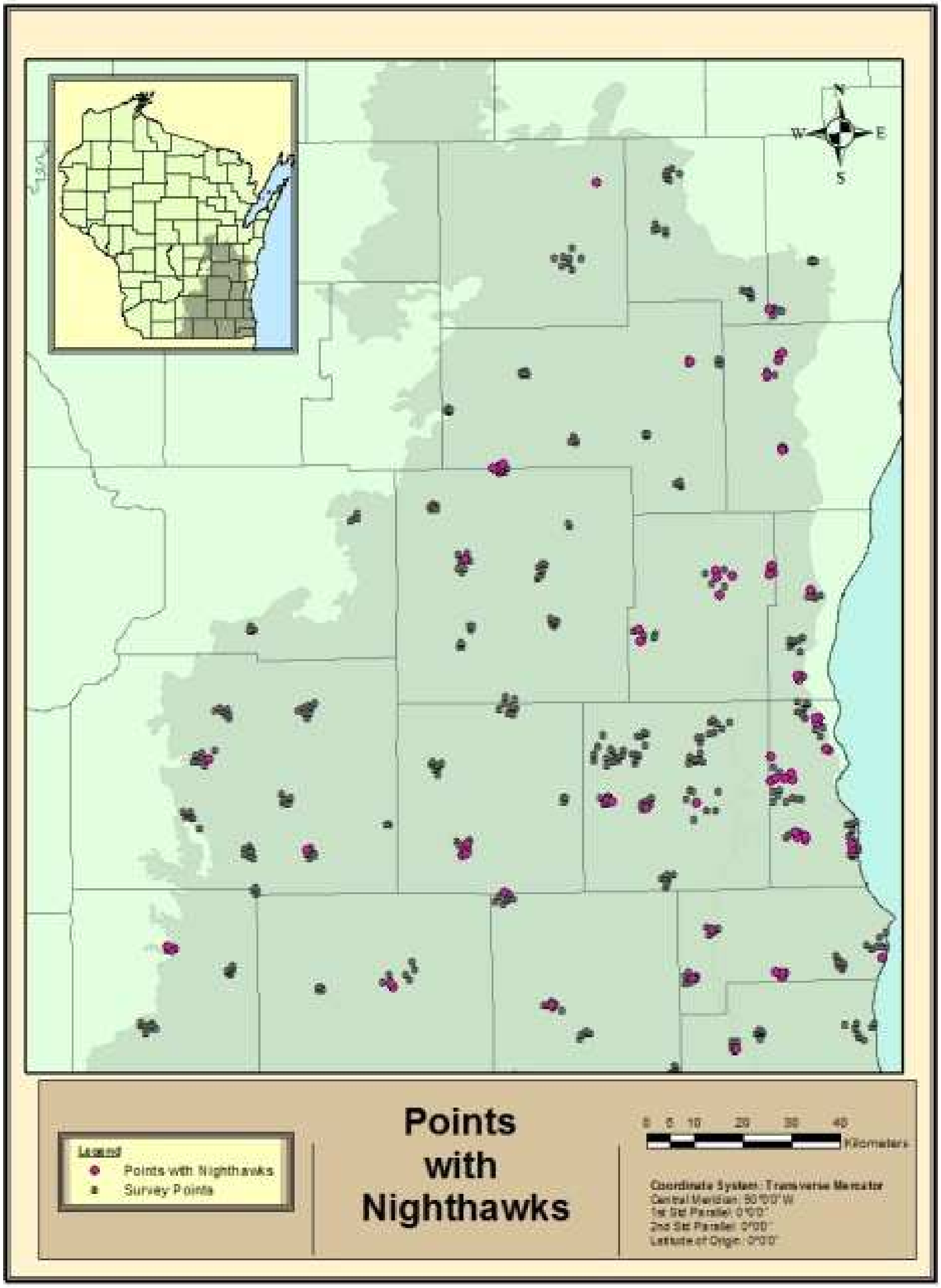



Figure 15: Map of survey results showing all points surveyed (gray dots) and points where Common Nighthawks were present (pink dots). *Legend on map uses Nighthawks instead of Common Nighthawks.*

At the end of each survey volunteers estimated the total number of CONI observed. CONI counts were low overall and because of the large number of zero counts in the dataset, descriptive statistic values for all surveys (mean = 0.01) and all points (mean=0.21) were exceptionally low (Table 8, 9, & 10).

Table 8: Frequencies of Common Nighthawk counts across all surveys (n = 1,412) and across all points (n = 494).

| **Total CONI** | **Point Level (n = 494)** | | **Survey Level (n = 1,412)** | |
|---|---|---|---|---|
| | **Frequency** | **Percent** | **Frequency** | **Percent** |
| **0** | 426 | 86.2 | 1314 | 93.1 |
| **1** | 44 | 8.9 | 69 | 4.9 |
| **2** | 16 | 3.2 | 21 | 1.5 |
| **3** | 6 | 1.2 | 6 | 0.4 |
| **4** | 2 | 0.4 | 2 | 0.1 |

Table 9: Descriptive Statistics for Common Nighthawk counts across all surveys (n = 1,412) and across all points (n = 494)
*Note, statistical means are listed here; however, whole integers were used in analysis as described in chapter 3*

| Statistic | Survey Level (n = 1,412) | Point Level (n = 494) |
|---|---|---|
| **Mean ± SE** | 0.01 ± 0.011 | 0.21 ± 0.027 |
| **Median** | 0.00 | 0.00 |
| **Mode** | 0 | 0 |
| **SD** | 0.400 | 0.592 |
| **Variance** | 0.160 | 0.351 |
| **Minimum** | 0 | 0 |
| **Maximum** | 4 | 4 |
| **Skewness ± SE skewness** | 3.436 ± 0.110 | 5.103 ± 0.065 |
| **Kurtosis ± SE kurtosis** | 13.056 ± 0.219 | 30.694 ± 0.130 |

Table 10: Descriptive Statistics for Common Nighthawk non-zero counts across all surveys (n = 98) and across all points (n = 68).
*Note, statistical means are listed here; however, whole integers were used in analysis as described in chapter 3*

| **Statistic** | **Survey Level (n =98)** | **Point Level (n = 68)** |
|---|---|---|
| **Mean ± SE** | 1.40 ± 0.071 | 1.50 ± 0.095 |
| **Median** | 1 | 1 |
| **Mode** | 1 | 1 |
| **SD** | 0.70 | 0.785 |
| **Variance** | 0.489 | 0.612 |
| **Minimum** | 0 | 0 |
| **Maximum** | 4 | 4 |
| **Skewness ± SE skewness** | 1.848 ± 0.244 | 1.542 ± 0.291 |
| **Kurtosis ± SE kurtosis** | 3.116 ± 0.483 | 1.754 ± 0.574 |

**4.2 Results of Environmental Factors Recorded by Volunteers during Surveys**

Volunteers recorded information on 12 different environmental variables during each survey and predator counts were combined making a total of 9 variables. The aim of analyzing most of the variables was to demonstrate that the surveys were not biased by weather conditions, temperature, noise, etc. Other variables recorded during surveys such as predator counts, Chimney Swift counts, insect activity and light pollution were analyzed to determine if there was any correlation between each variable and CONI presence/absence.

The first step in the analysis of these variables was to determine their significance. Since CONI counts were so low both at the survey and the point level for all counts (min=0, mode=0 max=4) as well as for non-zero counts (min=1, mode=1, max=4) (Table 8, 9, & 10), a comparison between occurrences of CONI presence (detection) vs. CONI absence (non-detection) was more likely to support a more meaningful interpretation of the data. The Mann-Whitney U Test was employed to compare the significance of the difference between the means of variables in group 1 = CONI Present vs. group 2 = CONI Absent (Table 11, 12, 13).

***Wind Speed, Sky Condition, and Noise Ratings***

The variables wind speed, sky condition, and noise were control variables that reflected the severity of environmental conditions that could decrease the chances of CONI detection at a point. A high value for wind speed or sky condition would imply extreme weather which could increase the chances of a false zero observation in two ways: by discouraging the birds from flying, in which case they would be less visible, or by impairing the observer’s ability to see or hear a bird. The variable noise is similar, except the occurrence of a false zero is more likely due to observer error resulting from impaired ability to detect birds aurally. Based on the Mann-Whitney U test results, the mean measurements of variables wind (p=0.16), sky (p=0.17), and noise (p=0.57) were not statistically significantly different between points where CONI were present vs. points where CONI were absent (Table 11). From this result, one could infer that the

variables wind speed, sky condition, and noise do not need to be considered further or added as a measure of observer error in further analysis.

***Light Pollution Rating***

Volunteers rated the amount of ambient light from artificial sources such as street lights and stadium lights. The alternative hypothesis ($H_1$)was that higher light pollution ratings would be positively correlated with CONI occurrence. However, given the statistically insignificant result from the Mann-Whitney U test (p=0.212) (Table 11) the null hypothesis ($H_0$) that there was no significant difference between the mean rating of light pollution between sites where CONI were present and sites where CONI were absent cannot be rejected.

