

NEST SITE SELECTION AND NEST THERMAL PROPERTIES OF
COMMON NIGHTHAWKS ON THE TALLGRASS PRAIRIE OF KANSAS

A Thesis

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by

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ABSTRACT

My research uses a behavioral ecology approach to understand Common Nighthawk (*Chordeiles minor*) declines and to inform nest-site restoration efforts in urban and suburban landscapes. The objectives of this study were to determine if nighthawks are choosing to nest non-randomly with respect to the distribution of types of vegetation and substrates within a tallgrass prairie landscape on Konza Prairie in Kansas, and to establish the thermal properties of nest sites for biologically informed restoration efforts. These two objectives were designed to identify nest-site characteristics that could be used to design suitable nesting substrates in urban and suburban landscapes.

In the summer of 2007, I investigated nest site selection. Common Nighthawks typically lay clutches of one to two eggs either directly on the ground or in a shallow scrape. Most nests that have been documented were on patches of rock, gravel, or bare ground, but I wanted to determine whether this was due to differences in detectability between open gravel patches and areas with more vegetation cover. In early May, prior to the breeding season, we identified 10 target watersheds on Konza Prairie Biological Field Station. I then surveyed 120 randomly-placed vegetation plots in those areas. The circular plots were 4 m in diameter and I recorded percent cover of 5 cover class types within each plot (forbs, grass, shrub, dead vegetation, and rock/gravel/bare ground). During the breeding season from mid-May to late July, I systematically searched for nests within the targeted watersheds. I found 27 nests in these areas. As soon as possible (zero to three days) after finding each nest, I surveyed the area directly around the location of the eggs

or chicks, recording percent cover in the same manner as the vegetation plots (4m diameter circle with percent cover of 5 cover classes). Post-breeding season, in early to mid-August, I re-surveyed the same 120 vegetation plots. At the same time, I also re-sampled the vegetation at all the nest sites. When I compared the summer re-survey of the nest plots to the summer re-survey of the random vegetation plots using a Mann-Whitney “U” test, I found that the birds were selecting areas with bare ground and rock at a significantly greater frequency than they occur in the surrounding landscape. I also observed that they were avoiding shrubs. Overall, 96% of 27 nests occurred on bare ground and rock. In 2008, I used a trained dog to find nests; 100% of the nests discovered by the dog were on bare ground and rock (n=9), a percentage similar to the percent in my 2007 sample.

To investigate the thermal properties of nest sites, from July 9 - July 29 of 2008, I placed iButton thermal data loggers at nests. The iButtons recorded the temperature, time, and date every five minutes. At each nest, I placed one iButton directly on the nesting substrate away from the eggs or chicks (on rock/bare ground), and I placed an additional iButton in the next nearest cover class (grass or forbs). At each nest, the iButtons were approximately .5m apart. I recorded the temperature at 6 nests for 1660 hours at each. I found that within a single month, the nesting substrate can experience temperatures that range from 14.5°C to 60°C. When I compared the vegetation versus the nest site I found that the average daily temperature and the high daily temperatures were significantly cooler in the vegetation during the day. Based on behavioral observations, these cooler areas serve as refuges for the young nighthawks during the day.

Based on these observations of nest-site characteristics I recommend that natural areas be managed to increase rock and gravel patches and that urban restoration efforts test patches that maximize the amount of shade available during the day.

BIOGRAPHICAL SKETCH

Rebecca Lohnes grew up on a small cattle farm in western Illinois. She graduated with a B.S. in Ecology and Evolutionary Biology from Yale University in spring 2005. During 2005 and 2006, before entering graduate school, Rebecca gained field experience with many different taxa and ecosystems. She spent the year monitoring nesting songbirds in the cypress swamps of southern Missouri, interpreting raptor migration for park visitors at Grand Canyon National Park, monitoring nesting Golden-Headed Quetzals in the cloud forest of eastern Ecuador, and conserving Mountain Plover nests in agricultural fields in northeastern Colorado. She also has previous undergraduate field experience in western Maryland, Cape Cod, Massachusetts, and Kansas.

