Local and site-level effects on nesting Barn Swallows

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Abstract

Aerial insectivore populations have been declining, and the reason for decline is unclear. There is recent concern over Barn Swallow *(Hirundo rustica)* populations, an aerial insectivore species, due to conflicting findings in current populations. We observed 20 sites in Harvard and Falmouth, Massachusetts from May through July, 2013 to identify factors that influenced site selection and nest success to improve understanding of Barn Swallow breeding behavior. Our data suggest that human activity can determine whether a site is selected for nesting, and that the presence of Eastern Phoebes (*Sayornis phoebe*) and European Starlings (*Sturnus vulgaris)* can affect Barn Swallow nest success.

Introduction

We can never have enough of nature.
Henry David Thoreau, *Walden*

Without aerial insectivores, the food chain would collapse. Aerial insectivores are organisms with the ability to fly who consume insects in the air. Examples of aerial insectivores include bats and some species of birds. Aerial insectivore populations have been declining, particularly migratory birds of North America's northeast, and the reason for the decline in population is unclear (Nebel et al. 2010). Some researchers believe acid rain or increased pesticide use reduces insect populations in breeding ranges, thus limiting predator populations (Connecticut Audubon Society 2013). Others believe that shifts in insect populations across migration paths limit the populations of migratory insectivores, who maintain their flight routes regardless of insect relocation (Nebel et al. 2010). Research suggests that humans may also have an impact; high human population density correlates with more avian species richness, so in densely human-populated areas, avian competition may be higher (Luck 2007). Since the

industrial revolution, combined with population shifts towards cities, there has been a decrease in farms and barns, which has been linked to a decrease in Barn Swallow abundance (Moller 2001). Barn Swallows, *Hirundo rustica,* are a common species of aerial insectivore whose populations are considered at risk in New England, and are the focus of this study.

Although considered an at risk species, Barn Swallows are an abundant and widespread swallow species (Massachusetts Audubon Society 2011). Barn Swallows live worldwide, and can be found across the United States and most of Canada during the summer for breeding season, and found year round in parts of Central America. Barn Swallows often migrate to Southern California, Florida, the Caribbean, and some parts of Central America for the winter (Brown and Brown 1999).

Since the 1800s, Barn Swallows have adapted to using manmade structures for nest sites, and this has led to an increased range and population size (Newton 1998). However, there is recent concern over the state of Barn Swallow populations due to conflicting findings in modern populations. According to the 2011 State of the Birds Report, Barn Swallow populations are stable but in need of monitoring (Massachusetts Audubon Society 2011). Barn Swallows had a 2.3% increase in population from 1974-1979 according to the Massachusetts Audubon Society's Breeding Bird Atlas, despite the Breeding Bird Survey finding a 1.3% decrease in population from 1966-2011 (Massachusetts Audubon Society 2011).

Barn Swallows can be spotted by the distinctive characteristic of their long, deeply forked tail, which is a trait found in no other swallow (Fig. 1). Barn Swallows have a blue hue on their back, wings and tail feathers, which can lead to confusion with Cliff Swallows, *Petrochelidon pyrrhonota,* which have similar coloration (Brown and Brown 1999). The tail has white spots, which are larger in adults, particularly males (Kose and Moller 1998).

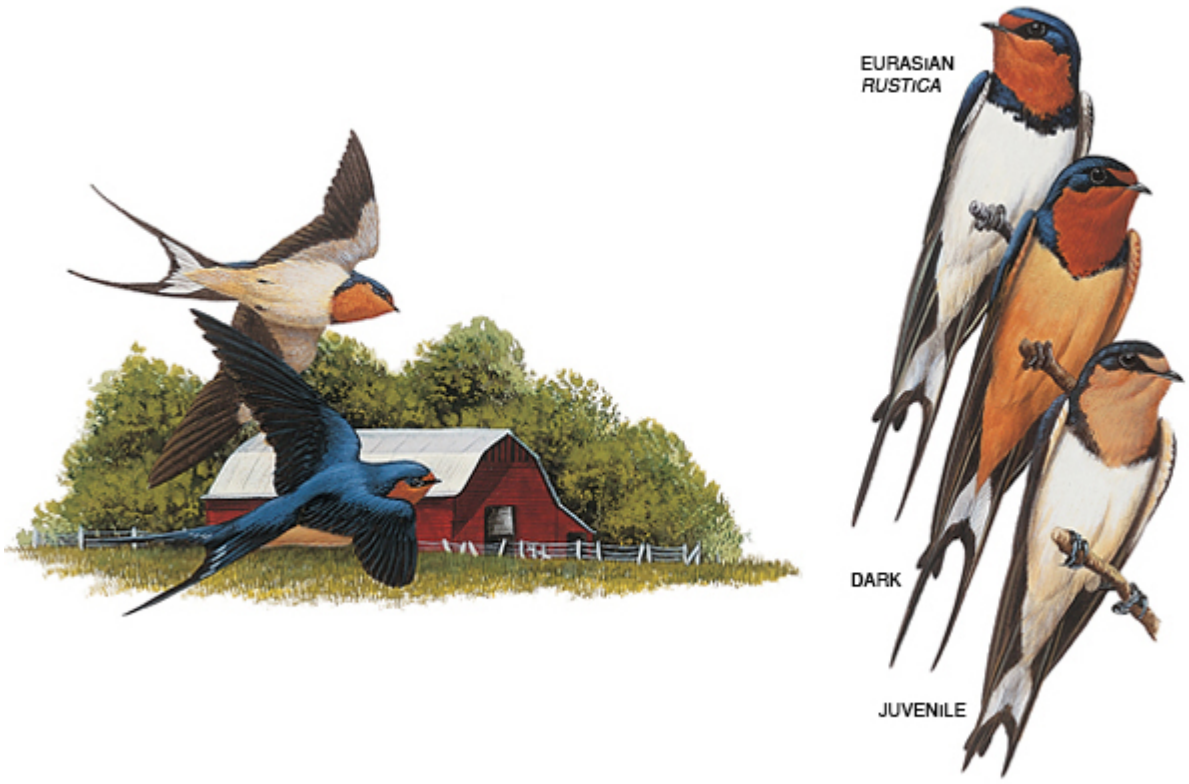

Figure 1: Barn Swallow identification guide (Pratt 2013).