***Insect Activity Rating***

Volunteers rated the amount of perceived insect activity during surveys. The alternative hypothesis ($H_1$) was that locations with higher ratings of insect activity would have more occurrences of CONI. The Mann-Whitney U test indicates that the relationship between insect activity and CONI occurrence was statistically insignificant (p= 0.458) (Table 11). The null hypothesis ($H_0$) that there is no significant difference between the mean rating of insect activity between sites where CONI were present and sites where CONI were absent cannot be rejected.

***Predator Counts***

Volunteers counted four types of potential predators to CONI; crows, gulls, birds of prey, and cats. The four counts were combined into one category called predators because counts for each individual were very low. The alternative hypothesis ($H_1$) was that predator counts and CONI presence would be negatively correlated. The results of the Mann-Whitney U test for predators were insignificant (p= 0.249) despite the fact the average predator counts in locations that did not have CONI (mean = 0.54) were almost three times higher than those in which CONI were present (mean = 0.17) (Table 11). Because the result was insignificant, the null hypothesis

($H_0$)that there is no significant difference between the mean count of predators between sites where CONI are present and sites where CONI are absent cannot be rejected.

### *Temperature Measurement*

Temperature (°F) was measured by volunteers using a thermometer or similar device. The alternative hypothesis ($H_1$) was that an increase in temperature (°F) would lead to an increase in CONI because of an increase in abundance and activity of their food source, aerial insects. The Mann-Whitney U test results indicated that temperature (°F) was not statistically significant (Table 11). This means the null hypothesis ($H_0$) that there was no significant difference between the mean temperatures (°F) between sites where CONI were present and sites where CONI were absent cannot be rejected.

### *Moon Illumination Percentage*

Moon Illumination was estimated by volunteers during surveys by circling the figure on the data sheet that looked most like the moon-phase on a given evening. These observations were later compared to a calendar actual moon phases and corresponding percentage of moon illumination given on the U.S. Naval Observatory (USNO) website. The percentages used in the analysis were not derived from estimations recorded during surveys, but rather taken from the USNO website (USNO, 2014). The null hypothesis ($H_0$) was that there would not be a significant difference between the mean percent Moon Illumination between sites where CONI were present and sites where CONI were absent. However, the Mann-Whitney U test indicates that difference in percent moon illumination ($p=0.004$) is significant at the 0.010 level, where the mean was higher on the occasions in which CONI were absent (mean = 54.28) and lower where CONI were present (mean=42.93) (Table 11).

### *Chimney Swift Counts*

Chimney Swifts were counted in each survey and counts were recorded using check boxes of a range of values. Each range was transformed to an integer so that Chimney Swifts

could be included in the analysis. The transformations were as follows; 1= (1 to 5), 2 = (6 to 10), 3 = (11 to 15), 4 = (16 to 20), and 5 = (25+). The expected outcome was the null hypothesis ($H_0$), that there would be no significant difference between the mean count of Chimney Swifts between sites where CONI were present and sites where CONI were absent. The outcome of the Mann-Whitney U test indicates that Chimney Swifts counts were significant at the $\alpha = 0.05$ level ($p=0.012$) and that Chimney Swift mean counts were higher at sites where CONI were detected (mean=0.61) than at sites where CONI were not detected (mean =0.43) (Table 11).

Table 11: Mann-Whitney U test comparison of means (± SE) for environmental variables recorded during surveys, $n_{present} = 98$, $n_{absent} = 1,142$

*Items in bold are significant. Significance codes: '**' 0.01 '*' 0.05*

| Variable | Birds Present | Birds Absent | p - value |
|---|---|---|---|
| **% Moon Illumination** | 42.93 ± 3.86 | **54.28 ± 0.99** | **0.004**** |
| Temperature °F | 70.55 ± 0.66 | 68.79 ± 0.39 | 0.068 |
| Wind Speed | 0.62 ± 0.06 | 0.7 ± 0.02 | 0.16 |
| Sky Cover | 1.06 ± 0.09 | 0.92 ± 0.02 | 0.168 |
| Insect Activity | 0.87 ± 0.07 | 0.82 ± 0.02 | 0.458 |
| Light Pollution | 0.80 ± 0.10 | 0.68 ± 0.03 | 0.212 |
| Noise | 1.31 ± 0.09 | 1.12 ± 0.03 | 0.57 |
| **Chimney Swifts** | **0.61 ± 0.09** | 0.43 ± 0.03 | **0.012*** |
| Predators | 0.17 ± 0.06 | 0.54 ± 0.11 | 0.249 |

### 4.3 Results of analysis of Landscape Features Recorded by Volunteers

Volunteers counted the number of flat rooftops and street lights within an estimated 100 meter buffer surrounding each survey point. These two variables were landscape features that did not change from survey to survey. Because the counts of these two features were consistent across all surveys, they were analyzed at the point level ($n_{present} = 68$, $n_{absent} = 426$) (Table 12). If a CONI was present at a point in one survey the site is included in the present category regardless of the number of surveys in which CONI were absent for the same point.

***Flat Rooftops***

The alternative hypothesis ($H_1$) for flat rooftop counts was that CONI would be more likely to be present in areas with more flat rooftops. Counts of flat rooftops counted by volunteers at each survey point were significantly higher at points where CONI were present (mean = 3.04, p=0.000) (Table 12). This means that the null hypothesis ($H_0$) that there was no significant difference between the mean count of flat rooftops between sites where CONI were present and sites where CONI were absent can be rejected.

***Street Lights***

It was expected that points with more street lights and other artificial light sources would be more likely to have CONI. The result for this count was statistically significant (p=0.022) (Table12). The null hypothesis ($H_0$) that there was no significant difference between the mean count of street lights and other artificial light sources between sites where CONI were present and sites where CONI were absent can be rejected

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Table 12: Mann-Whitney U test comparison of means (± SE) for landscape features counted by volunteers at each survey point, $n_{present} = 68$, $n_{absent} = 426$

*Items in bold are significant. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05*

| Variable | Present | Absent | p – value |
|---|---|---|---|
| **Flat Rooftops** | **3.04 ± 0.477** | 1.14 ± 0.111 | **0.000*****|
| **Lights** | **6.79 ± 0.780** | 5.41 ± 0.331 | **0.022*** |

### 4.4Results of Landscape Features and Land Cover Classes Examined Remotely

The 12 land cover classes, the total number of flat graveled rooftops, and the total area $m^2$ of flat graveled rooftops were analyzed using the Mann-Whitney U test. This was done for each site instead of for each survey as the land cover classes and characteristics were consistent across all surveys. The mean percentages of Development, High Intensity land cover (p=0.003), and Urban land cover (p=0.013) were significantly higher at sites in which CONI were present. The number of flat graveled rooftops (p=0.000) and the area of flat graveled rooftops ($m^2$) (p=0.000) were significantly higher at sites in which CONI were present as well. Means values for the land cover class Agriculture were significantly higher (p=0.000) at sites in which CONI were absent (Table 13).

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Table 13: Mann-Whitney U test comparison of means (± SE) % Land Cover measured remotely within a 500 meter buffer of survey site each point $n_{present} = 68$, $n_{absent} = 426$

*Items in bold are significant. Significance codes: 0 '***' 0.001 '**' 0.01*

| Variable | Birds Present | | Birds Absent | | p - value |
|---|---|---|---|---|---|
| | Mean (± SE) | SD | Mean (± SE) | SD | |
| Open Water | 2.58 ± 0.87 | 7.21 | 3.80 ± 0.45 | 9.25 | 0.864 |
| Open Green Space | 15.29 ± 1.31 | 10.81 | 13.15 ± 0.50 | 10.25 | 0.110 |
| Development, Low Intensity | 35.06 ± 1.98 | 16.32 | 31.67 ± 0.84 | 17.31 | 0.115 |
| Development, Medium Intensity | 18.41 ± 1.60 | 13.22 | 15.86 ± 0.66 | 13.64 | 0.061 |
| **Development, High Intensity** | **8.28 ± 1.20** | 9.89 | 5.43 ± 0.42 | 8.71 | **0.003**** |
| Barren | 0.00 ± 0.00 | 0.00 | 0.22 ± 0.08 | 1.69 | 0.085 |
| Forest | 4.82 ± 0.80 | 6.62 | 5.20 ± 0.42 | 8.66 | 0.907 |
| Grassland | 0.93 ± 0.37 | 3.01 | 1.06 ± 0.17 | 3.46 | 0.949 |
| **Agriculture** | 10.75 ± 2.01 | 16.55 | **19.73 ± 1.04** | 21.57 | **0.000***** |
| Wetland | 3.53 ± 0.62 | 5.15 | 4.30 ± 0.38 | 7.84 | 0.842 |
| Green Space | 21.04 ± 1.46 | 12.05 | 19.40 ± 0.68 | 13.97 | 0.093 |
| **Urban** | **61.75 ± 2.81** | 23.17 | 52.96 ± 1.31 | 27.11 | **0.013*** |
| **Number Flat Graveled Rooftops** | **28.84 ± 25.69** | 211.87 | 1.69 ± 0.12 | 2.44 | **0.000***** |
| **Area Flat Graveled Rooftops ($m^2$)** | **14,143.10 ± 2,458.36** | 20,272.14 | 6,555.55 ± 723.25 | 14927.68 | **0.000***** |

**4.5 Results from Statistical Models**

An alternative statistical approach that makes use of generalized linear regression modeling (GLM) was applied to the dataset to determine the correlation, if any, of the landscape class percentages and landscape features measured within a 500 meter buffer surrounding each survey point. CONI count data was used in the model and counts were estimated for each point based on the highest CONI count recorded at each point across all surveys (for further explanation of rationale see chapter 3, 'methods of statistical analysis'). Standard linear regression was not applied because the dataset did not follow a normal distribution (skewness (at the point level) = 5.103 ± 0.065, kurtosis = 30.694 ± 0.130) (Table 9). The negative binomial distribution was pursued instead of the Poisson distribution for modeling because the dataset was overdispersed (Alpha overdispersion parameter = 2.29, p=0.000) (Table 14).

