Measuring Bat Activity Levels through Use of Acoustic Detection Techniques

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White-Nose Syndrome (WNS), a fungal infection caused by *Pseudogymnoascus destructans*, has been decimating North American bat populations since its introduction in 2006. This disease and the bats it infects are not well understood, which calls for the development of techniques to monitor bats and eventually develop ways of combating WNS. We used a system of acoustic detection to monitor nightly bat activity levels in order to establish a baseline activity level before WNS infects local populations. We also attempted to gather data on variation in bat activity due to time, date, and weather conditions to better understand and monitor bat populations. We hypothesized that bat activity would increase with rising temperatures and decrease with inclement weather. Total bat activity increased significantly with temperature (least squares regression slope=2.08, F=4.851, p=0.034) and decreased significantly with the time after sunset that the survey began (slope=-0.02, F=16.674, p<0.001). We recommend an annual, week-long period of bat monitoring for future studies to obtain similar baseline levels of bat activity.

Introduction

Since its introduction to the eastern United States in 2006, a fungal disease known as White-Nose Syndrome (WNS) has killed well over 5 million bats in 25 states (U.S. Fish & Wildlife Service, 2014). WNS is caused by a fungal pathogen called *Pseudogymnoascus destructans* (formerly *Geomyces destructans*) (Frick, 2010). The fungus produces white patches on an affected bat's skin and fur, which act as an irritant. In hibernating bats, irritation can be deadly as it wakes them from their hibernation and causes them to burn through their fat reserves. If a bat is woken too often, it quickly uses up its store of energy and starves to death before winter ends (Blehert, 2008). It is hypothesized that *P. destructans* is native to Europe and was transferred to North America where it has had devastating effects on the bat populations of the East Coast (Frick, 2010).

One species of bat has been particularly affected by the introduction of WNS. *Myotis lucifugus*, the little brown bat, is a small (6-12 g) chiropteran with a high metabolism (Kurta, 1995). When active in the summer months, *M. lucifugus* needs to consume as much or more than its own body weight in insects each night to sustain itself and build up fat reserves for the winter (Kurta, 1995). When it is hibernating, the insects that *M. lucifugus* preys upon are no longer available, so the bats have no way to replace energy lost due to increased metabolism when they are wakened by the irritation of WNS. *Myotis lucifugus* hibernates and roosts in large colonies of hundreds or even thousands of individuals (Kurta, 1995) so *P. destrutans* can spread through a population very quickly. Hibernacula infected with WNS have been shown to decrease in population anywhere from 30-99% (Frick, 2010). With such dramatic decreases in population size, it is difficult to imagine how a species that only has one offspring per year (Kurta, 1995) can recover to its previous abundance, and it is feared that *M. lucifugus* will become regionally extirpated within the next 16 years (Frick, 2010).

While certainly worrying from a biodiversity standpoint, the potential loss of *M. lucifugus* would also have a major economic impact. Bats are estimated to have an economic value to the agricultural industry of $22.9 billion/year due to the amount of crop-destroying pests they consume (Boyles, 2011). If *M. lucifugus* and other insectivorous bat populations are reduced or lost due to WNS, there will be massive increase in crop pests and subsequent use of pesticides to control them, which may in turn have damaging ecological effects (Boyles, 2011). It is clear that measures must be taken to mitigate the effects of WNS.

The first step of controlling the spread of WNS is to gather more information about the bats it infects. In the past, bats have not been closely monitored, which makes it difficult judge drops in population that may indicate the introduction of WNS into a region (Frick, 2010). Our purpose with this study was to establish an easily repeatable procedure for monitoring bat activity. Past studies have found acoustic detection equipment to be an effective method of monitoring bat activity (Wolbert, 2014) (Stahlschmidt, 2012). We hope that using the techniques we develop in this study, others may be able to establish baseline activity levels for bats in as-yet unaffected areas and thus make it easier to detect the presence of WNS when activity levels start dropping and to quantify the ecological impact of bat population decreases. We also examined the effects of weather conditions on bat activity in order to provide a more well-informed recommendation for monitoring of bat activity. We hypothesized that nightly bat activity would decrease in response to lower temperatures as previously reported by Wolbert et al. (2014), as well as in response to inclement weather such as rain.