Monogamous for the breeding season, male and female Barn Swallows work together to build the nest, with male participation in nest construction varies anywhere from 0-68% (Brown and Brown 1999). Barn Swallows nest in mud cups, which are made by collecting mud in their bills and mixing the mud with grass stems or other materials to make pellets (Fig. 2). During the multistep process, a base is formed, which takes 1-5 days. Next, it takes 3-14 days to construct the mud shell. Stage 3 is the addition of a grass lining to the mud cup, which takes 1-5 days. Finally, the nest is complete at stage 4 when the lining of feathers, hair, moss, or other soft material is added, which takes 1-4 days (Brown and Brown 1999). The mud cups are typically gourd-shaped (Petersen and Meservey 2003). A complete mud-cup nest has approximately an 8

centimeter diameter and a 5 centimeter depth (Brown and Brown 1999). Swallows reuse nests, and replace the feathers and add a new layer of mud around the rim annually (Brown and Brown 1999).

Figure 2: Reused Barn Swallow mud-cup nest made with straw (Photograph by Mariah Eldredge).

Barn Swallows are often colonial, and tend to return to their nesting grounds year after year (Brown et al. 2002). Large colonies are usually populated by young birds, and nest success in the large colonies has been found to be less than that of individual nests or small colonies (Shields and Crook 1987). However, colonies can also have higher rates of nest success due to decreased predation and increased social stimulation (Snap 1976). Another possible contribution to poor nest success in Barn Swallows are House Sparrows, *Passer domesticus*, a fierce

competitor of Barn Swallows. They have been observed stealing nest linings and materials, and pecking or removing eggs or nestlings (Weisheit and Creighton 1989). Weisheit and Creighton found that the presence of House Sparrows reduced fledging success by 45% at one Barn Swallow nesting site in Maryland (Brown and Brown 1999).

Barn Swallows lay 3-7 eggs, and have one to two broods annually (Petersen and Meservey 2003). They begin laying eggs once the feather lining of the nest has been completed, one egg per day. The eggs are incubated between 12 and 17 days; both sexes incubate, but the female takes on most of the responsibility (Fig. 3).

Figure 3: Barn Swallow incubating her eggs (Photograph by Mariah Eldredge).

The eggs are a cream to pinkish white color, with spots that can be brown, lavender or gray. Once hatched, the Barn Swallow nestlings are naked with sparse patches of gray down, and have their eyes closed. The nesting period for these young birds is 15-27 days (Brown and Brown 1999). When they leave the nest, they have a lighter juvenile coloration (Fig. 1).

Swallows primarily feed on flies, but occasionally catch beetles, bees, wasps, ants, butterflies, moths and other flying insects (Brown and Brown 1999). Swallows prefer to eat one large insect over several small insects. Barn Swallows catch their prey while in flight. They fly low, skimming the ground or water surface where they are searching for food, with fluid wingbeats that pull their wingtips back at the end of a stroke (Brown and Brown 1999).

The Big Barn Study is a research study being conducted by the Massachusetts Audubon Society, investigating Barn and Cliff Swallow breeding populations in Massachusetts (Massachusetts Audubon Society 2012). The study intends to determine why certain sites are preferred over others, the characteristics of the used sites, and how sites have changed over time. The Big Barn Study is conducted through citizen science, and volunteers go to barns, bridges, and other potential nesting sites, observe the site 3 times, and record whether swallows are present or not. Citizen scientists are also asked to look for house sparrows, swallows' competitor (Massachusetts Audubon Society 2012). Our study is supporting the Big Barn Study, and investigating similar themes.

In our research, we gathered descriptive information about the locations of interest. We determined the frequency of human activity at each location, as well as distance to open fields, distance to bodies of water, and presence of livestock. We determined colony size at each location, and monitored the number of predator and competitor species in the vicinity of nests, including cats and House Sparrows. The goal of our research was to determine whether 1) there

is a difference between sites with Barn Swallow nests and sites without Barn Swallow nests and 2) factors such as colony size and competitor species presence affect Barn Swallow nest success. We hypothesized that there would be a difference between used and unused sites; we anticipated that barns and other structures that were close to bodies of water and open fields would be used more frequently than structures far from bodies of water and open fields. We also hypothesized that the presence of predator or competitor species would negatively affect nest success, and large colonies would positively affect nest success.

Methods

Study area.- Our study was conducted in the Harvard, Massachusetts area and Falmouth, Massachusetts areas because they have many bodies of water near open fields, which are ideal habitats for aerial insectivores due to food availability. Both towns are historically farming communities, and today still have many small farms, barns, and stables. These regions also have large land areas owned by conservation groups.

Field methods.- We visited and observed nesting sites every three to five days until nest success was determined, May 15 through August 18, 2013. Using the Massachusetts Audubon Society's Big Barn Study as a model, we monitored five active Barn Swallow nesting sites in each region, as well as 5 locations in each region with no swallows present. The active locations were homes of volunteers who had observed Barn Swallows on their properties (Figure 4). We determined the locations with no swallows present by randomly selecting locations in the study areas that are optimal swallow nesting sites, such as barns, overpasses, and bridges. We checked the sites with no swallows present three times each, and they were used as controls to determine if there is a significant difference between sites with Barn Swallow nests and those without.