Each of the 12 land cover classes, the total number of flat graveled rooftops, and the total area $m^2$ of flat graveled rooftops were modeled separately using the negative binomial distribution. Six of the variables were statistically significant: developed medium intensity (p= 0.0448), developed high intensity (p= 0.00688), agriculture (p= 0.0028), urban (p= 0.00314), the number of flat graveled rooftops (p=0.000827), and the area of flat of graveled rooftops ($m^2$) (p= 4.76e-05) (Table 14). This result is very similar to that obtained by the Mann-Whitney U tests (Table 13). The only difference was that the class developed, medium intensity was not statistically significant in the Mann-Whitney U test, however it was very close (p=0.061)(Table 13). The results show that individually, each of these 6 variables has a significant influence on the probability of CONI occupancy at a given point. Of the 6 variables, the variable agriculture is the only one that is negatively correlated with CONI counts. This means that points with less agriculture have a higher probability of having more CONI. The other 5 are positively correlated with CONI counts, meaning that CONI counts are likely to be higher at points with more flat

graveled rooftops, larger total area flat of graveled rooftops ($m^2$), or higher percentages of the land cover classes; developed medium intensity, developed high intensity or urban.

Table 14: Parameter estimates for single variable negative binomial models.
Items in bold are significant. Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

| Variable | Coefficient | SE | p - value | AIC | Log likelihood | Theta |
|---|---|---|---|---|---|---|
| Open Water | -0.01915 | 0.018 | 0.286 | 531.81 | -525.811 | 0.2458 |
| Developed, Open Space | 0.01699 | 0.012 | 0.164 | 531.29 | -525.286 | 0.2478 |
| Developed, Low Intensity | 0.008419 | 0.008 | 0.278 | 531.94 | -525.943 | 0.2452 |
| **Developed, Medium Intensity** | **0.018503** | 0.009 | **0.0448 *** | **529.17** | **-523.173** | 0.257 |
| **Developed, High Intensity** | **0.03397** | 0.013 | **0.00688 **** | **527.52** | **-521.517** | 0.2613 |
| Barren | -64.83 | 7448.315 | 0.993 | 527.59 | -521.589 | 0.2532 |
| Forest | -0.01289 | 0.018 | 0.466 | 532.56 | -526.56 | 0.2426 |
| Grassland | -0.02329 | 0.044 | 0.6 | 532.8 | -526.797 | 0.2418 |
| **Agriculture** | **-0.022921** | 0.008 | **0.0028 **** | **522.84** | **-516.845** | 0.2841 |
| Wetland | -0.02689 | 0.021 | 0.204 | 531.51 | -525.515 | 0.2454 |
| **Urban** | **0.014309** | 0.005 | **0.00614 **** | **525.76** | **-519.762** | 0.2689 |
| Green Space | 0.005789 | 0.010 | 0.546 | 532.76 | -526.759 | 0.2419 |
| Water | -0.01869 | 0.156 | 0.136 | 530.75 | -524.749 | 0.2493 |
| **Number of Flat Graveled rooftops** | **0.138** | 0.041 | **0.000827 ***** | **522.96** | **-516.962** | 0.2849 |
| **Area Flat Graveled Rooftops ($m^2$)** | **2.56E-05** | 0.000 | **4.76e-05 ***** | **524.95** | **-518.953** | 0.2625 |

All possible combinations of the six variables that were significant individually in the negative binomial model framework were analyzed to formulate a better, more inclusive multivariate negative binomial model. Only one multivariate negative binomial model out-performed all 6 of the single variable negative binomial models. The multivariate model that best fit the dataset included only two variables: agriculture, and the number of flat graveled rooftops (Model 1) (Table 15). Parameters used to compare models were the AIC values and the Log likelihood values. Models with lower AIC values are generally assumed to be better than those with higher AIC values (Sokal & Rohlf, 1995). Models with larger Log likelihood values are generally assumed to be superior to models with smaller Log likelihood values. Model 1 had an AIC value of 520, which was lower than the AIC values in all the univariate negative binomial models and a Log likelihood value of -512.002 (Table 15), which was larger than the Log likelihood values for the univariate models (Table 14).

Table 15: Parameter estimates for negative binomial Model 1

*Items in bold are significant. Significance codes: '***' 0.001 '*' 0.05*

| **Variable** | **Negative Binomial** | | | |
|---|---|---|---|---|
| | **Coefficients (b)** | **SE** | **Z value** | **p - value** |
| Intercept | -1.584278 | 0.216 | -7.323 | **2.43e-13 *** ** |
| % Agriculture | -0.016934 | 0.008 | -2.161 | **0.031 *** |
| Number Flat Graveled Rooftops | 0.098653 | 0.043 | 2.278 | **0.023 *** |
| **Alpha (over-dispersion parameter)** | 2.290 **(p=0.0002639***)** | | | |
| **AIC** | 520 | | | |
| **Log likelihood** | -512.002 | | | |
| **Null Deviance** | 235.05 on 493 DF | | | |
| **Residual Deviance** | 219.09 on 491 DF | | | |

***Zero-Inflated Negative Binomial***

While the negative binomial model allows for overdispersion, it does not specifically account for overdispersion caused by excessive zeros or zero-inflation in the data set. A zero-inflated negative binomial (ZINB) model was employed to model the data in a way that accounts for both overdispersions in the non-zero counts as well as zero inflation (for explanation of ZINB model framework see chapter 3 'statistical analyses'). ZINB was applied Model 1, the only multivariate negative binomial model. In the parameter estimates for the ZINB model, the count portion of the model shows that neither Agriculture (p=0.670) nor the Number of Flat Graveled Rooftops (p=0.798) are significant. In the zero inflation part of ZINB model, the variable Agriculture (p=0.239) is not significant, but the Number of Flat Graveled Rooftops (p=0.086) is significant at the α=0.1 level. The AIC = 519.0245 and the Log likelihood = -252.5 (Table 16). Both the AIC and the Log likelihood values for the ZINB model suggest that the ZINB model is a better fit than Model 1.

The Vuong test is a test used to compare zero-inflated negative binomial models to their standard negative binomial model counterpart. The low p-value (0.064) for the z-value calculated in the Vuong test indicates that the ZINB model is superior to the standard negative binomial model at the α=0.01 level. The interpretation of the Vuong test is that between the two models, ZINB and Model 1, ZINB is closer to the true model (Table 17).

Table 16: Parameters for the zero-Inflated negative binomial model
*Items in bold are significant. Significance codes: '*' 0.05 '.' 0.1*

| Number of CONI | ZINB | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Zero Inflation Model (binomial, log)** | | | | **Count Model (negative binomial)** | | | |
| | **Coefficient** | **SE** | **Z value** | **Sig** | **Coefficient** | **SE** | **Z value** | **Sig** |
| **Intercept** | 1.114 | 0.499 | 2.229 | **0.026*** | -0.117 | 0.268 | -0.438 | 0.662 |
| **% Agriculture** | 0.016 | 0.014 | 1.179 | 0.239 | -0.005 | 0.011 | -0.425 | 0.670 |
| **Number Flat Graveled Rooftops** | -0.141 | 0.082 | -1.718 | **0.086.** | 0.011 | 0.043 | 0.257 | 0.798 |
| AIC | 519.0245 | | | | | | | |
| Theta | 9.826 | | | | | | | |
| Log likelihood | -252.5 on 7 Degrees of freedom | | | | | | | |

Table 17: Vuong test to compare goodness of fit between the negative binomial model and the ZINB model
*Items in bold are significant. Significance codes: '*' 0.05*

| | z-value | Outcome | sig |
|---|---|---|---|
| **Negative Binomial (Model 1) vs ZINB (Model 2)** | -1.520801 | model2 > model1<br>ZINB > Negative Binomial | **0.064*** |

### 4.6 Results from Comparison of Survey Results with ebird Entries

At the time of analysis, there were no direct conflicts with the observations collected in surveys and those listed on the ebird website. Oconomowoc and West Allis were the only two locations that had ebird entries that conflicted with the results of this study. Both locations had ebird observations during the survey time frame. CONI were not detected in Oconomowoc or West Allis in surveys for this study. The ebird observations, while nearby, were not at the exact coordinates surveyed by volunteers. There was only one ebird observation listed for Oconomowoc and it was located in between the City of Oconomowoc and the Village of Oconomowoc Lake. West Allis was a bit more problematic. There were multiple ebird entries for West Allis during the survey time frame in 2013 and for many years prior. While none of the ebird observations for West Allis were located at the exact coordinates of survey points, quite a few were very close to a survey point. Observations were reported in Greenfield Park, which is located in West Allis within 1 km of point 1. However, point 1 in West Allis is not located in Greenfield Park; rather it is located in a rather busy area at the intersection of W Lincoln Ave and 116$^{th}$ street right in front of Nathan Hale High school. It is possible that CONI were not detected due to noise or other distractions at West Allis point 1. It is also possible that CONI did not fly over the exact point at which the observers were standing in any of the surveys. West Allis was the only location that seemed to be missed in this study likely due to poor point placement. Overall, the observations documented on ebird mirrored those documented in surveys for this study.