Methods

Study Site

Our study took place on the University of Michigan Biological Station (UMBS) campus in Cheboygan County of northern Michigan. Members of the 2014 Field Mammalogy class walked fixed routes on forested roads that included red pine (*Pinus resinosa*), white pine (*Pinus strobus*), quaking aspen (*Populus tremuloides*), red oak (*Quercus rubra*), and sugar maple (*Acer saccharum*). Students walked two routes, one after another (Figure 1). The first followed Upper Drive for 0.4 miles (start: 45.5600, -84.6756, end: 45.5600, -84.6687), is more wooded and extends through a rural cabin area. Lower Drive is 0.38 miles in length (start: 45.5600, -84.6687, end: 45.5600, -84.6740, 0.38 miles) and follows campus along the lake shore and is sparsely wooded, but is more heavily used by camp residents.

Protocol

Bat activity was measured nightly from June 26th to August 1st, 2014. Bat activity was measured by members of the Field Mammalogy class using an Anabat II detector (Titley Electronics, Ballina, Australia), which detects echolocation and divides the frequency so that it is audible to humans. It is not always possible to distinguish species using this acoustic detection technique, but *Myotis lucifugus* is one of the most common bat species in rural northern Michigan (Kurta, 1995) and is known to be abundant at the UM Biological Station, so we attributed all activity to *M. lucifugus.* Students walked each of the described routes at a measured pace, attempted to walk each route in approximately 15 minutes. We attempted to start the route approximately 45 minutes after sunset each night, though there was some variation in this timing. We carried the Anabat II detector at approximately chest height, held at a 45° angle from the ground and recorded each time a bat pass was detected by the Anabat II detector. One pass was defined as a series of clicks or "feeding buzz" indicating echolocation. Single clicks from the detector were considered background noise and were not counted.

Each route was counted separately to determine if bats varied their foraging locations by time of night, time of year, or weather. We walked both routes each night, but alternated which route was walked first to account for variation in bat activity by time. These data were combined into one nightly total of bat activity when we found no significant difference between them. Weather data such as temperature, wind speed, barometric pressure, and humidity were obtained from the Douglas Lake Buoy, which measures air and water conditions every 10 minutes (http://uglos.mtu.edu/station_page.php?station=UMBIO).

In addition to the established walking routes, we performed stationary activity monitoring on June 28th and August 4-6th, 2014. We stood outside known bat roosts at Houghton Laboratory on UMBS campus and a maintenance shed also on campus (Fig. 1) and recorded the number of bat passes that occurred in each five minute period for one hour using the same acoustic detection technique used for the mobile activity monitoring.

Data analysis

We performed a Mann-Whitney U Test to determine if there was a significant difference between the two routes we walked. We also plotted bat activity against temperature, humidity, barometric pressure, wind speed, proportion of moonlight (determined by roughly estimating the percentage of the moon showing through the course of the month), and time after sunset to identify any relationships. We performed linear regressions on the only variables that appeared to be related to activity (temperature and time after sunset). There were not a sufficient number of rainy nights to compare clear weather with rain.

Results

There was no significant difference in mean bat activity between the two routes (n = 62, Mann-Whitney U value = 428, p = 0. 459) so for the following analyses we summed counts from the two routes into one total bat activity reading for each night.

We found no relationship between total bat activity and wind speed (Fig. 2), humidity (Fig. 3), barometric pressure (Fig. 4), or proportion of moonlight (Fig. 5). Activity appeared to decline with date (Fig. 6); the relationship, however, was not statistically significant (least-squares regression slope=-.502, F=2.511, p=0.122). Activity increased significantly on warmer nights (least-squares regression slope=2.08, F=4.851, p=0.034; Fig. 7). Activity decreased significantly with the time after sunset that the survey began (least-squares regression slope=-0.02, F=16.674, p<0.001; Fig. 8).

Activity during stationary bat monitoring on June 28th showed peaks at 22:15 and 22:30, 50 and 65 minutes after sunset respectively (Fig. 9). Activity for the nights of August 4-6 was totaled, and showed a peak at 22:55, 117 minutes after sunset (Fig. 10).