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INTRODUCTION

The Common Nighthawk (*Chordeiles minor*, hereafter “nighthawk”) is a Neotropical migrant that breeds across North America. While nighthawks are still locally common in some areas, there is general agreement within the monitoring community that they are now declining across their range, especially in urban and suburban areas. Unfortunately, nighthawk populations are difficult to sample using traditional methods, so it has been difficult to obtain an accurate assessment of changes in abundance over time. Breeding Bird Survey (BBS) data indicate wide-spread declines; however, BBS routes are sampled in the morning when nighthawks are not active (Peterjohn et al. 1995, Sauer et al. 2008). Even without reliable data, citizens, birders, and scientists often report that nighthawk populations have disappeared in the last thirty years. Historically, nighthawks nested on flat gravel rooftops (Poulin et al. 1996, Gross 1940, Dexter 1952, Dexter 1956, Dexter 1961), but now most flat roofs have been converted to rubber or bitumen, which are unsuitable substrates for nesting nighthawks. Several ongoing citizen- and scientist-driven urban restoration projects focus specifically on placing gravel patches on rooftops, but so far no patches have been occupied by nesting nighthawks (R. Suomala pers comm., T. Hoppe pers. comm). Urban restoration projects of this kind could prove to be crucial to the conservation of this species. At this stage, however, such efforts have been speculative because of our poor understanding of which factors have been responsible for nighthawk declines.

Although nighthawks have been historically common and are locally abundant in some areas, many aspects of their ecology and behavior are poorly known (Poulin et al. 1996). Abundance itself is no protection against

extinction, a lesson learned well from the story of the Passenger Pigeon (*Ectopistes migratorius*, Cokinos 2000) and from the ongoing decline of native populations of the House Sparrow (*Passer domesticus*, Hole et al. 2002, Robinson et al. 2005). In Great Britain, the House Sparrow population is experiencing local extinctions due to changes in agricultural practices (Hole et al. 2002). Local extinctions lead to greater distances between populations and lessen the probability of recolonization, and this could be a contributing factor to the decline of nighthawks, especially in urban areas.

There are several other possible reasons for the observed decline in nighthawk populations. Their disappearance may be part of a larger phenomenon of declines in aerial insectivores, including swifts, swallows, flycatchers, and other nightjars. Major factors in these declines could include decreases in prey abundance due to increased pesticide use, mismatch of phenology of the insect and avian seasons due to climate change, and decreases in available nesting and foraging habitat (Evans et al. 2007, McCracken 2008, Parody et al. 2001, Sauer et al. 1996).

Alternatively, it is possible that Whip-poor-wills (*Caprimulgis vociferous*) and nighthawks experienced artificial increases in abundance due to deforestation caused by European settlers and that their declines have been caused by recent reforestation (Brooks 2003, Stevenson et al. 1983).

An alternative set of hypotheses for nighthawk declines in urban populations focuses on breeding-specific variables. As previously mentioned, the replacement of gravel roofs with rubber and bitumen membrane roofs has left the nighthawk with little to no suitable nesting habitat in urban areas. The smooth, flat surface of the rubber or bitumen does not mimic the natural nesting habitat as well as the gravel roofs did. Another hypothesis is that

increased predation rates have reduced success of urban nests. This could be due to the increased visibility of both roosting nighthawks and eggs against a monochromatic rubber or bitumen roof. Increased populations of avian predators such as American Crows (*Corvus brachyrhynchos*) or Herring Gulls (*Larus argentatus*) in urban areas could also play a role (Belant 1997, Marzluff et al. 2001, Marzilli 1989).

A third urban-specific hypothesis is that the thermal properties of rubber or bitumen roofs are different than gravel roofs and that nighthawks are unable to cope with the increased temperatures. Ambient temperature can influence embryo development by causing the egg to be heated or cooled outside the optimum temperature range for development (between 36°C and 40°C for most birds). Hyperthermia, or overheating, is more damaging to the developing embryo than hypothermia and results in lower hatching success (Webb 1987). At temperatures above 40.5°C eggs cease development and will perish unless they are promptly cooled (Bennett and Dawson 1979, Webb 1987). Incubating female nighthawks are capable of moving their eggs short distances and have been observed moving their eggs to shaded areas during periods of intense heat (Sutton and Spencer 1949, Woods 1924).