### 4.7 Results of Common Nighthawk Occurrences and Behavior Observations

Common Nighthawks were detected on multiple occasions in 8 cities; Burlington, Glendale, Fort Atkinson, Janesville, Racine, South Milwaukee, Waupun, and Wauwatosa, and in 4 villages; Elkhart Lake, Monticello, Union Grove, and Wales. The cities Burlington, Waupun, Wauwatosa, Janesville and Fort Atkinson had the most CONI activity overall based on the types of behavior observed and the frequency of sightings. Also, there seemed to be 'centers' of activity

in Burlington, Waupun, Wauwatosa, and Janesville. The CONI activity at these locations was generally near water bodies, parks, and either large industrial complexes with flat graveled rooftops or many smaller commercial buildings with flat graveled rooftops.

CONI booming behavior was observed in a total of 7 different surveys. Booming was observed once in Greendale and once in Waupun (Appendix A & B). Booming was observed twice in Fort Atkinson, once at point 1 and once at point 2 (Appendix A & B). Booming was observed on three separate occasions in Burlington at point three (Appendix C). It is likely that CONI were in fact nesting at or nearby the points at which they were observed booming in Greendale, Waupun, Fort Atkinson, and Burlington. All four of these cities had reoccurring observations of CONI flying and/or peenting at the same point or at surrounding points which supports the hypothesis that the birds were in fact nesting near these locations.

In the city of Burlington, a CONI was observed booming at point 3 on three different evenings and flying CONI was observed on one occasion at point 2, which is located slightly more than 500 meters to the east of point 3. There are no exceptionally large buildings with flat graveled rooftops near either point. However, there are several regular sized shops and office buildings in the downtown area near point 3. Also, large and small parks surround point 3 in every direction except to the west. Additionally, three water bodies are near point three. Echo Lake is about 700 meters from point 3 and the Fox River is about 153 meters to the west of the point. Rockland Lake is about 900 meters east of point 3.

In the city of Waupun, a CONI was observed booming near Waupun Memorial Hospital, which appears to have a large flat graveled rooftop. Within about a half mile (800 meters) is the Dodge Correctional Institute, which also appears to have a large flat graveled rooftop. Both Waupun Memorial Hospital and Dodge Correctional Institute have rooftops that have different levels and sections. The different levels and sections would likely cast shadows on various portions of the rooftops at different times of the day. It has been documented that CONI prefer

rooftops that provide some sort of shade or protection from the elements (Armstrong, 1965). Observations of CONI in Waupun seemed to be most common near the hospital and near the Rock River and Meadow View Heights Park, which are both a little over a half a mile (between 800 and 900 meters) northeast of the hospital.

Observations in the city of Wauwatosa were mostly of flying and peenting CONI. Roosting was observed at two points with one point being much further north than the other observations. Most of the CONI observations were near the Milwaukee Regional Medical Center, a campus with many large buildings, many of which have flat graveled rooftops. There are a number of small parks in the area and the Menomonee River is nearby.

In the city of Janesville, CONI were observed flying and peenting on three different occasions at point 1 and two different occasions at point 2. Point 1 is located at the edge of the Rock River and point 2 is about 600 meters north of point 1. There are three moderate sized parks—Lustig Park, Marquette Park, and Lions Park—near point 1. There is a large industrial park across the river and approximately 600 meters south of point 1. The industrial park has what looks to be one large building with many connected segments having rooftops of various substrates, a good portion of which appear to be graveled.

In the city of Fort Atkinson, a CONI was observed booming at point 1 on one occasion, flying at point 2 on two occasions, and flying at point 5 on one occasion. There are many commercial buildings near all three points. Points one and two are located near a downtown area with a number of small flat roofed buildings and point 5 is located in an area with more industrial-type buildings. All three points are within a mile of the Rock River.

In the remaining three cities; Glendale, Racine, and South Milwaukee, Common Nighthawk activity did not seem to be centered around or associated with any particular landscape features. However, either commercial or industrial buildings with flat rooftops were

observed near most points where CONI were detected at each point. In the Village of Union Grove, CONI activity occurred near flat roved buildings with rooftops that appeared to be graveled. CONI activity in the remaining 3 of the villages did not seem to be associated with flat graveled rooftops. In the Village of Elkhart Lake, CONI activity was spread out and seemed to be associated with the forested areas surrounding the lake and the outskirts of the village. In the village of Wales, all CONI observations occurred at a point located at the edge of a golf course. In the village of Monticello, CONI were observed on three different occasions at point 1, once at point 2, and once at point 5. Point 1 is about 0.8 miles (approximately 1,300 meters) east of points 2 and 5. Point one is surrounded by mostly agricultural lands with some patches of trees. There is one small water body, Little Sugar River, near point 1.  There do not appear to be any flat graveled rooftops near any of the points.

## Chapter 5: Discussion

Overall, Common Nighthawk counts were very low with the majority of locations having zero CONI in all surveys. Even the non-zero counts were low. However, this result was not surprising. CONI are often seen migrating in large groups before and after the breeding season, but are rarely detected in large numbers during the breeding season (Brigham et al., 2011). CONI males are very territorial during the breeding season and have been observed actively defending their home ranges from other CONI (Armstrong, 1965; Brigham et al., 2011). If a site were occupied by nesting CONI, it would be very common to observe a single bird, which would likely be the male CONI displaying and foraging especially given the short 10 minute observation period. The next most likely observation would be two CONI, the male and the female. The third most likely scenario would be observing the male, the female, and their young. Since the females generally lay a maximum of three eggs, but usually two, each season, it is unlikely to view more than 4 to 5 CONI at an occupied site during the breeding season (Brigham et al., 2011).

### 5.1 Discussion of Environmental Variables Rated by Volunteers during Surveys

Volunteers recorded information on a number of variables during surveys. The goal was to collect as much information as possible during surveys, which in retrospect was probably unnecessary. Many of the variables including the ratings for insect activity and light pollution, and the counts for predators, would have been better analyzed using different methods either remotely or in a different capacity, e.g. in an entirely different survey. However, it was useful to test the methods of data collection used in this study to inform and improve protocol for future studies.

The framework for the surveys was based on that of the Wisconsin Nightjar Survey and New Hampshire Audubon’s Common Nighthawk surveys (Brady, 2009; Hunt, 2009). The environmental variable rating system for wind speed, sky condition, and noise level was borrowed from the Wisconsin Nightjar Survey. These 3 variables were rated by observers and

served as indicators of potential bias that the variables may have caused during the study. For example, a loud train passing or dog barking may impair the observer's ability to detect CONI aurally. High wind speeds and large amounts of cloud cover could impair an observer's ability to see and hear CONI. The aim of rating these variables was to remind observers of inappropriate surveying conditions when they occurred. For example, an observer may arrive at a point to conduct a survey, begin rating the environmental variables, and realize that the wind was picking up, the sky was getting suspiciously cloudy, or that there was an excessive amount of noise at the point that day. All of these would be red flags to the observer and would, in theory, deter the individual from continuing the survey, reducing the chances of recording false zero observations due to non-detection. Based on the Mann-Whitney U test results, the mean measurements of variables wind ($p=0.16$), sky ($p=0.17$), and noise ($p=0.57$) were not statistically significant, indicating that they did not cause bias in the surveys (Table 11).

The variable temperature (°F) was measured in this study because it is commonly measured in similar studies such as the Wisconsin Nightjar Survey (Brady, 2009; Hunt, 2009; Ng, 2009). Some studies have found that CONI are more likely to be detected on warmer nights (Ng, 2009). This was not the case in this study as the Mann-Whitney U test yielded an insignificant result ($p=0.068$) (Table 11). However, this result is very close to significant at the $\alpha = 0.05$ level. Points with CONI tended to have higher temperatures, but the trend was not statistically significant.

Percent moon illumination is a common variable measured in Nightjar surveys because it is an important factor for nocturnal nightjars such as the Whip-poor-will (Cink, 2002). One theory is that a brighter moon increases the nocturnal nightjar's ability to see which in effect makes the bird more active and easier to detect (Cink, 2002). Since the CONI is a crepuscular bird, the importance of the moon is unclear, particularly in cities and villages where other ambient artificial light is more abundant making the moonlight less important (Ingels et al., 1999). In this

case, the null was the expected outcome; however the Mann-Whitney U test revealed a statistically significant negative correlation between percent Moon Illumination and CONI occurrence (p=0.004) (Table 11). This means that the null could be rejected and that percent Moon Illumination may be more meaningful than originally assumed. However, interpretation that CONI are more active when the moon is less full because the moon is producing less light is not intuitive. It seems unlikely that CONI would be more active under less moon illumination. It is more likely that the significance of this measure is coincidental or associated with some other factor that was not investigated in this study.