Discussion

Our data supported the hypothesis that bat activity would increase with temperature. Nightly prevalence of insects increases with temperature as well, so bats are likely hunting more actively on warm nights when there are more insects (Wolbert, 2014). No other weather conditions displayed any strong relationship to bat activity, perhaps because weather conditions varied little over the course of the study. Wind speed never rose above 6 MPH, and it is possible that a relationship between bat activity and wind speed might be observed at increased wind speeds. We also had very few nights when it rained during our activity monitoring time, so it is impossible to draw any conclusions about bat activity in inclement weather. We found no relationship between bat activity and amount of moonlight as well. We expected there to be less bat activity on nights with the most moonlight, as increased light makes the bats more susceptible to nocturnal predators such as owls (Lima, 2013). One possibility is that the lights from the UMBS campus render moonlight a moot point, as they are a constant source of illumination. Even during a new moon, there is always some light on the campus, and so the bats would have no reason to prefer flying when the moon is darkest.

Activity levels decreased over the course of the summer. While this finding was statistically non-significant, there was a distinct visual negative trend when we plotted activity by date. While we found no clear reason for this trend, we hypothesize that this may be due to the fact that female *Myotis lucifugus* are pregnant or lactating in early summer (Kurta, 1995) and so need to hunt more in order to feed themselves and their offspring. However, one might expect yet more activity as the summer continues when the young emerge and begin foraging for themselves, but we did not observe this increase to occur. The young may have dispersed to new hunting locations, or their emergence may have been delayed and so was not detected by our monitoring.

Finally, we attempted to determine the time that bat activity levels were highest. We predicted this peak would occur at a relatively constant time interval after sunset each night. We found a significant negative association between time after sunset and bat activity, with the highest activity levels between 25 and 50 minutes after sunset; however, our earliest starting point was 25 minutes after sunset which may have led to us missing a peak in activity before our starting time. The data from our stationary bat monitoring contradicted these findings of early bat activity; we found peaks in activity anywhere from 1 to 2 hours after sunset, depending on the date. On June 28th, we found peaks in activity 50 and 65 minutes after sunset, while during August 4-6th, we observed a peak 117 minutes after sunset. There is no clear explanation for why this might be true, except that there is a great deal of nightly variation in bat activity, so it is possible that we did not perform enough nights of stationary bat monitoring to show a representative picture of bat activity. *Myotis lucifugus* also tends to forage multiple times a night, with periods of roosting in between periods of activity (Anthony, 1981). We may have been observing either the first or second waves of foraging activity on different nights which would account for some variation in peak timing.

We found acoustic detection to be a relatively simple and effective method of monitoring bat activity. As we observed considerable nightly fluctuation in bat activity, we recommend monitoring bat activity over the course of at least one week to account for nightly variation. For annual bat monitoring, we further recommend choosing approximately the same week each year to ensure similar temperatures and times of sunset between yearly activity monitoring. We further recommend stationary activity monitoring periods to determine peak levels of bat activity so that monitoring takes place during a consistent point in the bats' foraging periods. Alternatively, future studies could simply monitor bat activity through the night to observe all trends in nightly activity. We hope future studies are able to refine our techniques, and use methods such as these to better understand bat populations. These data are valuable in monitoring bat populations and behavior before, during, and after the onset of devastating pathogens such as *P. destructans.* We hope these data and data like it are useful in developing strategies to mitigate the effects of WNS and protect our bats.

Acknowledgements

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Literature Cited

Anthony, E., Stack, M., & T. Kunz. 1981. Night Roosting and the Nocturnal Time Budget of the Little Brown Bat, *Myotis lucifugus*: Effects of Reproductive Status, Prey Density, and Environmental Conditions. Oecologia 51(2):151-156.

Blehert, D., Hicks, A., Behr, M., Meteyer, C., Berlowski-Zier, B., Buckles, E., Coleman, J., Darling, S., Gargas, A., Niver, R., Okoniewski, J., Rudd, R., & W. Stone. 2008. Bat White-Nose Syndrome: An Emerging Fungal Pathogen? Science 323(5911):227.