Heatstroke can be a cause for mortality in young chicks when exposed to high ambient temperatures with no relief (Overstreet and Rehak 1982). The lethal maximum body temperature for young birds has been estimated at 46.0°C to 47.8°C (Randall 1942). While both adult and young nighthawks cool themselves by increasing evaporative water loss via gular fluttering (Cowles and Dawson 1951, Lasiewski and Dawson 1964), it might not be adequate to cool young nighthawks in the absence of shade. Howell (1959) exposed week-old nestlings to direct sun (ambient temperature = 42°C) for only seven

minutes and their body temperatures rose from 40 °C to 44°C. The chicks showed “great distress” and Howell discontinued the experiment for fear that the chicks would succumb to heatstroke. By the time the chicks were 11 to 12 days old, he could no longer expose them to sun for more than 15 minutes because they would move to shaded areas and remain there. Marzilli (1989) found that the average temperatures of a simulated gravel surface and a simulated rubber surface on the same roof during one twenty four-hour period were 41.6°C and 56.3°C respectively. At these temperatures, without a brooding parent or access to shade, young nighthawks could become hyperthermic. At a roof nest, during a day of intense heat (gravel surface = 60°C) Gross (1926) observed one nighthawk chick die of heatstroke while the other chick was able to find shade among the structures on the rooftop.

Nighthawks lay their eggs directly on a flat surface (Poulin et al. 1996). They build no nest and, at most, create a small bare area, scraped clean of debris, on which to lay their clutch of one to two eggs. The eggs hatch after about 18 days. The young are semiprecocial, covered in down and with open eyes, but lacking the mobility of precocial birds. The chicks stay in the nest area for another 18 – 21 days before fledging. The chicks gain limited mobility after the first few days and are able to walk to areas of different substrate and/or vegetation type within the nest area. Several published studies have been done involving very few (one to five) nighthawk nests on rooftops (Bowles 1921, Gross 1926, Gross 1940, Dexter 1952, Dexter 1956, Dexter 1961, Parks 1946, Roth and Jones 2001, Sutton and Spencer 1949) and in natural areas (Fowle 1946, Kitchin 1926, Rust 1947, Weller 1958, Woods 1924), but no study has searched for nests in a methodical way to systematically determine the characteristics of nests. By investigating

breeding biology and measuring nesting parameters in a native landscape, it should be possible to predict the range of characteristics most likely to prove successful in urban and suburban landscapes. This is the first study of nighthawk nest site selection and nest microclimate in native landscapes, and it is a logical starting point for understanding the requirements of nighthawks in urban areas.

METHODS

Study Site:

This study was conducted at on Konza Prairie Biological Field Station, a Long-Term Ecological Research site (hereafter, “Konza Prairie”, 39°05'N, 96°35'W) during the spring and summers of 2007 and 2008. Konza Prairie is a 3,487 ha preserve of tallgrass prairie located in the Flint Hills region of northeastern Kansas. The vegetation is dominated by warm season perennial grasses including Big Bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), Little Bluestem (*Andropogon scoparius*), and Switchgrass (*Panicum virgatum*). In addition, there is a diversity of other plants including over 500 species (Freeman and Hulbert 1985, Towne 2002). Konza is divided into treatment areas by watershed. Each watershed is assigned a specific burning interval ranging from every year to every twenty years. There are three grazing treatments: grazed by either bison (*Bos bison*) or cattle (*Bos taurus*), and ungrazed. Different burning and grazing treatments result in areas with different vegetation structures, composition, and heights (Hartnett et al. 1996). My study focused on ten watersheds with a variety of burn histories, from annually burned to unburned since 2000. Two of these watersheds have been grazed by bison since 1987 and eight have been

ungrazed since 1970 (Table 1). Nighthawk breeding activity on Konza has been monitored since 2001. Nighthawks arrive at Konza in late April and early May. The earliest nests are started in mid-May and females continue to initiate nesting attempts through mid-July.

Table 1 – Information on target watersheds (Nomenclature taken from Konza Prairie).

Watershed Name*	area (Ha)	year of last burn	grazed?	nests #
R20A	26.33	2000	no	1
K4B	76.13	2004	no	3
4B	54.5	2005	no	3
N2A	101.22	2006	bison	2
2A	27.96	2006	no	5
FB	11.18	2006	no	1
N1A	93.86	2007	bison	3
R1A	48.66	2007	no	4
1D	41.55	2007	no	2
2D	48.41	2007	no	3

Nest Searching:

In the spring and summer of 2007 (May 23 to July 24), I located nighthawk nests by systematically searching the target watersheds. Based on experience during six previous years of research on Konza Prairie, one effective way of finding nests is to walk through the designated area and observe where female nighthawks flush. Unlike some other species of grassland birds, nighthawk females tend to flush from locations very close to the nest and use distraction displays to lead predators away. I had observed in a previous season that the average initial flushing distance (recorded the first time I flushed a female off a nest) was approximately $6.4 \text{ m} \pm 1.2$ ($n=16$, range = 20 m to 3 m), and so in order to ensure maximum coverage, I walked transects back and forth across a watershed approximately 7m apart (Figure

1). My search effort ensured systematic and extensive coverage of the target areas. The watersheds ranged from 11.8 ha to 101.2 ha and were on average 53.0 ± 29.4 ha.