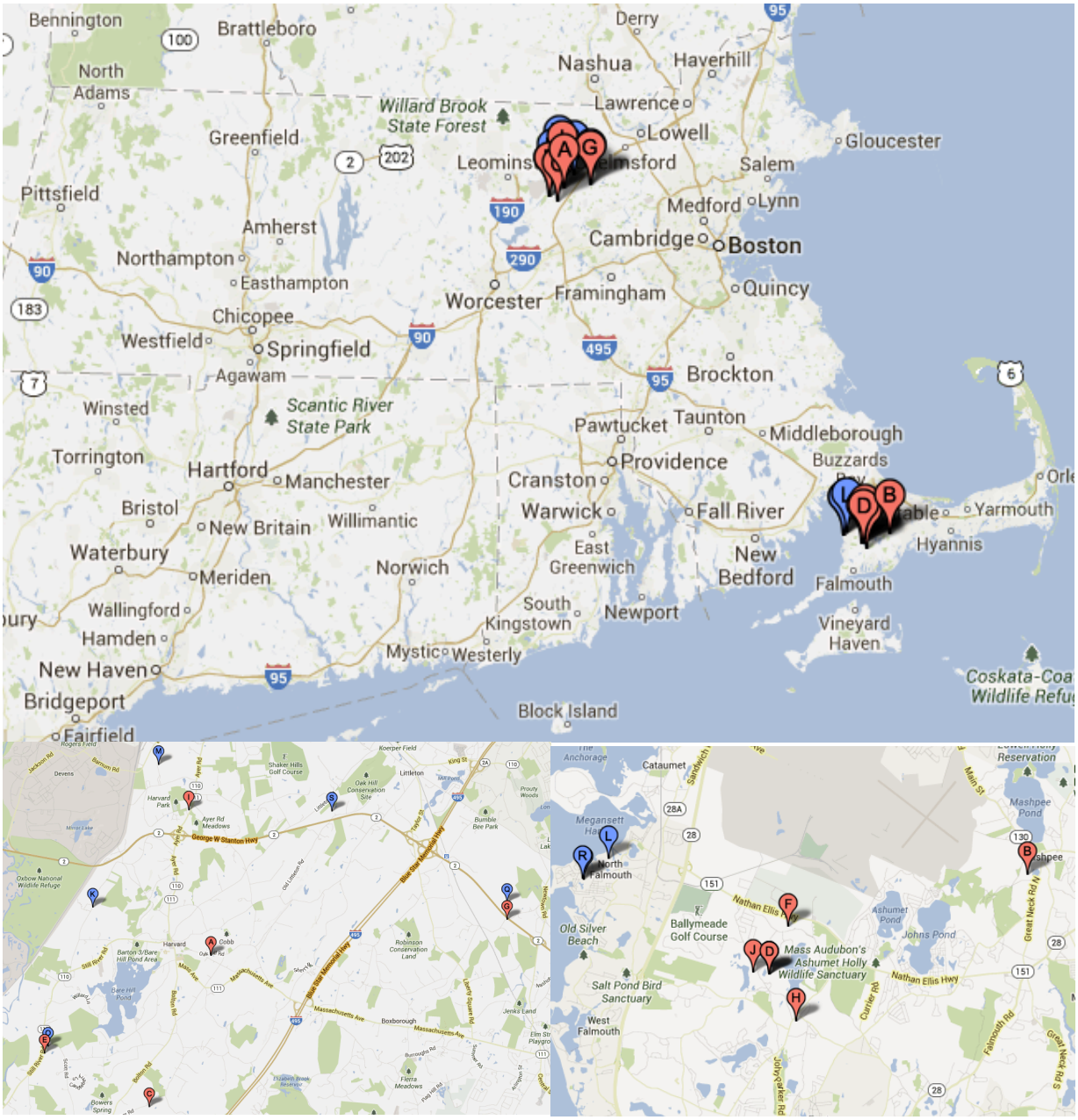

Figure 4: Active and control locations.
Red markers are locations with active Barn Swallow nests, and blue markers are control locations (Maps by Google Maps).

At each test site we counted the number of nests, identified the structure on which they were built, and measured geographical characteristics of the nest area. Some of the geographical

characteristics included distance in meters to fields, bodies of water, and wooded areas. We also quantified the amount of daily human activity causing a disturbance at each location, as follows:

1) No daily human activity
2) Some daily human activity (humans around nest once or twice per day)
3) Frequent daily human activity (humans around nest three times per day or more)

We monitored the status of each nest. Status was identified with a numbered code, as follows:

1) Nest appears active
2) Nest has eggs, female actively incubating
3) Nest has eggs, female flushed
4) Nest has eggs, female not present
5) Nest has hatchlings
6) Nest has fledglings
7) Nest failed, most likely predation
8) Nest failed, unknown causes
9) Other (identify)

If it was possible to determine, depending on the height of the nest, we counted the number of eggs or young birds. Finally, we looked for other species in the area that can influence nesting location and success for Barn Swallows. The species that we looked for were European Starlings (*Sturnus vulgaris*), Eastern Phoebes (*Sayornis phoebe*), House Sparrows, and Brown-headed cowbirds (*Molothrus ater*), as well as predators such as birds of prey and cats and other terrestrial predators. These species could all have an effect on nest success, whether due to brood parasitism, nest competition, or predation.

Data analysis.- To determine the percentage of overall nest success, we used a 'traditional method' which divides the number of successful nests by the number of total nests found (Jehle et al. 2004). To compare the daily survival probability in different nest locations, we used the

Mayfield Estimator (Garaldi 2006). We calculated the daily survival probability at each site, and compared the survival rates of sites with different characteristics. By comparing the daily survival probability of different nest locations, we drew preliminary conclusions about which locations lead to higher nest success.

To identify whether there is a significant difference between sites with Barn Swallow nests and those without Barn Swallow nests, we conducted a multivariate analysis of variance (MANOVA), based on distance of structure to body of water and distance of structure to open field. A chi-squared test was used to determine the difference between sites with Barn Swallow nests and sites without Barn Swallow nests based on the presence of livestock. The null hypothesis was that there is no difference between sites with and sites without Barn Swallow nests in terms of the presence of livestock. We used a chi-square test to determine whether human activity at a location affects Barn Swallows nest site selection, using a null hypothesis that human activity has no impact on whether a site is selected for Barn Swallow nesting.

We used an analysis of variance (ANOVA) to compare a surrogate of nest success, mean number of fledglings at each site, to the mean number of House Sparrows observed in the area of active nests, mean number of European Starlings in the area of active nests, mean number of Eastern Phoebes in the area of active nests, and colony size to determine if these factors affect nest success. We used a Bonferroni correction to avoid Type I error caused by comparing multiple potential variables (Bland and Altman 1995). Because we used 4 tests, we divided our "normal" p-value by 4, resulting in a new p-value of 0.0125. We used a correlation analysis to determine if these variables were correlated. Because our data were non-normal we used a Spearman correlation analysis.

Results

We monitored 55 Barn Swallow nests from May 15-July 18, 2013, and 48 nests were successful (87.27%). The mean number of days for a nest to be active was 36.15 (6.21 SE, standard error). The mean number of fledglings from each nest was 4.06 (0.25 SE). For additional nest and nest success data, refer to appendix A.

Predators (i.e., cats, dogs, and hawks) present at each site were recorded, but because there were not many predators and no predation events observed, predator data were not considered for further analysis (Table 1). Human activity, competitor species (House Sparrows (HOSP), European Starling (EUST), Eastern Phoebe (PHOE)) present at each site, and colony size were also recorded (Table 1). We also calculated the daily survival probability, or Mayfield Estimate (Table 1). For further descriptive statistics and individual nest success data, refer to appendix B.

After conducting the MANOVA analysis, we determined that there is no significant difference in sites with or without Barn Swallow nests when considering distance to body of water or open field (Wilks' Lambda $F_{2,17} = 0.64$, $P = 0.54$). The data used in this calculation can be found in table 2. For sites with Barn Swallow nests, the distance we measured to water ranged from 22 meters to 914 meters. The average distance to water at sites with nests was 201.2 meters. For sites without Barn Swallow nests, the distance to water ranged from 64 meters to 1322 meters. The average distance to water at sites without nests was 249.2 meters. For sites with Barn Swallow nests, we measured distance to field ranging from 8 meters to 49 meters. The average distance to a field at sites with nests was 21.2 meters. For sites without Barn Swallow nests, distance to a field ranged from 3 meters to 75 meters. The average distance to water at sites without nests was 29 meters.