Boyles, J., Cryan, P., McCracken, G., & T. Kunz. 2011. Economic Importance of Bats in Agriculture. Science 332(6025):41-42.

Frick, W., Pollock, J., Hicks, A., Langwig, K., Reynolds, D., Turner, G., Butchkoski, C., & T. Kunz. 2010. An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species. Science 329(5992):679-682.

Lima, S., & J. O'Keefe. 2013. Do predators influence the behavior of bats? Biological Reviews 88(3):626-644.

Kurta, A. 1995. Mammals of the Great Lakes Region. United States of America: The University of Michigan Press.

Stahlschmidt, P., & C. Brühl. 2012. Bats as bioindicators – the need of a standardized method for acoustic bat activity surveys. Methods in Ecology and Evolution 3(3):503-508.

U.S. Fish & Wildlife Service. 2014. White-Nose Syndrome: The devastating disease of hibernating bats in North America.

Wolbert, S., Zellner, A., & H. Whidden. 2014. Bat Activity, Insect Biomass, and Temperature Along an Elevational Gradient. Northeastern Naturalist 21(1):72-85.

Figures

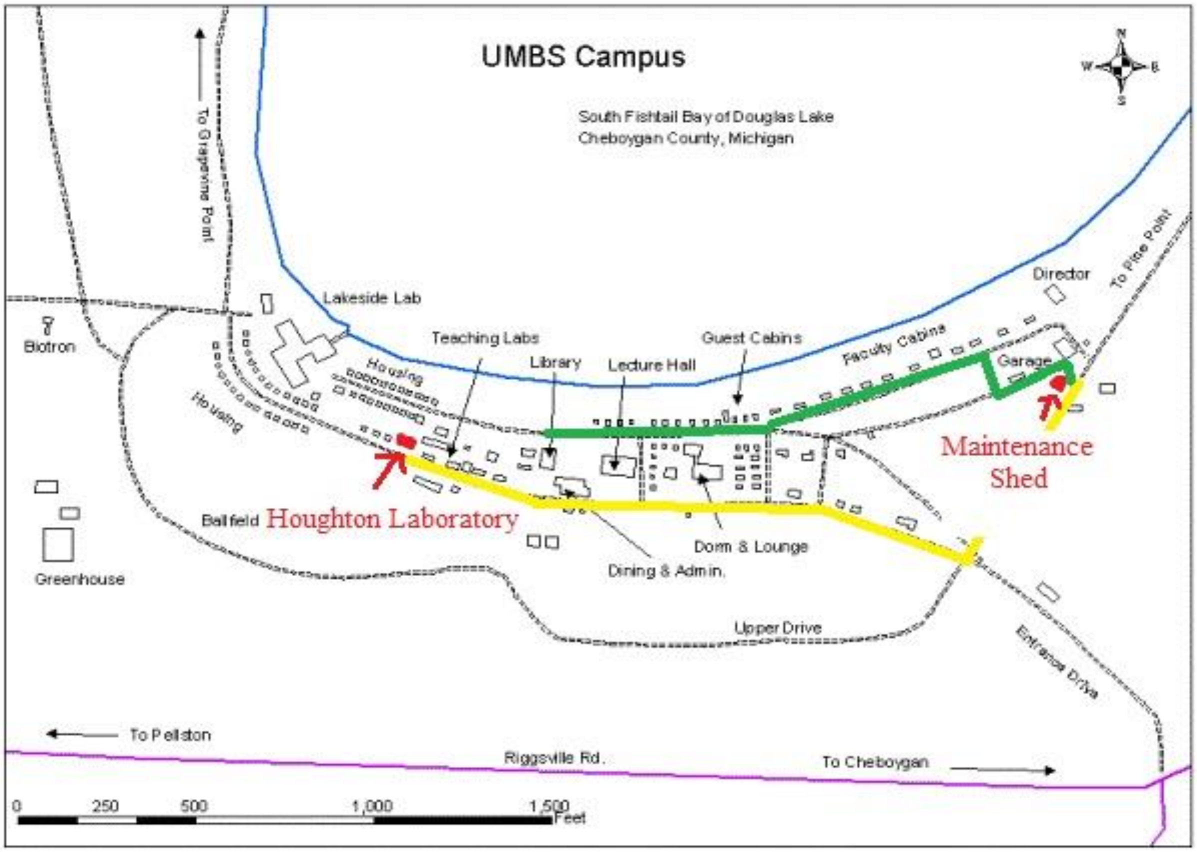

Figure 1: Map of UMBS Campus. Houghton Laboratory and the maintenance shed are indicated in red. Route 1 on Upper Drive is indicated in yellow. Route 2 on Lower Drive is indicated in green.