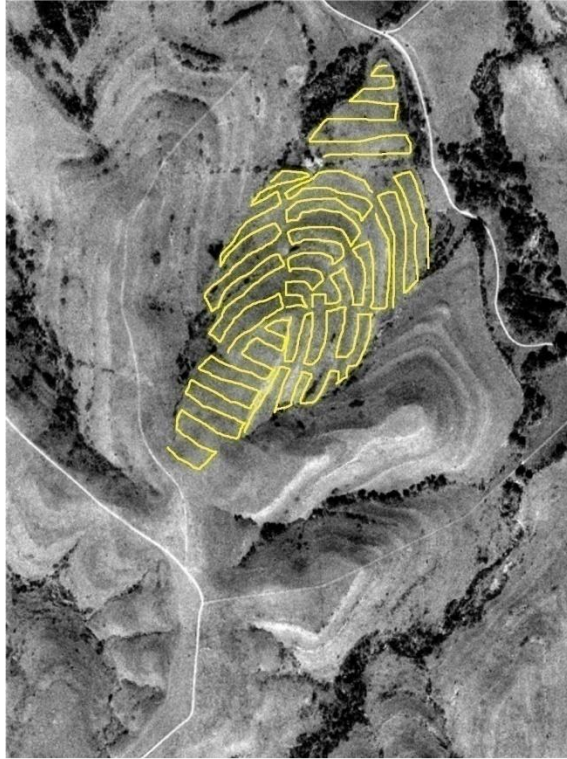


Figure 1 – Schematic representation of our search pattern (not to scale).

The first nest that I found was on May 23 and the last nest was on July 24; these dates also correspond to the first and last dates of nest searching. I searched each watershed once during the breeding season. It is possible that I failed to record nests that were initiated after I searched or that were completed before I searched, but because of my extensive search pattern, I am confident that I achieved a representative sample of the nests that existed in the target areas at the time they were searched. I marked each nest upon discovery with flagging tape and recorded the location in UTM coordinates. All

areas were searched by a single observer (RGL). I found 27 nests on the target watersheds and documented at least one nest in each watershed.

Vegetation sampling:

I established 120 systematically-distributed plots at which to measure vegetation. Plots occurred at the points of intersection of a 200 by 200 meter grid within each target watershed. I measured the percent cover of five classes of vegetation and substrate in a 4 m diameter circle around the random point. I chose this size because the chicks gain limited mobility before fledging, and this size plot would encompass the typical area traversed by the young chicks. The cover classes recorded included grass, shrub (woody vegetation), forbs, dead vegetation (dead grass and forbs that build up due to lack of fire or grazing), and gravel/rock/bare ground. The last variable, hereafter rock/bare ground, is a combination of all substrates without vegetation. This category includes all rock from small gravel to large rocks (most large rocks were less than 70cm above the ground and were less than 2m in diameter) and all exposed soil. I measured random plots in early spring 2007 (May 11 to May 23) and again in late summer 2007 (July 25 to August 5).

I measured vegetation at each nest using identical methods as soon as possible after the discovery of a nest (regardless of when in the breeding season the nest was found) and again in late summer 2007 (August 6 to August 14). Due to the rapid rate of growth of the vegetation of the tallgrass prairie, large differences in vegetation structure can occur in a relatively short time (Hartnett et al. 1996). I used post-breeding-season vegetation measurements in the comparative analysis to minimize the potential bias due

to temporal differences in the measurements of the early spring random plots with the nest plots scattered throughout the spring and summer. All vegetation measurements were taken by a single observer (RGL).

In early spring 2008 (May 15 to May 18) I resurveyed the nest sites from the previous season that were in watersheds that had the same burning and grazing regimes as 2007 (n=17). I compared these measurements with the early spring vegetation plots from 2007 (n=120).

Thermal properties of nests:

From July 9 - July 29 of 2008, I placed iButton thermal data loggers at 6 nests (Thermochron iButton, Maxim, Dallas, Texas, USA; Figure 2). The iButtons recorded the temperature, time, and date every five minutes. At each nest, I placed one iButton directly on the nesting substrate away from the eggs or chicks (rock/bare ground), and I placed an additional iButton in the next nearest (by distance) cover class (grass or forbs). The iButtons were approximately .5m apart. I recorded the temperature at 6 nests for a total of 1660 hours (per iButton placement location). During this period, I recorded 918 hours (55.3%) at 5 nests with eggs and 742 hours (44.7%) at 3 nests with chicks (2 nests hatched during the observation period). Two nests hatched during the recording period, one was only recorded after hatch, and three were recorded only during incubation. All nests varied in their initiation dates, so during each day in the recording period nests in both stages were represented.