This study was a first time trial run for the rated variables light pollution and insect activity. Rating these two variables did not add significantly to the study. The aim of rating light pollution was to determine if areas with larger amounts (higher ratings) of ambient light attracted more CONI than those with less or no ambient light. Rating light pollution was an attempt to characterize the amount of ambient light that could potentially attract CONI to insects congregating near light sources. The results of the Mann-Whitney U test indicate that the light pollution rating was insignificant (p = 0.212) (Table 11). There are a few considerations that make this result less meaningful. First, the rating of light pollution was subjective and unfamiliar to most volunteers, making it more variable and less reliable. Second, if surveys were conducted before dark the light pollution rating was often zero. Third, the light pollution observed was very localized and unlikely to be a sample representative of the light pollution present in a given CONI home range. A better method of estimation of light pollution is needed and such estimation may not be appropriate at the ground level.

The purpose of rating the insect activity was to characterize the insect population and activity at the point. Methods for sampling insects at all survey points were unaffordable and unfeasible for this study. The expected outcome was that high levels of insect activity would be positively correlated with CONI presence. The insect activity rating was problematic in the same

way as the light pollution rating. Insect activity at the ground level may not be representative of the insect activity where CONI forage. It is also highly subjective, unfamiliar, and poorly defined in the study protocol thus, its insignificance is not surprising (Table 11).

The study was also a trial run for the predator and Chimney Swift counts. Predator counts did not show a statically significant influence on CONI (p=0.249) (Table 11). However, the methodology used to count predators in the study was problematic. First of all, CONI counts were carried out at a time of day when crows and gulls are less active (Pollet et al., 2012; Verbeek & Caffrey, 2002). Cats are stealthy and may be missed in counts when one is looking up at the sky for birds. A good portion of predation likely occurs during the day when birds are more active or at night when more predators are active. Overall, predators were underrepresented in this study, making the results from statistical analysis of predator counts less meaningful.

Prior to surveys, there was little consideration given to the potential significance of Chimney Swift counts with respect to CONI occurrence, as the primary reason for collecting CHSW data was to have a 'back-up' dataset in the case that CONI detection was unsuccessful survey-wide. Chimney Swift counts that were positively correlated with CONI occurrence in The Mann-Whitney U test indicated a statistically significant correlation between Chimney Swift counts and CONI occurrence (p=0.012) (Table 11). This was not expected, but it is not surprising since both species are aerial insectivores that nest on artificial structures (Brigham et al., 2011; Cink, 2002).It is possible that both species are drawn to similar habitats because they have similar dependence on human-made structures and have similar dietary needs (Cink & Collins, 2002).

At the survey point volunteers counted the number of tall street lights and other similar structures capable of producing ambient light at night. This measure was another attempt to estimate the influence of ambient light on CONI, and the hypothesis and reasoning was similar to that for light pollution. It was suspected that areas with more artificial light sources would be more likely to have CONI present because CONI could potentially be drawn to feed on the

insects that are drawn to the light sources (Ingels et al., 1999). One issue with the counts was that it was unclear to volunteers whether they were supposed to count lights at any time or only when the lights were illuminated. The intent if the protocol was that volunteers only count lights once and include all lights visible within an estimated 100 meter radius. It was ideal to count lights after dark in order to get a more accurate account. These instructions were not explicitly explained in the protocol so counts were likely inconsistent. That being said, the locations in which CONI were present had a statistically significant higher mean (mean=6.79, p=0.022) than those that did not have CONI (mean=5.41) (Table 12). Regardless of inconsistencies in counts, this result is interesting and meaningful because the literature suggests that CONI may be more likely to nest on buildings that either have artificial lights attached to them or artificial lights nearby. This is based on the theory that insects would be drawn to the lights, which would provide a convenient foraging site for nearby rooftop nesting-CONI (Brigham, 1989; Ingels et al., 1999).

### 5.2 Discussion of Rooftop Estimates

It is well known that Common Nighthawks nest on flat graveled rooftops in urban areas, namely cities and villages (Brigham et al., 2011). This landscape characteristic was measured in three different ways in this study: flat rooftops were counted at each point at the ground level (100 meter radius), the numbers of flat graveled rooftops were counted remotely (500 meter radius), and the area ($m^2$) of flat graveled rooftops was measured remotely (500 meter radius).All three measures exhibited statistically significant positive correlations with CONI occurrence. Both of the remote measures estimated within a 500 meter buffer from aerial photos; the flat graveled rooftop counts (Mann-Whitney U p=0.000, and negative binomial p=0.000) and the area ($m^2$) of flat graveled rooftops (Mann-Whitney U p=0.000, and negative binomial p=0.000) were statistically significant in both the Mann-Whitney U tests and negative binomial models (Table 13 & 14). The counts of flat rooftops recorded by volunteers at the survey point were not

analyzed using the negative binomial but were statistically significant based on the Mann-Whitney U test (p=0.000) (Table 12).

Volunteers counted flat rooftops at each point, and while they were not able to discern whether the rooftops were gravel, the results show that flat rooftop counts were significantly higher at points where CONI were present (mean = 3.04) than at points where CONI were absent (mean=1.14) (Table12). This measure on its own may not be reliable because, as stated previously, the volunteers counted flat rooftops, not flat graveled rooftops. An additional problem with counting flat rooftops at each point was that it was often unclear to volunteers whether the counts were supposed to be of buildings with flat rooftops or of the flat rooftops themselves. In a number of cases, volunteers expressed confusion because they encountered large buildings with many different rooftop levels that were all connected, but seemed different enough to be counted individually. The intention, while not explicitly stated in the protocol, was that volunteers would count buildings with flat rooftops instead of the flat rooftops individually. A count of individual rooftops would be more accurate if all rooftops were visible. It would not be feasible for an observer to view and differentiate between all flat rooftops from the ground level. Therefore, counting each individual rooftop from the ground level would likely yield a less accurate result based on a less consistent method of estimation. It seems likely that because this information was not included in the protocol, flat rooftops may have been measured both ways. The unreliability of this measurement is due to a flaw in study design, which is to be expected given that this was a baseline study. The estimation of flat rooftops surrounding a point at the ground level could be improved by clarifying the instructions in the protocol.

The remote measures of flat graveled rooftops were more reliable and accurate than the counts taken from the ground because the rooftops themselves could be viewed in the aerial photos. Still, there was likely some error in the measurements, because the substrate of each rooftop was estimated based on comparison to similar images of known flat graveled rooftops.

There were likely some instances where the substrate was misidentified. However, while human error was inevitable, the fact that all three of these measures were statistically significant is meaningful (Tables12 & 14). These measures are particularly meaningful because it was expected that CONI would be present in locations with flat graveled rooftops. If the opposite had been true, e.g. CONI were found in areas with less flat graveled rooftops, then questions would be raised regarding the design of the study.

**5.3 Discussion of Land Cover Class Statistics**

Land cover class percentages were analyzed to determine if there were correlations between the classes and CONI presence. It was expected that CONI would be present in urban areas having flat graveled rooftops. The results of the study did show that CONI were in areas that were more developed. Developed, high intensity land cover showed the most statistically significant positive relationship with CONI occurrence (Mann-Whitney p= 0.003, negative binomial p=0.006) and areas that had high percentages of developed, medium intensity land cover came in second with only the negative binomial being statistically significant (p=0.044) (Table 14) and the Mann-Whitney U being very close to statistically significant (p=0.061) (Table 13). The three land cover classes that represented built-up areas—developed- low, medium, and high intensity—were combined into one 'urban' land cover class which was also positively correlated and statistically significant (Mann-Whitney p=0.013 , negative binomial p=0.006) (Table 13 & 14). These results show that in the cities and villages sampled, CONI were present in areas that are more built-up with more buildings and other human-made structures.

Interestingly, the land cover class agriculture exhibited statistically significant negative correlations with Common Nighthawk occurrence in both the Mann-Whitney U test and the negative binomial model. In the Mann-Whitney U test, agricultural land cover mean percentages were statistically significant (p= 0.000), in that mean percentages were higher at points where CONI were absent (mean= 19.73) and lower at points where CONI were present (mean=10.75)

(Table 13). In the negative binomial model, the coefficient for agriculture was negative (b= -0.022921) and statistically significant (p=0.003) (Table 14). This could mean that CONI actively avoid Agricultural land cover near cities and villages, or that urban-nesting CONI prefer other land cover types. Little was found in the literature on the specific topic of CONI and agricultural land cover. Some sources indicate that CONI forage over agricultural landscapes; however, details of the proximity of these agricultural areas to cities and villages where CONI nest are not documented (Brigham et al., 2011). This could be tested by sampling agricultural landscapes near and far from city and village centers to see if CONI avoid all agricultural areas or just those in close proximity to cities and villages.