Table 1: Daily survival probability and potential factors influencing nest success.

Location	Number of nests	Daily Survival Probability (Mayfield Estimate)	Mean # Observed Cat	Mean # Observed Hawk	Mean # Observed Dog	Human activity rating	Mean # Observed HOSP	Mean # Observed EUST	Mean # Observed PHOE	Colony Size
Saafield's Barn	6	1	0	0	0	2	0.39	0.06	0.67	6
Micheldever Farm	5	1	0	0	1	2	5.36	0	0.64	5
Post Office	3	0.99	0	0	0	3	0.05	0.24	0	3
Stable	1	1	4.77	0	0	3	1.85	0	0	1
Flintlock Farm	18	1	0	0	0	2	0	0	0.07	18
Coonamessett Farm	2	1	0	0	0	3	12.38	0.75	0.25	2
Crooked Pond Farm	5	1	0	0	0	2	0	0	0	5
Boxberry Farm	1	1	0.78	0	0.78	3	3.11	0	0	1
Smithfield Farm	2	0.98	0.18	0	2.27	3	4.09	0	0	2
Maushop	12	0.99	0	0	1.4	2	10.7	0	0	12

Table 2: Data used for MANOVA.

Location	Swallow Nests?	Distance to water (m)	Distance to field (m)	Human activity	Livestock present?
Saafield's Barn	Yes	27	20	2	No
Micheldever Farm	Yes	27	8	2	Yes
Post Office	Yes	44	16	3	No
Stable	Yes	49	13	3	Yes
Flintlock Farm	Yes	22	11	2	No
Coonamessett Farm	Yes	74	24	3	yes
Crooked Pond Farm	Yes	161	16	2	yes
Boxberry Farm	Yes	550	21	3	yes
Smithfield Farm	Yes	914	34	3	yes
Maushop	Yes	144	49	2	yes
Dunroven Farm	No	142	17	3	Yes
Fruitlands	No	1322	13	1	No
Still River Farm	No	146	19	3	Yes
Glimerton Farm	No	115	15	3	Yes
Bazarnick's House	No	64	3	2	No
Nyes Neck Farm	No	212	41	2	No
Grove Barn	No	140	58	3	No
Old Storage Shed	No	161	75	2	No
Farm Storage Shed	No	75	34	2	Yes
Play Shack	No	115	15	3	Yes

We found no evidence that presence of livestock influenced nest selection by Barn Swallows (χ^2=0.80, P= 0.15). Of the 10 sites with Barn Swallow nests present, 7 sites had livestock present as well. The Post Office, Flintlock Farm, and Saafield's Barn did not have livestock present. We did find evidence that occasional to frequent human activity influences Barn Swallow nest site selection (χ^2=0.83, P= 0.03). Locations with human activity ratings of 2 or 3 were the locations with Barn Swallow nests (Fig. 5).

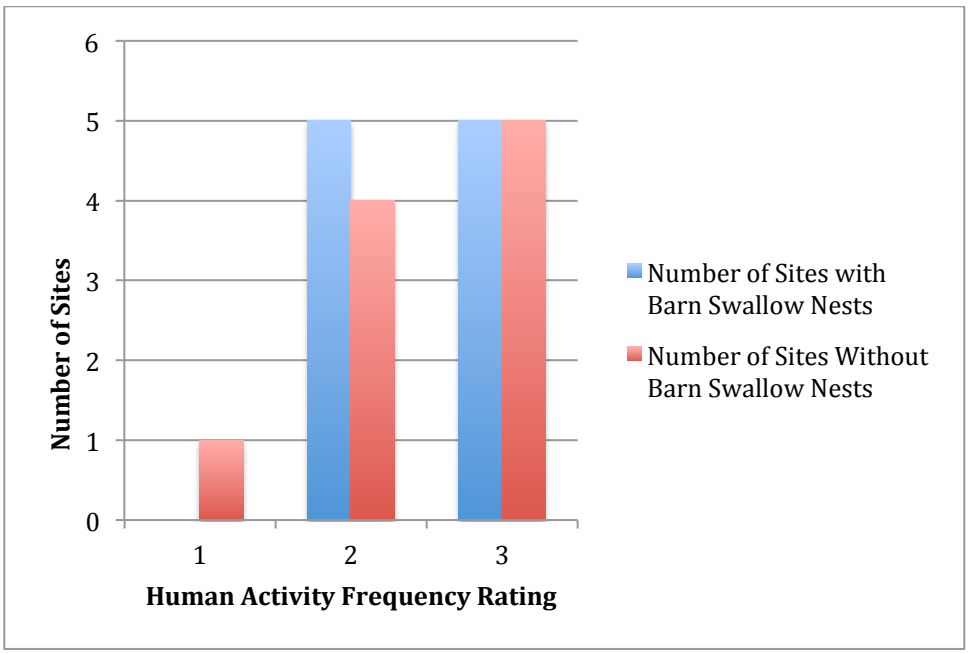

Figure 5: Human activity frequency and Barn Swallow nest presence.

Based on the ANOVA, considering the Bonferroni adjustment, there is a significant difference in number of fledglings when European Starlings ($F_{2,9} = 4.41$, $P < 0.001$) or Eastern Phoebes ($F_{2,9} = 4.41$, $P < 0.001$) were observed in the area of Barn Swallow nests. When European Starlings were sighted more often, we found that there were fewer Barn Swallow fledglings; there is a slightly negative relationship (Figure 6). Conversely, there was a slight positive relationship between Eastern Phoebe sightings and number of fledglings (Figure 6). The Spearman correlation did not find that the relationship between number of fledglings and presence of competitor species was significant (Table 3).

Table 3: Spearman correlation data (n=10).