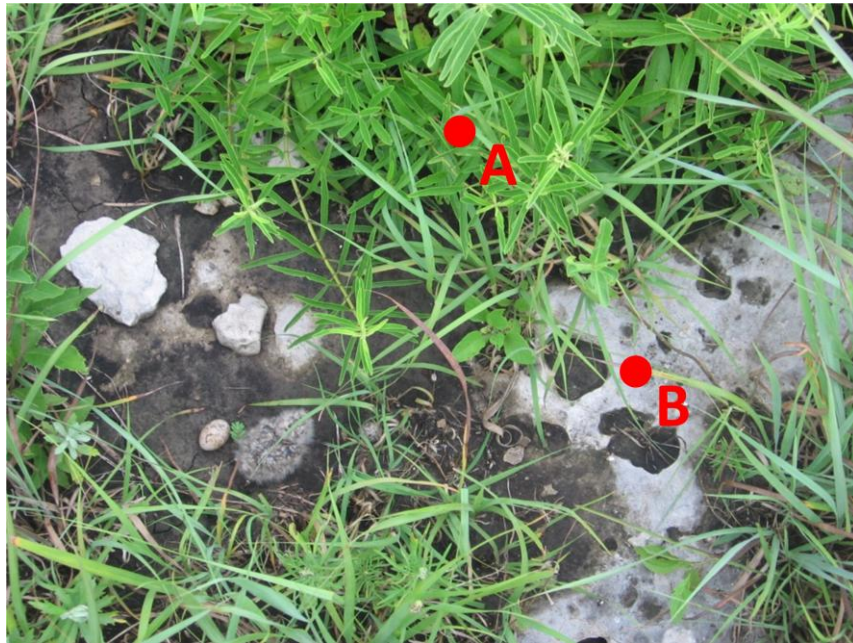


Figure 2 – iButton placement at a nest; A = vegetation, B = nest (iButtons represented by red dots, not to scale)

Statistics and Analysis:

Nest site selection: I tested for differences between each cover class for the random plots and the nest sites using a Mann-Whitney U test in JMP. I used the August measurements for these tests since, as stated previously, the vegetation changes drastically over the spring and summer. I then compared the 2008 early spring resurveys of 2007 nest sites with the 2007 early spring vegetation plots using Mann-Whitney U tests in JMP.

Thermal Properties: I calculated the daily and nightly mean, minimum, and maximum temperature for both treatments (nest site and vegetation) for all six nests using Microsoft Excel. I then compared the mean difference between daily or nightly values for the same variables between the nest and vegetation locations using a Wilcoxon Signed-Rank test in JMP.

For all multiple analyses, to control for Type I error, I replaced alpha with $di^* = (i/k) f_F$ for i of k comparisons to yield a false discovery rate, $f_F = 0.05$ (Curran-Everett 2000). Test result is significant when $p\text{-value} \leq di^*$.

RESULTS

Nest site selection:

Twenty six of the 27 nighthawk nests were located on rock/bare ground. These nests always occurred on rock or gravel, usually interspersed with patches of bare ground, but they never occurred on bare ground without rock or gravel (Illustration 1). The twenty-seventh nest was located in a seldom-burned watershed (R20A) on a mat of dead grass. In 2008, I used a trained dog to find nests; 100% of the nests discovered by the dog were on bare ground and rock ($n=9$), and overall all nests found in 2008 were on bare ground and rock ($n = 43$).

Based on our initial analysis using the summer 2007 random and nest plots, I found that nighthawks were selecting nest sites non-randomly with respect to two cover class variables. They were selecting areas with almost three times more percent cover of rock/gravel/bare ground (mean = 27) than random (mean = 10; $p = <0.0001$, $di^* = 0.01$). Also, they were choosing areas with less shrub cover (mean = 2) than random (mean = 9; $p = 0.02$, $di^* = 0.02$). All other cover classes were not significantly different (Table 2) for the late summer comparison.