Positive correlations between the percentages of open water and green space with CONI occurrence were expected. The reasoning behind these expectations was that CONI drink water on the wing and would therefore need areas of open water from which to drink (Brigham et al., 2011). Also, green space, or areas with large amounts of vegetation supporting large insect populations, would provide ideal foraging habitat for CONI (Brigham et al., 2011). The combination of these two land cover classes would in theory provide CONI with ideal drinking and foraging habitat. Both foraging and drinking habitat were analyzed in number of ways by combining land cover percentages from different categories and by analyzing the interaction between classes using negative binominal regression. The class green space was a combination of all classes that could have been potential CONI foraging habitat. The green space category was not significant in either the Mann-Whitney U test (p=0.110) or the negative binomial model (p= 0.546) (Table 13 & 14). The wetland land cover class which could potentially have been foraging or drinking habitat for CONI was not statistically significant either (Mann-Whitney p=0.842, negative binomial p=0.245) (Table 13 & 14). However, the hypothesis that wetland could provide foraging and drinking habitat for CONI was loosely drawn from the literature. Some documents suggest that wetland could be CONI foraging and drinking habitat, but no specific evidence was

found in the literature to support this theory. The open water land cover class was not statistically significant either (Mann-Whitney p=0.864, negative binomial p=0.286) (Table 13 & 14). Additionally, the parameter estimates from the negative binomial model, while statistically insignificant, suggested a negative correlation between open water and the number of CONI (b= -0.019). It appears as though the 'openness' of the water source is not important based on the results of this study. A measurement of distance to nearby water sources may be more meaningful and could be investigated in future studies (Ng, 2009).It is possible some of these results were insignificant because a 500 meter buffer was too small. Perhaps it would be more appropriate to analyze larger areas. Or, perhaps it would be more appropriate to utilize an approach similar to that used by Armstrong (1965) by first locating nesting CONI and determining the center of their home range based on the breeding displays of males, and then analyzing the landscape surrounding the estimated center of the home range. This method would likely produce more meaningful results for all land cover classes.

**5.4 Discussion of the Multivariate Negative Binomial and ZINB Models**

All significant variables from the negative binomial models were combined and one model (Model 1) emerged that performed better than the single-variable models (AIC = 520, Log likelihood = -512) (Table 15). Model 1 included the variables agriculture and the number of flat graveled rooftops. In the equation, agricultural land cover exhibited a statistically significant negative correlation with CONI occurrence (b= -1.584278, p= 0.030) and the number of flat graveled rooftops exhibited a statistically significant positive correlation with CONI occurrence (b=0.098653, p= 0.023) (Table 15). Model 1 suggests that points with less agricultural land cover and more flat graveled rooftops are likely to have higher counts of CONI.

More sophisticated methods to model zero inflation were employed to investigate the data further because there were a large number of zeros for both CONI occurrence and counts in the dataset. The Vuong test indicated that the zero-inflated negative binomial model was

significantly superior to the standard negative model using the same variables (p=0.064) (Table17). However, variables in the ZINB model are less significant. In the count portion of the ZINB model, agriculture was negatively correlated with CONI presence, but the relationship was not statistically significant (b= -0.005, p= 0.067) and the Number of Flat Graveled Rooftops was positively correlated with CONI presence, but was not statistically significant either (b= 0.011, p= 0.798) (Table 16). In the zero inflation portion of the model, the estimated coefficient for agriculture was opposite in sign, but not statistically significant (b= 0.016, p=0.236) and the coefficient for the number of flat graveled rooftops was also opposite in sign, but was statistically significant (b=-0.141, p=0.086) (Table 16). The zero inflation portion of the model is a logistic regression estimating the probability of obtaining a zero. The count portion of the model is a negative binomial regression estimating the probability of obtaining a non-zero. The zero inflation portion of the model suggests that the probability of obtaining a zero increases with a decrease in the number of flat graveled rooftops and increases with an increase in agricultural land cover. The count portion of the model suggests that the probability of obtaining a non-zero increases with an increase in the number of flat graveled rooftops and increases with a decrease in agricultural land cover. Despite a lesser degree of significance in the explanatory variables agriculture and the number of flat graveled rooftops, overall, the ZINB model performed better than the standard negative binomial model.

### 5.5 Discussion of ebird and Common Nighthawk Occurrence and behaviors

In summary, based on visual analysis of aerial photos and observed behaviors, CONI were most active in medium sized to large cities that had a combination of flat graveled rooftops, water bodies, and parks. Activity centers seemed apparent in locations having all three of these features. Activity centers were particularly obvious in Burlington, Waupun, and Fort Atkinson where CONI were observed booming. ebird entries indicate that CONI have been observed near the Waupun Correctional Institution since the 1990s, which, combined with the findings of this

study, is a good indication that CONI have been nesting either on the building or nearby. There are numerous ebird reports of CONI dating back to 2007 in both Burlington and Fort Atkinson, many of which were very close to survey points at which CONI were detected. The city of Janesville had a large amount of CONI activity near the downtown area. Numerous ebird accounts with records dating back to 1939 suggest that CONI have been nesting in downtown Janesville for decades.

As mention earlier, booming was observed in Greendale. However, booming activity was not observed on multiple occasions at points in Greendale despite multiple surveys. There is only one reported sighting of CONI in Greendale from June 2$^{nd}$, 2011, which does not provide any more evidence for CONI nesting since the observation occurred early in the season, at a time when CONI could still be migrating. CONI were very active in the city of Wauwatosa during surveys for this study, and while the activity seemed to be centered near the Milwaukee Regional Medical Center, it is unclear where the birds may have been nesting. Surprisingly, there was only one ebird record of CONI during the breeding season for all years.

Reports on ebird, the results of this study, and other anecdotal evidence suggest that CONI have been nesting somewhere in the city of Glendale, but the nest site locations are unclear. The cities of Racine and South Milwaukee had CONI sightings on multiple occasions and had flat graveled rooftops near points where CONI were observed, but activity centers were less obvious. CONI activity did not seem to be associated with flat graveled rooftops in any of the villages that had CONI sightings on multiple occasions, with the exception of Union Grove. The points in Elkhart Lake, Wales, and Monticello may not have been the best measure of ‘urban’ CONI habitat since they were placed in primarily rural or agricultural areas. The CONI in these villages may have been rural, ground-nesting birds and not urban, flat rooftop-nesting birds.

# Chapter 6 Summary, Recommendations for Future Research and Conclusions

## 6.1 Summary

The goal of this thesis was to conduct a baseline study to locate CONI in cities and villages in Wisconsin and to characterize the habitats in which they were found. A citizen science approach was adopted which used surveys to collect primary data. One of the great successes of this thesis was the use of citizen science to collect a large amount of data in a short amount of time. Recruiting passionate, dedicated, and reliable volunteers for this study was accomplished through various social networks. Wisconsin was listed as one of the top three states in the U.S. for bird watching (second only to Vermont and tied with West Virginia) in 2011 based on information provided by residents ages 16 or older in a report given by the U.S. Fish and Wildlife Service (Carver, 2013). Wisconsin's robust birding community is a significant reason why this study was so successful.

Overall, this study was successful in locating Common Nighthawks in cities and villages in southeastern Wisconsin. Citizen science-based methodology allowed for data collection across a large geographical area in a short amount of time. Volunteers surveyed 82 of the 92 cities and villages in the random sample. CONI were detected in 32 (39%) of these locations (Table 7). The majority of the locations in which CONI were observed most often were larger cities with human populations between 5,436 and 23,411. Visual analysis of aerial photos and maps of each point show that CONI were most active at points that had a combination of parks, water bodies, and flat graveled rooftops nearby. In a few cities CONI activity seemed to be centered near large industrial or commercial buildings that appeared to have flat graveled rooftops in aerial photos. The hypothesis was that CONI presence would be positively correlated with high numbers of flat graveled rooftops, high percentages of green space (e.g. parks), and high percentages of open water sources (e.g. lakes and rivers). Statistical analyses did not show that parks or water bodies

were of any particular significance to CONI presence; however, qualitative-visual investigation of aerial photos suggests that these variables are significant in number of locations.

### 6.2 Recommendations for Future Research

Annual monitoring of Common Nighthawks in cities and villages in Wisconsin will aid in understanding the magnitude of population declines. The work conducted for this thesis sets the framework for future studies. Annual surveys should be conducted at points where CONI were observed in order to track changes in populations. Regular monitoring will yield a more robust data set that will be better suited for statistical analyses such as occupancy modeling and multivariate analysis of environmental factors and landscape features of possible importance to CONI.

Survey sites could be further refined by observing CONI behaviors and determining centers of activity. Analysis of land cover at the activity center will likely yield more meaningful correlations between CONI presence and land cover classes. If remote analyses of land cover classes are pursued in future studies, larger buffers from 1 km to at least 3 km should be used since CONI have a wide range of home range sizes (Armstrong, 1965). Distance from CONI observations to water bodies should also be explored. Methods for measuring light pollution remotely should also be investigated.

In future studies, observers should collect more information on fewer variables. Detailed information on buildings with flat rooftops should be collected where CONI are observed. Details such as the age of the building, the size of the roof, whether or not the roof has levels or parapets, and if there are artificial light sources attached to or near the building would help characterize the nesting habitat preferred by CONI in cities and villages. More detailed descriptions of the types of CONI behavior observed should be recorded, e.g. whether flight was erratic or soaring. Cardinal directions of observations and flight paths should also be recorded. Future surveys

should be conducted from a high vantage point when possible such as a parking structure or rooftop to limit obstruction of view and gain perspective on rooftops and other features.

Separate studies will be necessary to obtain meaningful measurements of insects and predators. Methods of insect collection at higher altitudes should be investigated and implemented at locations were CONI are regularly observed. Each predator should be monitored during the time of day when it is most active.