	Mean Fledges	Mean HOSP	Mean EUST
Mean HOSP	-0.46		
Mean EUST	-0.13	0.13	
Mean PHOE	0.15	0.14	0.39
Colony Size	0.43	-0.27	0.39

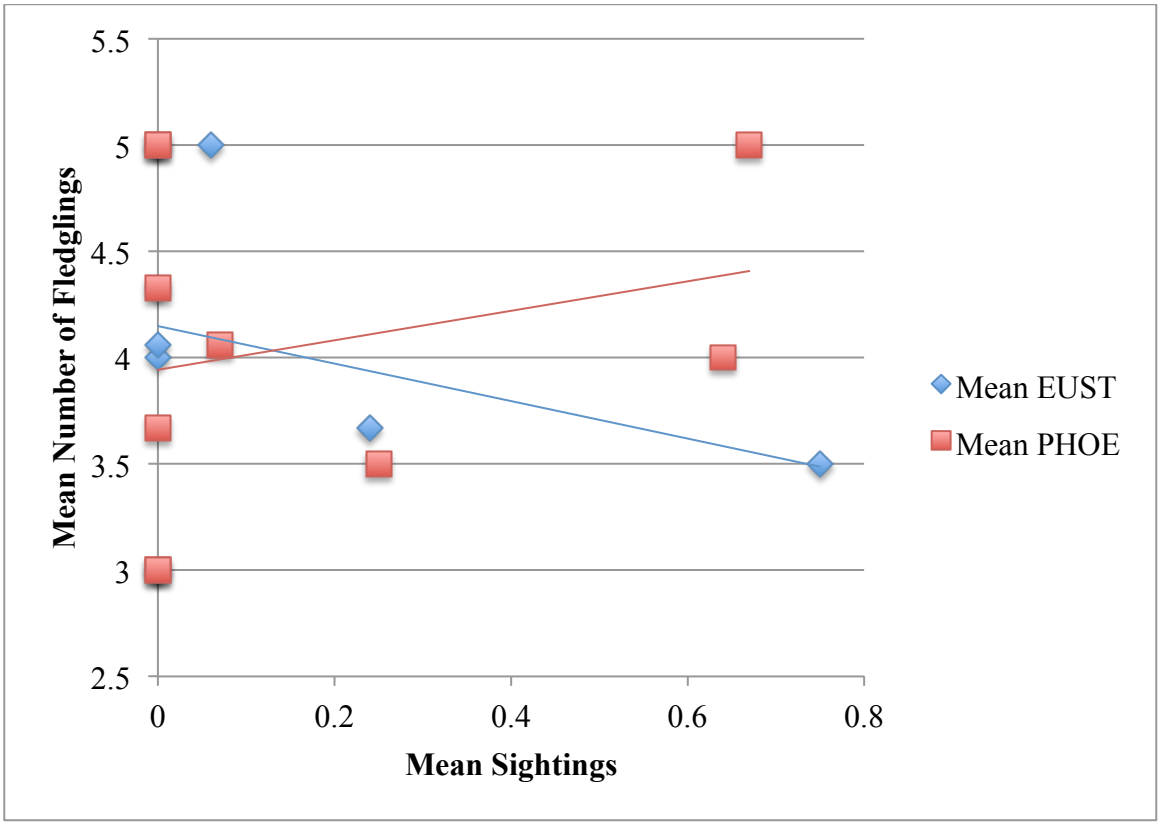

Figure 6: Comparison of number of competitor species (European Starling, EUST and Eastern Phoebe, PHOE) sightings and number of Barn Swallow fledglings.

We found no significant differences in the number of fledglings when House Sparrows ($F_{2,9} = 4.41$, P=0.86) were sighted in the vicinity of nests. There were also no significant differences in number of fledglings based on colony size, although there was a slight positive relationship ($F_{2,9} = 4.41$, P=0.42; Figure 7). The Spearman Correlation did not find a significant correlation between number of fledglings and colony size or mean number of competitor species sightings (Table 3).

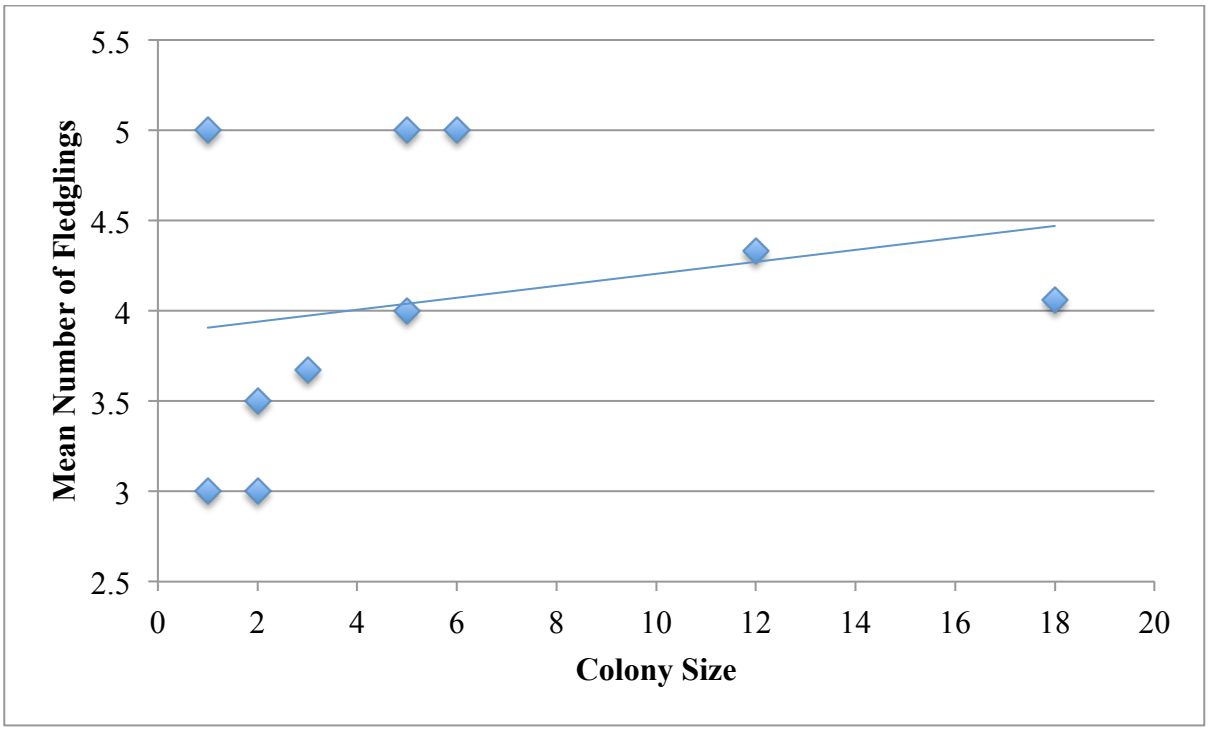

Figure 7: Comparison of colony size and mean number of Barn Swallow fledglings.

Discussion

We found that both local and site-level factors influenced Barn Swallow nesting activities. Our study found that increased human activity was positively associated with nest site selection by Barn sSwallows. Initially, we believed that having low human activity would be a positive nesting site characteristic and would lead to larger colonies or a greater chance of site selection.