I found in the early spring that nest sites were even more different from the surrounding landscape. When I compared the early spring 2008 resurvey of 2007 nest sites with identical burning and grazing regimes, I found that in early spring all cover class variables were significantly different at nest sites than at

random sites. Nest sites had a higher percentage of the dead plants and bare ground/rock cover classes, and lower percentages of grass, shrubs, and forbs (Table 3).

Table 2 – Comparison of late summer 2007 survey of nest sites and late summer 2007 random vegetation plots by cover class category. P-values from Mann-Whitney *U* test and critical significance level (d_i^*) from false discovery rate procedure. Mean difference is significantly greater than zero when p-value $\leq d_i^*$ (significant variables in bold.) For all tests: nests n = 27 and random n = 120.

2007	nest	random	M-W U	
Cover Class	% cover \pm SE	% cover \pm SE	p-value	d_i^*
Dead Plants	7.6 \pm 1.5	6.6 \pm 0.9	0.07	0.03
Grass	40.1 \pm 3.1	46.4 \pm 2.3	0.2	0.04
Bare Ground/ Rock	27.1 \pm 2.6	9.8 \pm 1.4	0.0001	0.01
Shrubs	1.9 \pm 1.4	9.3 \pm 2.0	0.02	0.02
Forbs	23.3 \pm 2.5	27.9 \pm 1.7	0.4	0.05

Table 3 - Comparison of early spring 2008 survey of 2007 nest sites and early spring 2007 random vegetation plots by cover class category. P-values from Mann-Whitney *U* test and critical significance level (d_i^*) from false discovery rate procedure. Mean difference is significantly greater than zero when p-value $\leq d_i^*$ (significant variables in bold.) For all tests: nests n = 17 and random n = 120.

2008	nest	random	M-W U	
Cover Class	% cover \pm SE	% cover \pm SE	p-value	d_i^*
Dead Plants	28.1 \pm 7.2	18.5 \pm 2.5	0.0023	0.05
Grass	9.5 \pm 2.0	20.7 \pm 1.3	0.0009	0.04
Bare Ground/ Rock	58.8 \pm 6.3	33.6 \pm 2.7	0.0003	0.03
Shrubs	0.06 \pm 0.06	12.3 \pm 2.1	0.0002	0.02
Forbs	3.2 \pm 1.0	16.2 \pm 1.2	0.0001	0.01