Interactions between variables recorded by volunteers were not investigated in this study because the methods of estimation were new and unreliable. This is particularly true for the rated variables light pollution and insect activity, and the counts for predators and artificial light sources. Once more accurate and reliable measurements of insect abundance/availability, light pollution, and predators are established, the interactions between variables should be investigated. The interaction between insects, temperature (°F), and light pollution, etc. should explored. Also, the interaction between ambient light pollution, artificial light sources, and the number and total area of flat graveled rooftops should be investigated.

Studies comparing points in cities and villages with points in rural areas would be helpful in identifying similarities and differences in the habitat preferences of urban and rural nesting CONI. A study sampling points in agricultural lands both near and far from cities and villages would help to further understanding of the meaning of the negative correlation between agricultural land cover and CONI occurrence observed in this study.

**6.3 Conclusions**

Common Nighthawk population decline is a multifaceted issue with no simple answer (Brigham et al., 2011; Nebel et al, 2010). There are likely multiple factors influencing declines in Wisconsin including habitat loss, predation, and food reduction (Brady, 2009; Brigham et al., 2011; Nebel et.al, 2010). The goal of this thesis was to investigate one aspect of the decline in

southeastern Wisconsin by locating Common Nighthawks in cities and villages to determine where Common Nighthawks still persist and what environmental factors and landscape features are associated with their presence. Since CONI were found in larger cities that had more individual flat rooftops and more total area of flat rooftops, it is reasonable to assume that flat graveled rooftops are being used by nesting Common Nighthawks in cities in southeastern Wisconsin. This study suggests a negative correlation between CONI presence and agricultural land cover. Agricultural land cover dominates the non-urban areas of the study region with approximately 58% of the total land cover in the Southeast Glacial Plains and approximately 39% of total land cover in the Southern Lake Michigan Coastal ecological landscapes (WDNR, 2014). The results of this study suggest that in southeastern Wisconsin, CONI conservation efforts should be focused in cities and villages. It will be important for future studies to determine if CONI are avoiding agricultural landscapes region-wide by sampling agricultural lands at different distances from city and village centers.

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# APPENDICES

**Appendix A Class 1 (161 - 1,172 people) 30 randomly selected villages, 6 locations had Common Nighthawks**

***Location had volunteer coverage, but contact was lost***

*****Location had volunteer coverage, volunteer was unable to survey and contact was made***

| Location | Human Population (2010) | Surveyed? | Nighthawks Detected? | Number of Points |
|---|---|---|---|---|
| **Kekoskee village** | 161 | Yes | No | 2 |
| **Rockdale village** | 214 | Yes | No | 2 |
| ***North Bay village** | 241 | No | n/a | n/a |
| **Lowell village** | 340 | Yes | No | 4 |
| **Fairwater village** | 371 | Yes | No | 4 |
| Glenbeulah village | 463 | Yes | Yes | 4 |
| **St. Cloud village** | 477 | Yes | No | 4 |
| ***Elmwood Park village** | 497 | No | n/a | n/a |
| **Chenequa village** | 590 | Yes | No | 5 |
| **Oconomowoc Lake village** | 595 | Yes | No | 8 |
| **Stockbridge village** | 636 | Yes | No | 5 |
| **Sullivan village** | 669 | Yes | No | 4 |
| ****Fremont village** | 679 | No | n/a | n/a |
| **Reeseville village** | 708 | Yes | No | 4 |
| Cascade village | 709 | **Yes** | **Yes** | 3 |
| Mount Calvary village | 762 | **Yes** | **Yes** | 3 |
| **Cambria village** | 767 | Yes | No | 4 |
| **St. Nazianz village** | 783 | Yes | No | 4 |
| **Footville village** | 808 | Yes | No | 4 |
| **Arlington village** | 819 | Yes | No | 5 |
| **Eden village** | 875 | Yes | No | 3 |
| Elkhart Lake village | **967** | **Yes** | **Yes** | 3 |
| ***Dane village** | 995 | No | n/a | n/a |
| **Albany village** | 1018 | Yes | No | 7 |
| **Rosendale village** | 1063 | Yes | No | 6 |
| **Oakfield village** | 1075 | Yes | No | 5 |
| **Lannon village** | 1107 | Yes | No | 4 |
| **Hustisfordillage** | 1123 | Yes | No | 6 |
| Monticello village | **1217** | **Yes** | **Yes** | 5 |
| Newburg village | **1254** | **Yes** | **Yes** | 5 |

**Appendix B Class 2 (1,173 -5,435 people) 30 randomly selected cities and villages, 9 locations had Common Nighthawks**

***Location had volunteer coverage, but contact was lost**

| Location | Human Population (2010) | Surveyed? | Nighthawks Detected? | Number of Points |
|---|---|---|---|---|
| Nashotah village | 1395 | Yes | No | 5 |
| Brooklyn village | 1401 | Yes | No | 4 |
| Fox Lake city | 1519 | Yes | No | 6 |
| Sharon village | 1605 | Yes | No | 4 |
| Campbellsport village | 2016 | Yes | No | 4 |
| **Dousman village** | **2302** | **Yes** | **Yes** | 7 |
| *Winneconne village | 2383 | No | n/a | n/a |
| **Silver Lake village** | **2411** | **Yes** | **Yes** | 6 |
| **Wales village** | **2549** | **Yes** | **Yes** | 8 |
| Williams Bay village | 2564 | Yes | No | 8 (5 surveyed) |
| Sherwood village | 2713 | Yes | No | 7 |
| Paddock Lake village | 2992 | Yes | No | 7 |
| Genoa City village | 3042 | Yes | No | 7 |
| Thiensville village | **3235** | **Yes** | **Yes** | 5 |
| New Holstein city | 3236 | Yes | No | 6 |
| Horicon city | 3655 | Yes | No | 8 |
| **Kiel city** | **3738** | **Yes** | **Yes** | 6 |
| **Saukville village** | **4451** | **Yes** | **Yes** | 6 |
| **Union Grove village** | **4915** | **Yes** | **Yes** | 6 |
| **Waterford village** | **5368** | **Yes** | **Yes** | 7 (6 surveyed) |
| Lake Mills city | 5708 | Yes | No | 8 |
| Sturtevant village | 6970 | Yes | No | 7 |
| *Delafield city | 7085 | No | n/a | n/a |
| Mukwonago village | 7355 | Yes | No | 8 |
| McFarland village | 7808 | Yes | No | 8 (6 surveyed) |
| *Jefferson city | 7973 | No | n/a | n/a |
| Pewaukee village | 8166 | Yes | No | 7 |
| **Delavan city** | **8463** | **Yes** | **Yes** | 7 |
| *De Forest village | 8936 | No | n/a | n/a |
| Oregon village | 9231 | Yes | No | 8 |

**Appendix C Class 3 (5,436 – 23,411 people) 30 randomly selected cities and villages, 16 had Common Nighthawks**

*****Location had volunteer coverage, volunteer was unable to survey and contact was made***

| Location | Human Population (2010) | Surveyed? | Nighthawks Detected? | Number of Points |
|---|---|---|---|---|
| **Waukesha city** | **70718** | **Yes** | **Yes** | **8** |
| Watertown city | 23861 | Yes | No | 8 |
| **Beaver Dam city** | **16214** | **Yes** | **Yes** | **8** |
| **Greendale village** | **14046** | **Yes** | **Yes** | 8 |
| **Grafton village | 11459 | No | n/a | n/a |
| **Whitewater city** | **14390** | **Yes** | **Yes** | 8 |
| Cudahy city | 18267 | Yes | No | 6 |
| Sun Prairie city | 29364 | Yes | No | 8 |
| **Neenah city** | **25501** | **Yes** | **Yes** | 6 (1 surveyed) |
| **Wauwatosa city** | **46396** | **Yes** | **Yes** | 8 |
| **Fond du Lac city | 43021 | No | n/a | n/a |
| Oshkosh city | 66083 | Yes | No | 8 |
| Oconomowoc city | 15759 | Yes | No | 8 (7 surveyed) |
| **Hartford city** | **14223** | **Yes** | **Yes** | 8 |
| **Burlington city** | **10464** | **Yes** | **Yes** | 7 |
| **Glendale city** | **12872** | **Yes** | **Yes** | 8 |
| **West Bend city** | **31078** | **Yes** | **Yes** | 8 |
| Brown Deer village | 11999 | Yes | No | 8 |
| **Stoughton city** | **12611** | **Yes** | **Yes** | 8 |
| Waunakee village | 12097 | Yes | No | 7 |
| Monroe city | 10827 | Yes | No | 8 |
| Cedarburg city | 11412 | Yes | No | 7 |
| West Allis city | 60411 | Yes | No | 8 |
| Sussex village | 10518 | Yes | No | 8 |
| **Janesville city** | **63575** | **Yes** | **Yes** | 8 |
| **Fort Atkinson city** | **12368** | **Yes** | **Yes** | 8 |
| **South Milwaukee city** | **21156** | **Yes** | **Yes** | 7 |
| Verona city | 10619 | Yes | No | 7 |
| **Waupun city** | **11340** | **Yes** | **Yes** | 8 |
| Middleton city | 17442 | Yes | No | 8 |
| Pleasant Prairie village | 19719 | No | n/a | n/a |
| Greenfield city | 36720 | No | n/a | n/a |
| Menasha city | 17353 | No | n/a | n/a |
| Elkhorn city | 10084 | No | n/a | n/a |

**Appendix D Class 4 (23,412 – 99,218 people) 2 cities in the random sample, 1 had CONI and Beloit, which had Common Nighthawks**

| Location | Human Population (2010) | Surveyed? | Nighthawks Detected? | Number of Points |
|---|---|---|---|---|
| **Racine city** | **78860** | **Yes** | **Yes** | 8 |
| Kenosha city | 99218 | Yes | No | 8 |
| **Beloit city** | **36966** | **Yes** | **Yes** | 5 |

Appendix E Table of locations at which Common Nighthawks were detected on one survey evening.