However, there was a positive relationship between selection of nesting sites and frequent human activity. Though this relationship does not agree with our original hypothesis, it can be explained. Barn Swallows live in man-made structures, such as stables or barns. If a stable or barn has no human activity, it could be difficult for Barn Swallows to get into the building without humans leaving doors and windows open. The control barns with low human activity are generally kept closed off to wildlife. Human presence has also been linked to avian species richness, with more densely populated areas of people correlating with more birds (Luck 2007). The presence of more humans around a nest site could be linked to more humans being nearby to open barns. Humans could also, whether inadvertently or purposefully, keep predators away from their property and thus the Barn Swallow nests.

We found no relationship between nest site selection and livestock. In other studies, the presence of livestock has been considered a positive characteristic of a location for Barn Swallow nesting because manure of livestock has been proven to attract insect populations (Moller 2001). Another previous study found that livestock presence does not affect nest success for single brood nests, because for these nests, swallows select the optimal time to raise their young; for multi-brood nests, the favorable conditions created by livestock presence allows the multiple broods to be raised at generally less convenient times in the breeding season (Gruebler et al. 2010). Livestock presence increases temperature in the microclimate around the nest, and higher temperatures are useful for the multiple-brood birds, who lay earlier in the season when it is cooler, and finish raising their last clutch later in the season when it is once again cool (McCarty & Winkler 1999; Dawson et al. 2005).

We found that other species present in the area of Barn Swallow nests affected nest success. European Starling sightings had a negative relationship with Barn Swallow nest success,

and that Eastern Phoebe sightings had a positive relationship with nest success. At Flintlock Farm, one nest was observed being taken over by an Eastern Phoebe, and the Barn Swallow eggs were removed, so the positive relationship in this small sample size may be attributed to habitat quality. At the Post Office location, one of the nests was started in a European Starling nest, after the Starlings fledged. Other studies have found high rates of nest competition between European Starlings and other species, where the European Starlings took over 50% of the Red-Bellied (*Melanerpes carolinus)* and Red-Headed (*Melanerpes erythrocephalus)* Woodpecker nests being monitored (Ingold 1989). The Spearman correlation did not find a significant correlation between number of fledglings and competitor species presence, but the relationship may still be biologically relevant in a larger sample size.

We did not detect a significant relationship between colony size and nest success. However, our sample size may have been too low to detect differences. In fact, sites with ≥5 nests had an average 4.5 fledglings compared to 3.6 fledglings at sites with <5 nests. Although the Spearman correlation determined that there is no significant correlation between colony size and number of fledglings, mean number of fledglings did increase with colony size. Shields and Crook (1987) determined that large colonies are less successful because the birds are generally younger, and Snap (1976) determined that larger colonies are generally more successful because there is less predation and more social stimulation. Our data suggest that the relationship between colony size and nest success is in fact non-linear. Mid-sized colonies appeared to have the highest degree of nest success, which is consistent with past studies showing higher nest success in colonies, but lower nest success in large, young colonies.

Our research did not show a relationship between Barn Swallow nest presence and distance to field or water. In the past, research has indicated that open field space is positively

linked to Barn Swallow presence if livestock is also present (Henderson et al. 2007). Beyond this, little research has been conducted specifically related to nest site proximity to bodies of water or open field spaces. Distance to water bodies and open fields could have an impact on site selection, because these locations are ideal habitats for insects, the food source of Barn Swallows. If a location has a steady food supply, it might be more attractive than a location with inconsistent or difficult to find food.

This study could be improved by adding more locations to be monitored. Because the sample size was small, and only 10 sites with nests were monitored (20 sites were monitored total), statistical significance was difficult to draw because of high variability due to a single year of sampling. Because of this variability, it would be helpful to compare data from different years because it is possible that a site had an unusually good or bad year. Finally, it would be helpful to monitor multiple broods from the same year because other studies have found results can change based on number of broods (Gruebler et al. 2010).

Because we had high rates of nest success, 87% overall, and observed no predation events, we believe that the decline of Barn Swallows is caused by loss of habitat or limitation of barn use. At several of the control locations, homeowners explained that the barns are often kept closed to discourage Barn Swallow entry. At one active barn that had Barn Swallows, the homeowner wanted to know if we could remove the Barn Swallows from the property because they were considered a nuisance. Another factor that could be studied further is barn owners' willingness to host Barn Swallows, and the effects of this on nest site selection and nest success. At the Crooked Pond Farm location, the owners of the property screened in a particular part of the loft of their barn and kept all windows to it shut until the start of Barn Swallow breeding season to keep out competitor species. Their efforts to keep other species out and to attract Barn

Swallows back to their property may have had an influence on that location's 100% nest success, therefore supporting the idea that human willingness to host Barn Swallows leads to Barn Swallow nests. An educational campaign about the benefits of Barn Swallows could lead to more barn-owners becoming willing to host nest sites. By simply conducting our study, we were able to educate some homeowners. At one location, the homeowners have decided to construct Barn Swallow nesting platforms in their barn to facilitate nesting for future breeding seasons.

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Appendix A: Comprehensive Nest Data

Table A- 1: Site locations and characteristics.

Active Locations			
Harvard		Falmouth	
Location	Saafield's Barn	Location	Maushop Equestrain Center
Structure	Barn	Structure	Barn
Address	15 Woodchuck Hill Road, Harvard, MA, 01451	Address	31 Quashnet Rd Mashpee, MA 02649
Coordinates	42.497303,-71.571829	Coordinates	41.643119, -70.486806
Geography Description	Large field, pond	Geography Description	Small property, Washburn Pond nearby
Human Activity	2	Human Activity	2
Location	Micheldever Farm	Location	Coonamessett Farm
Structure	Barn	Structure	small barn
Address	159 E Bare Hill Road, Harvard, MA, 01451	Address	277 Hatchville Rd East Falmouth, MA
Coordinates	42.46459,-71.590324	Coordinates	41.617509, -70.575911
Geography Description	Large pasture, pond	Geography Description	large fields, variety of barns with a variety of sizes
Human Activity	2	Human Activity	3
Location	Flintlock Farm	Location	Boxberry Hill Farm
Structure	Barn	Structure	Barn
Address	327 Still River Road, Harvard, MA, 01451	Address	407 Boxberry Hill Rd, East Falmouth, MA
Coordinates	42.4762692, -71.6212437	Coordinates	41.629902, -70.569370
Geography Description	Marshy area, large field	Geography Description	Large property, pond near by, large fields
Human Activity	2	Human Activity	3
Location	Stable	Location	Smithfield Farm
Structure	Barn	Structure	barn/indoor riding ring
Address	45 Boxboro Road, Littleton, MA	Address	809 Sandwich Road East Falmouth, MA 02536