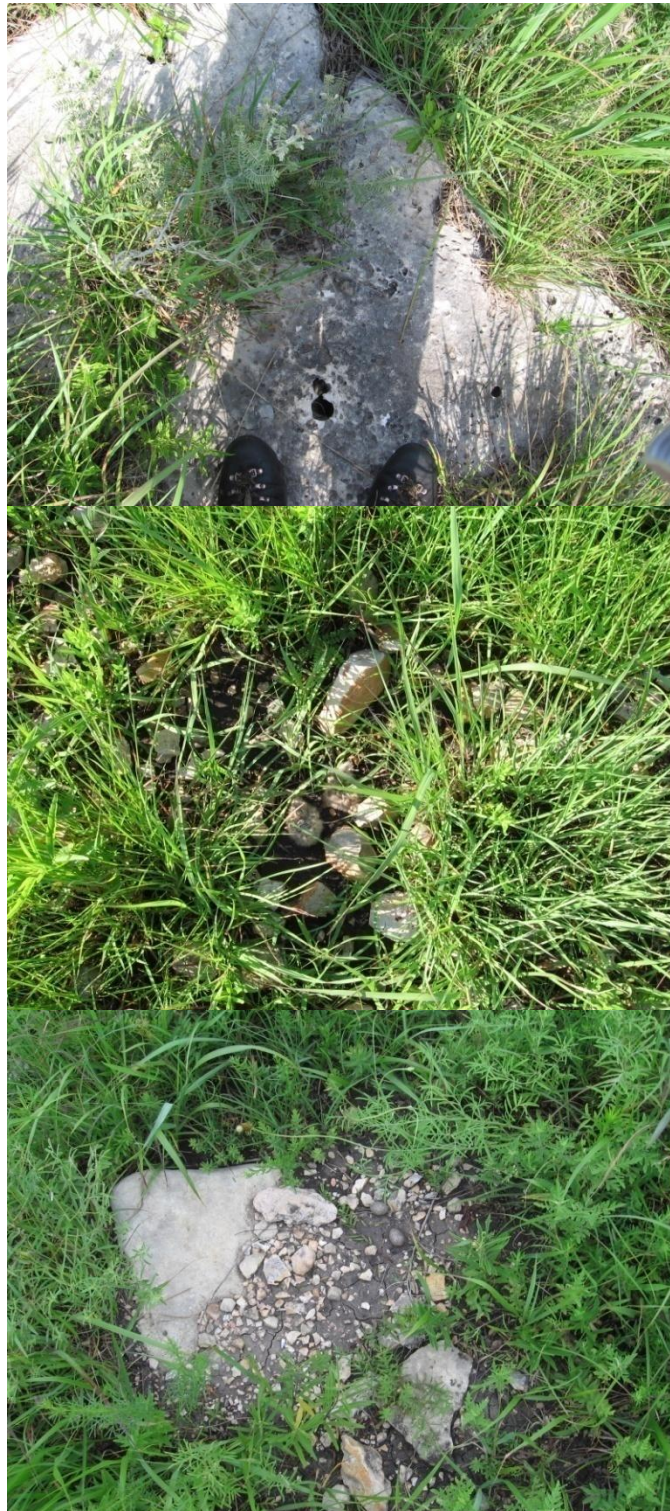


Illustration 1 - Three typical nest types of Common Nighthawks on Konza Prairie: large rock (top), no distinct rock patch (middle), and large rock with gravel (bottom).

Thermal properties of nests:

I found that within a single month, the nesting substrates experienced temperatures that ranged from 14.5°C to 60°C. When I compared the mean difference in values for vegetation versus the nest site I found that the high daily temperatures were significantly cooler in the vegetation during the day (mean $\Delta = -9.58 \pm 2.35$, $p = 0.02$, $di^* = 0.02$). For detailed comparisons see Table 4. As seen in Figure 3, all locations experienced similar fluctuations, but the temperatures at the nest-site substrate were consistently higher.

Table 4 – Mean differences in temperature (°C) for nest sites (N) minus surrounding vegetation (V) \pm standard error for the daily and nightly high, mean, and low. P-values from Wilcoxon signed-rank test and critical significance level (di^*) from false discovery rate procedure. Mean difference is significantly greater than zero when $p\text{-value} \leq di^*$ (variables in bold.) For all tests: $n = 6$, $df = 5$.

	$\Delta (N - V)$ in °C \pm SE	p -value	di^*
daily high	9.58 \pm 2.35	0.0156	0.0167
daily mean	2.57 \pm 0.57	0.0156	0.0083
nightly high	0.83 \pm 0.40	0.0938	0.025
nightly mean	0.13 \pm 0.40	0.2188	0.0333
nightly low	0.00 \pm 0.53	0.4375	0.0417
daily low	0.00 \pm 0.46	0.4688	0.05

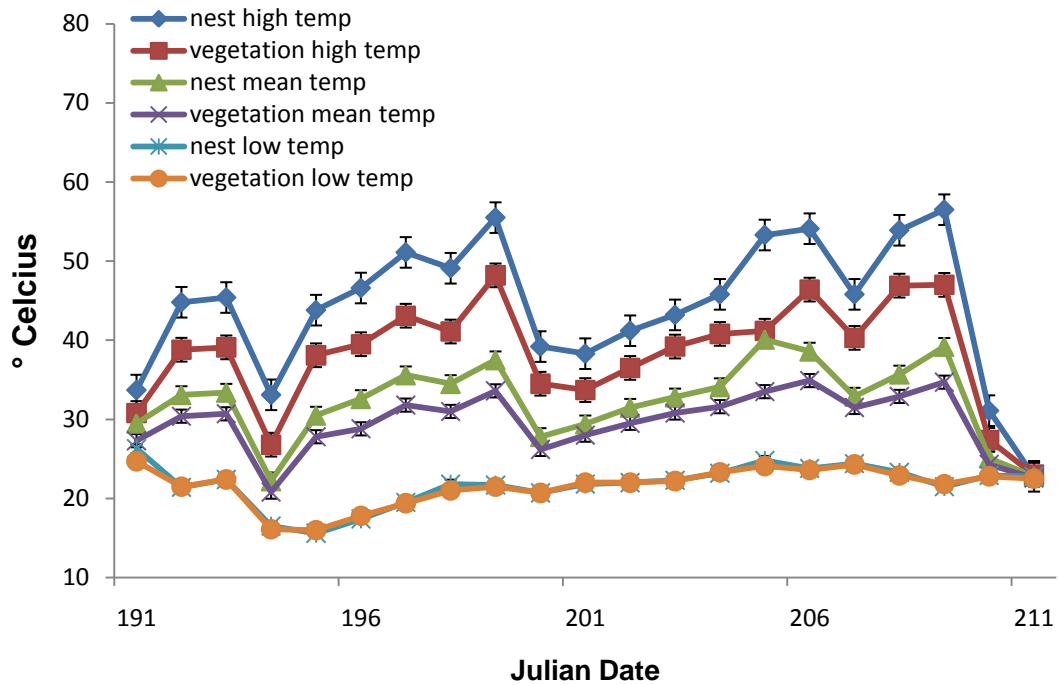


Figure 3 – Graph of high, low, and mean temperatures (°C) for nest and vegetation sites with standard error bars by Julian date.