Total times surveyed indicate the total number of surveys that were conducted at the point. Survey date indicates the date of the survey in which Common Nighthawks were observed. Observed activity indicates all Common Nighthawk behaviors observed during each 10 minute point count. Behavior codes are as follows; B=booming or diving, F = flying, P=peenting, R=roosting. Behavior codes are described in detail in Chapter 2, 'conducting the survey'.

| City / Village Name | Point Name | Survey Date | Observed Activity | Total times point was surveyed |
|---|---|---|---|---|
| **Beaver Dam City** | Beaver Dam_5 | 6/8/13 | F | 3 |
| **Burlington city** | Burlington_2 | 7/6/13 | FP | 3 |
| **Cascade Village** | Cascade_2 | 6/8/13 | P | 2 |
| **Cascade Village** | Cascade_3 | 6/8/13 | P | 2 |
| **Delavan City** | Delavan_5 | 6/11/13 | P | 3 |
| **Dousman village** | Dousman_5 | 6/20/13 | F | 3 |
| **Dousman village** | Dousman_6 | 6/14/13 | F | 3 |
| **Dousman village** | Dousman_7 | 6/14/13 | F | 3 |
| **Elkhart Lake Village** | Elkhart_3 | 6/10/13 | F | 5 |
| **Fort Atkinson** | Fort Atkinson_1 | 6/8/13 | **BFP** | 4 |
| **Fort Atkinson** | Fort Atkinson_5 | 7/5/13 | FP | 4 |
| **Glenbeulah Village** | Glenbeulah_1 | 6/7/13 | P | 3 |
| **Glendale city** | Glendale_1 | 6/10/2013 | P | 3 |
| **Glendale city** | Glendale_6 | 7/6/2013 | FP | 3 |
| **Glendale city** | Glendale_7 | 6/18/2013 | F | 3 |
| **Glendale city** | Glendale_8 | 6/21/2013 | P | 3 |
| **Greendale village** | Greendale_1 | 6/23/13 | P | 4 |
| **Greendale village** | Greendale_2 | 6/23/13 | P | 2 |
| **Greendale village** | Greendale_3 | 6/23/13 | **BFP** | 3 |
| **Greendale village** | Greendale_8 | 6/9/2013 | P | 2 |
| **Hartford city** | Hartford_1 | 6/10/13 | FP | 3 |
| **Hartford city** | Hartford_7 | 6/13/13 | FP | 3 |
| **Kiel city** | Kiel_4 | 6/9/13 | P | 3 |
| **Middleton city** | Middleton_5 | 6/10/13 | P | 2 |
| **Monticello village** | Monticello_2 | 6/27/13 | FP | 3 |
| **Monticello village** | Monticello_5 | 6/14/13 | P | 3 |
| **Mount Calvary village** | MtCalvary_3 | 6/10/13 | F | 3 |
| **Neenah city** | Neenah_2 | 6/16/2013 | FP | 1 |
| **Newburg village** | Newburg_1 | 6/8/13 | FP | 3 |
| **Newburg village** | Newburg_3 | 6/8/13 | FP | 3 |
| **Saukville village** | Saukville_6 | 6/19/13 | F | 3 |

| | | | | |
|---|---|---|---|---|
| **Silver Lake village** | Silver Lake_3 | 6/19/13 | F | 2 |
| **South Milwaukee City** | South Milwaukee_6 | 6/19/13 | F | 3 |
| **Stoughton city** | Stoughton_6 | 6/19/13 | F | 3 |
| **Thiensville village** | Thiensville_1 | 6/8/13 | FP | 3 |
| **Thiensville village** | Thiensville_2 | 6/10/13 | P | 3 |
| **Union Grove village** | Union Grove_6 | 6/15/13 | F | 5 |
| **Waterford village** | Waterford_4 | 6/13/13 | P | 3 |
| **Waukesha city** | Waukesha_4 | 6/29/13 | FP | 3 |
| **Waupun city** | Waupun_3 | 6/26/13 | P | 3 |
| **Waupun city** | Waupun_5 | 6/26/13 | FP | 3 |
| **Wauwatosa city** | Wauwastosa_8 | 6/13/13 | P | 3 |
| **West Bend city** | West Bend_1 | 6/10/13 | F | 3 |
| **West Bend city** | West Bend_2 | 6/9/13 | F | 3 |
| **West Bend city** | Wes tBend_5 | 6/10/13 | F | 3 |
| **West Bend city** | West Bend_8 | 6/9/13 | F | 3 |
| **Whitewater city** | Whitewater_7 | 6/13/13 | FP | 3 |

Appendix F Table of locations where Common Nighthawks were detected on two survey evenings.

Total times surveyed indicate the total number of surveys that were conducted at the point. First survey date indicates the first survey in which Common Nighthawk(s) were observed and second survey date indicates the second survey in which Common Nighthawk(s) were observed. Observed activity indicates all Common Nighthawk behaviors observed during each 10 minute point count. Behavior codes are as follows; B=booming or diving, F = flying, P=peenting, R=roosting. Behavior codes are described in detail in Chapter 2, 'conducting the survey'.

| City / Village Name | Point Name | First Survey Date | Observed Activity | Second Survey Date | Observed Activity | Total times point was surveyed |
|---|---|---|---|---|---|---|
| **Elkhart Lake Village** | Elkhart_1 | 6/10/13 | F | 6/16/13 | FP | 5 |
| **Fort Atkinson** | Fort Atkinson_2 | 6/8/13 | FP | 7/5/13 | **BFP** | 2 |
| **Janesville city** | Janesville_2 | 6/8/13 | FP | 6/25/13 | F | 3 |
| **Racine city** | Racine_3 | 6/23/13 | F | 6/27/13 | F | 3 |
| **South Milwaukee City** | South Milwaukee_5 | 6/11/13 | FP | 6/19/13 | P | 3 |
| **Union Grove village** | UnionGrove_1 | 6/11/13 | P | 6/16/13 | R | 5 |
| **Union Grove village** | UnionGrove_3 | 6/11/13 | P | 6/19/13 | F | 5 |
| **Wales village** | Wales_2 | 6/16/13 | P | 6/20/13 | P | 3 |
| **Waupun city** | Waupun_2 | 6/11/13 | P | 6/26/13 | P | 3 |
| **Waupun city** | Waupun_4 | 6/11/13 | **BFP** | 6/18/13 | P | 3 |
| **Waupun city** | Waupun_6 | 6/11/13 | P | 6/26/13 | P | 3 |
| **Waupun city** | Waupun_7 | 6/11/13 | P | 6/26/13 | P | 3 |
| **Wauwatosa city** | Wauwastosa_1 | 6/14/13 | R | 6/19/13 | P | 3 |
| **Wauwatosa city** | Wauwastosa_2 | 6/13/13 | FP | 6/24/13 | P | 3 |
| **Wauwatosa city** | Wauwastosa_4 | 6/19/13 | FP | 6/24/13 | P | 3 |
| **Wauwatosa city** | Wauwastosa_7 | 6/19/13 | FPR | 6/24/13 | FP | 3 |

Appendix G Table of locations where Common Nighthawks were detected on three survey evenings.

Total times surveyed indicate the total number of surveys that were conducted at the point. First survey date indicates the first survey in which Common Nighthawk(s) were observed, second survey date indicates the second survey in which Common Nighthawk(s) were observed, and third survey date indicated the third. Observed activity indicates all Common Nighthawk behaviors observed during each 10 minute point count. Behavior codes are as follows; B=booming or diving, F = flying, P=peenting, R=roosting. Behavior codes are described in detail in Chapter 2, ‘conducting the survey’.

| City Name | Point Name | First Survey Date | Observed Activity | Second Survey Date | Observed Activity | Third Survey Date | Observed Activity | Total times point was surveyed |
|---|---|---|---|---|---|---|---|---|
| **Burlington city** | Burlington_3 | 6/25/13 | B | 6/30/13 | BF | 7/6/13 | BFP | 3 |
| **Glendale city** | Glendale_4 | 6/10/13 | FP | 6/18/13 | P | 6/23/13 | F | 3 |
| **Janesville city** | Janesville_1 | 6/8/13 | FP | 6/18/13 | P | 6/26/13 | FP | 3 |
| **Monticello village** | Monticello_1 | 6/14/13 | P | 6/19/13 | P | 6/27/13 | F | 3 |
| **Wauwatosa city** | Wauwastosa_3 | 6/13/13 | FP | 6/19/13 | FP | 6/24/13 | FP | 3 |