Coordinates	42.5053606, -71.4847222		Coordinates	41.605411, -70.566443
Geography Description	Pastures nearby		Geography Description	large property, pond near by, field
Human Activity	3		Human Activity	3
Location	Post Office		Location	Crooked Pond Farm
Structure	Building		Structure	Barn Loft
Address	215 Ayer Road, Harvard, MA, 01451		Address	308 Hatchville Rd, East Falmouth, MA 02536
Coordinates	42.529381,-71.578551		Coordinates	41.617978, -70.581282
Geography Description	Open Fields		Geography Description	large field, pond nearby
Human Activity	3		Human Activity	2
Control Locations				
Harvard			Falmouth	
Location	Fruitlands		Location	Nyes Neck Farm
Structure	Barn		Structure	barn
Address	98 Prospect Hill Road, Harvard, MA 01451		Address	1 Sweet Road North Falmouth MA
Coordinates	42.508157,-71.607524		Coordinates	41.647143, -70.631076
Geography Description	Large fields		Geography Description	Large field with old barn on property, surrounded by marsh
Human Activity	1		Human Activity	1
Location	Dunroven Farm		Location	Coonamessett (Farm Storage Shed)
Structure	Barn		Structure	large shed/small barn
Address	62 Old Mill Road, Harvard, MA, 01451		Address	277 Hatchville Rd East Falmouth, MA
Coordinates	42.538892,-71.588518		Coordinates	41.617509, -70.575911
Geography Description	Large pasture area		Geography Description	large farm area, pond near by

Human Activity	3
Location	Still River Farm
Structure	Barn
Address	203 W Bare Hill Road, Harvard, MA, 01451
Coordinates	42.477662,-71.620278
Geography Description	Large pastures
Human Activity	3
Location	Glimerton Farm
Structure	Barn
Address	51 Boxboro Road, Littleton, MA
Coordinates	42.509027, -71.484763
Geography Description	Large fields
Human Activity	3
Location	Bazarnick's House
Structure	Deck
Address	355 Old Littleton Road, Harvard, MA 01451
Coordinates	42.529059,-71.536148
Geography Description	Large yard, nearby pond
Human Activity	2

Human Activity	3
Location	Coonamessett Farm (Play Shack
Structure	
Address	277 Hatchville Rd
Coordinates	41.617509, -70.575911
Geography Description	Large farm area, pond near by
Human Activity	2
Location	Old storage shed
Structure	shed
Address	15 Grove Street
Coordinates	41.642086, -70.640181
Geography Description	Large yard, right by marsh
Human Activity	2
Location	Grove Barn
Structure	barn
Address	4 Grove Street
Coordinates	41.641805, -70.639562
Geography Description	large yard, surrounded by marsh
Human Activity	2

Table A- 2: Nest success descriptive data.

Location	Number of nests (sample size)	Daily Survival Probability (Mayfield Estimate)	Total Survival Probability ($Mayfield^{days}$)	% Successful Nests	Mean Days Active/ Nest
Saafield's Barn	6	1	1	100	36.17
Micheldever Farm	5	1	1	100	37.4
Post Office	3	0.99	0.62	66.67	24
Stable	1	1	1	100	38
Flintlock Farm	18	1	0.87	83.33	42.22
Coonamessett Farm	2	1	1	100	27
Crooked Pond Farm	5	1	1	100	11.6
Boxberry Farm	1	1	1	100	27
Smithfield Farm	2	0.98	0.58	50	32
Maushop	12	0.99	0.76	83.33	86.11

Table A- 3: Comprehensive nest success summary.

Location	Mean Nestlings	SE Nestlings	Lower Confidence Interval (LCI) Nestlings (95%)	Upper Confidence Interval (UCI) Nestlings (95%)	Mean Fledglings	SE Fledglings	LCI Fledglings (95%)	UCI Fledglings (95%)
Saafield's Barn	5	0.15	4.69	5.31	5	0.15	4.69	5.31
Micheldever Farm	4	0.34	3.26	4.74	4	0.34	3.26	4.74
Post Office	3.67	0.7	2.2	5.13	3.67	0.7	2.21	5.13
Stable	5	0	5	5	5	0	5	5
Flintlock Farm	4.28	0.52	3.17	5.39	4.06	0.56	2.86	5.26
Coonamessett Farm	3.5	0.25	2.91	4.09	3.5	0.25	2.91	4.09
Crooked Pond Farm	5	0.41	3.95	6.05	5	0.41	3.95	6.05
Boxberry Farm	3	0	3	3	3	0	3	3
Smithfield Farm	3	1.28	0.15	5.85	3	1.28	0.15	5.85
Maushop	4	0.67	2.47	5.53	4.33	0.7	2.74	5.92

Table A- 4: Individual nest success.

Location	Nest Label	Fate	# Fledglings	Length of Activity (days)
Saafield's Barn	A	Successful	5	38
Saafield's Barn	B	Successful	5	38
Saafield's Barn	C	Successful	4	38
Saafield's Barn	D	Successful	6	38
Saafield's Barn	E	Successful	5	34
Saafield's Barn	I	Successful	5	31
Micheldever Farm	A	Successful	4	36
Micheldever Farm	B	Successful	2	38
Micheldever Farm	C	Successful	4	36
Micheldever Farm	D	Successful	5	34
Micheldever Farm	E	Successful	5	43
Post Office	A	Failed	0	9
Post Office	B	Successful	6	33
Post Office	C	Successful	5	30
Stable	A	Successful	5	38
Flintlock Farm	A	Failed	0	27
Flintlock Farm	F	Successful	2	40
Flintlock Farm	G	Successful	5	44
Flintlock Farm	H	Failed	0	39
Flintlock Farm	I	Successful	5	43
Flintlock Farm	K	Successful	5	48
Flintlock Farm	M	Successful	5	44
Flintlock Farm	N	Successful	6	48
Flintlock Farm	O	Successful	5	39
Flintlock Farm	Q	Successful	6	44
Flintlock Farm	T	Successful	6	44
Flintlock Farm	W	Successful	4	48
Flintlock Farm	Z	Successful	4	44
Flintlock Farm	DD	Successful	5	48
Flintlock Farm	FF	Failed	0	39
Flintlock Farm	II	Successful	5	39
Flintlock Farm	JJ	Successful	6	39
Flintlock Farm	NN	Successful	4	43
Coonamessett Farm	A	Successful	4	27
Coonamessett Farm	B	Successful	3	27
Crooked Pond Farm	A	Successful	4	12
Crooked Pond Farm	C	Successful	6	12
Crooked Pond Farm	G	Successful	6	12

Crooked Pond Farm	L	Successful	4	11
Crooked Pond Farm	R	Successful	5	11
Boxberry Farm	A	Successful	3	27
Smithfield Farm	A	Failed	0	51
Smithfield Farm	B	Successful	6	13
Maushop	A	Successful	6	18
Maushop	B	Successful	5	24
Maushop	C	Successful	5	26
Maushop	D	Successful	4	21
Maushop	E	Failed	0	0
Maushop	F	Failed	0	16
Maushop	G	Successful	4	21
Maushop	H	Successful	6	21
Maushop	I	Successful	6	26
Maushop	J	Successful	7	26
Maushop	K	Successful	4	26
Maushop	L	Successful	5	28

Appendix B: Comprehensive Descriptive Statistics

Table B- 1: Visit summary descriptive statistics.