DISCUSSION

This is the first study in which nighthawk nests were systematically located within any habitat. With such a cryptic species, systematic searching for nests is particularly important when studying nest site selection. I found that nighthawks select open rocky areas on which to lay their eggs. I also observed that these areas can become very hot and that the chicks will move to use the surrounding grass and forbs for shade.

In the early spring when nest sites are selected, the differences between nest sites and the greater landscape are pronounced. Nest sites show a general trend towards openness with less grass, shrubs, and forbs, and more rock/bare ground. As the season progresses the differences in the

percent cover of most vegetation classes disappear, but nighthawk nest sites retain a bias towards use of rock/bare ground and an avoidance of shrubs. To manage areas of prairie for this species, I recommend targeting locations with rocky soils for frequent burning to curb early spring vegetation growth (particularly shrubs) and to expose rock or gravel patches.

The temperature of the nest site is important to both the incubating female and the chicks. On gravel rooftops the mean daily temperature (41.6°C; Marzilli 1989) and the high temperature (61°C; Weller 1958) are both slightly higher than the temperatures I found at our natural nest sites. In the original rooftop restoration study, patches were placed in all four corners of rubber roofs (Marzilli 1989). All of the rooftop patches that were utilized were in the southern corners less than 30 cm from the parapet where shade would be available for the greatest amount of time every day. This pattern suggests that females use thermal information in nest site selection; however, neither Marzilli's (1989) nor our study measured the relationship between thermal properties of the substrate and egg or chick survival. Even so, these data suggest that rooftop restoration projects will be more successful if they place patches in areas that provide thermal refuges for chicks and females.

Although both eggs and chicks may be influenced by micro-climate, the mobility of nighthawk chicks may offer some protection from extreme temperatures. Nighthawk chicks are capable of moving long distances during the nesting cycle if the nest site is in a very open habitat. For example, at a nest site in a dry stream channel with little vegetation or shade, Pickwell and Smith (1938) observed the chicks move 51 m from their original nest site over the course of a week. Bowles (1921) observed the chicks from a rooftop nest

move 75 feet (22.86 m) in one day and night. Weller (1958) monitored one nest on the Wildlife Building at the University of Missouri where the female and chicks moved all around the roof on a daily basis in order to utilize shade from pipes and other structures. He notes that the chicks spent the majority of their time in the shade. Although in our study chicks rarely moved more than 2 m in any direction from the original nest site, I hypothesize that this is because shade was available in the immediate area, and that vegetation provides a thermal refuge for chicks. It is possible that moving farther from the nest reduces feeding efficiency of semi-precocial young due to the time it takes parents to locate their offspring when they return from a foraging trip.

In summary, I propose that the following strategies should be tested for management efficacy in efforts to restore urban and suburban nighthawk populations on rooftops: 1) placing a single gravel patch near a structure that will provide shade for the maximum amount of time possible during the day, 2) placing a matrix of patches that accommodate movement between multiple shady areas throughout the day, 3) placing a single patch with a predator exclosure, 4) placing a single patch that incorporates artificial vegetation or other artificial shade-providing structures in a single gravel patch. The final configuration could also reduce predation rates on rooftop nests by decreasing the visibility of the birds.

Finally, it would be valuable to determine the impact of each of these four treatments on nest site use and nesting success (hatching and nest success, adult survival rates) in urban and suburban areas where nighthawks are already present and abundant. This strategy will be more efficient than installing nest sites where the birds have already disappeared because the tests will not be hindered by low colonization rates. By observing these

demographic parameters, we can determine whether urban and suburban areas are able to support viable populations of nighthawks or whether they are ecological traps.

By testing restoration techniques in areas that already have nighthawk populations, we might create stepping stones of rooftops from active areas to areas where there are currently no nighthawk nests. This stepwise restoration strategy will effectively separate the quality of the restored nest site and the mortality factors from the challenges of getting nighthawks to recolonize areas where they have already disappeared.

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