Location	Days Active (Sample Size)	Mean Swallows	SE Swallows	LCI (95%)	UCI (95%)	Mean HOSP	SE HOSP	LCI HOSP (95%)	UCI HOSP (95%)
Saafield's Barn	18	18.24	1.1	15.92	20.56	0.39	0.14	0.09	0.69
Micheldever Farm	13	11.38	0.53	10.23	12.53	5.36	0.9	3.4	7.32
Post Office	21	2.33	0.33	1.63	3.03	0.05	0.05	-0.05	0.15
Stable	13	2	0.23	1.51	2.49	1.85	0.68	0.37	3.33
Flintlock Farm	14	58.57	0.97	56.49	60.65	0	0	0	0
Coonamessett Farm	8	3.88	0.52	2.66	5.1	12.38	1	10.02	14.74
Crooked Pond Farm	6	7	0.52	5.67	8.33	0	0	0	0
Boxberry Farm	9	2.22	0.28	1.58	2.86	3.11	0.35	2.3	3.92
Smithfield Farm	11	3.09	0.61	1.73	4.45	4.09	0.37	3.27	4.91
Maushop	10	16.9	1.23	14.11	19.69	10.7	0.9	8.68	12.72
Dunroven Farm	3	0	0	0	0	3.33	0.88	-0.46	7.12
Fruitlands	3	0	0	0	0	1.67	0.88	-2.12	5.46
Still River Farm	3	0	0	0	0	1	1	-3.3	5.3
Glimerton Farm	3	0.33	0	0.33	0.33	11.67	0.88	7.88	15.46
Bazarnick's House	3	0	0.33	-1.43	1.43	1.33	0.88	-2.46	5.12
Nyes Neck Farm	3	0	0	0	0	3.67	0.88	-0.12	7.46
Grove Barn	3	0	0	0	0	2.33	1.45	-3.92	8.58
Old Storage Shed	3	0	0	0	0	1	0.58	-1.48	3.48
Farm Storage Shed	3	2.66	0.88	-1.13	6.45	10.33	0.88	6.54	14.12
Play Shack	3	4	0.58	1.52	6.48	12.67	1.2	7.5	17.84

Table B- 2: Additional visit summary statistics.

Location	Mean EUST	SE EUST	LCI EUST (95%)	UCI EUST (95%)	Mean PHOE	SE PHOE	LCI PHOE (95%)	UCI PHOE (95%)
Saafield's Barn	0.06	0.06	-0.06	0.18	0.67	0.27	0.1	1.24
Micheldever Farm	0	0	0	0	0.64	0.32	-0.06	1.34
Post Office	0.24	0.17	-0.11	0.59	0	0	0	0
Stable	0	0	0	0	0	0	0	0
Flintlock Farm	0	0	0	0	0.07	0.07	-0.08	0.22
Coonamessett Farm	0.75	0.53	-0.49	1.99	0.25	0.25	-0.34	0.84
Crooked Pond Farm	0	0	0	0	0	0	0	0
Boxberry Farm	0	0	0	0	0	0	0	0
Smithfield Farm	0	0	0	0	0	0	0	0
Maushop	0	0	0	0	0	0	0	0
Dunroven Farm	0	0	0	0	1	0.58	-1.48	3.48
Fruitlands	0	0	0	0	0	0	0	0
Still River Farm	0	0	0	0	0.33	0.33	-1.1	1.76
Glimerton Farm	0	0	0	0	0.33	0.33	-1.1	1.76
Bazarnick's House	0	0	0	0	0	0	0	0
Nyes Neck Farm	0	0	0	0	0	0	0	0
Grove Barn	0	0	0	0	0	0	0	0
Old Storage Shed	0	0	0	0	0	0	0	0
Farm Storage Shed	0	0	0	0	0	0	0	0
Play Shack	0	0	0	0	0	0	0	0

Table B- 3: Visit summary predator sighting statistics.

Location	Mean Cat	SE Cat	LCI Cat (95%)	UCI Cat (95%)	Mean Hawk	SE Hawk	LCI Hawk (95%)	UCI Hawk (95%)	Mean Dog	SE Dog	LCI Dog (95%)	UCI Dog (95%)
Saafield's Barn	0	0	0	0	0	0	0	0	0	0	0	0
Micheldever Farm	0	0	0	0	0	0	0	0	1	0	1	1
Post Office	0	0	0	0	0	0	0	0	0	0	0	0
Stable	4.77	0.52	3.63	5.9	0	0	0	0	0	0	0	0
Flintlock Farm	0	0	0	0	0	0	0	0	0	0	0	0
Coonamessett Farm	0	0	0	0	0	0	0	0	0	0	0	0
Crooked Pond Farm	0	0	0	0	0	0	0	0	0	0	0	0
Boxberry Farm	0.78	0.32	0.03	1.52	0	0	0	0	0.78	0.32	0.03	1.52
Smithfield Farm	0.18	0.18	-0.22	0.59	0	0	0	0	2.27	0.38	1.42	3.13
Maushop	0	0	0	0	0	0	0	0	1.4	0.4	0.5	2.3
Dunroven Farm	0	0	0	0	0.33	0.33	-1.1	1.77	4	0	4	4
Fruitlands	0	0	0	0	0.33	0.33	-1.1	1.77	0	0	0	0
Still River Farm	1.33	0.67	-1.54	4.2	0	0	0	0	0	0	0	0
Glimerton Farm	0.67	0.33	-0.77	2.1	0	0	0	0	0	0	0	0
Bazarnick's House	0	0	0	0	0	0	0	0	0	0	0	0
Nyes Neck Farm	1.67	0.33	0.23	3.1	0.33	0.33	-1.1	1.77	0	0	0	0
Grove Barn	1.33	0.67	-1.54	4.2	0.33	0.33	-1.1	1.77	0	0	0	0
Old Storage Shed	1	0.58	-1.48	3.48	0.33	0.33	-1.1	1.77	0	0	0	0
Farm Storage Shed	0	0	0	0	0	0	0	0	0	0	0	0
Play Shack	0	0	0	0	0	0	0	0	0	0	0	0