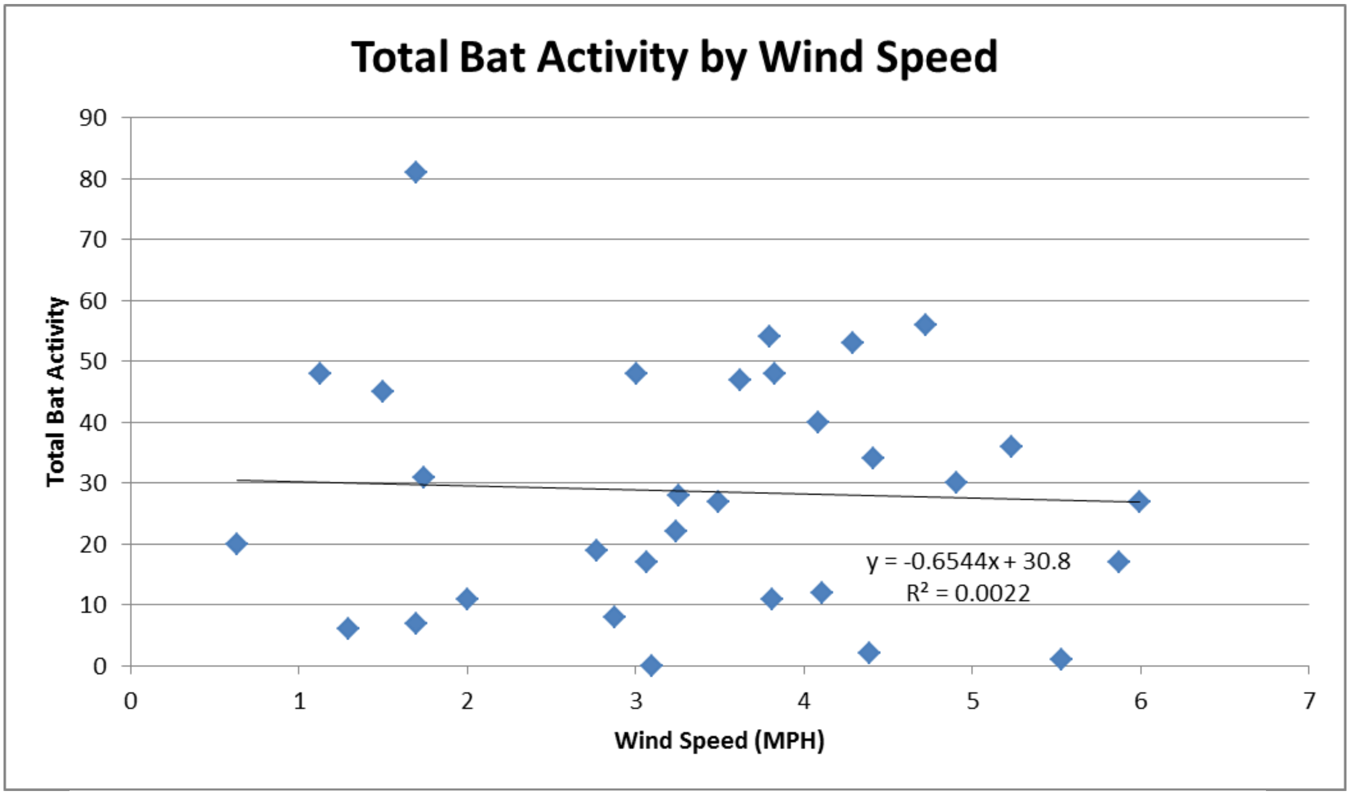

Figure 2: Total bat activity has a very weak negative correlation with wind speed in MPH

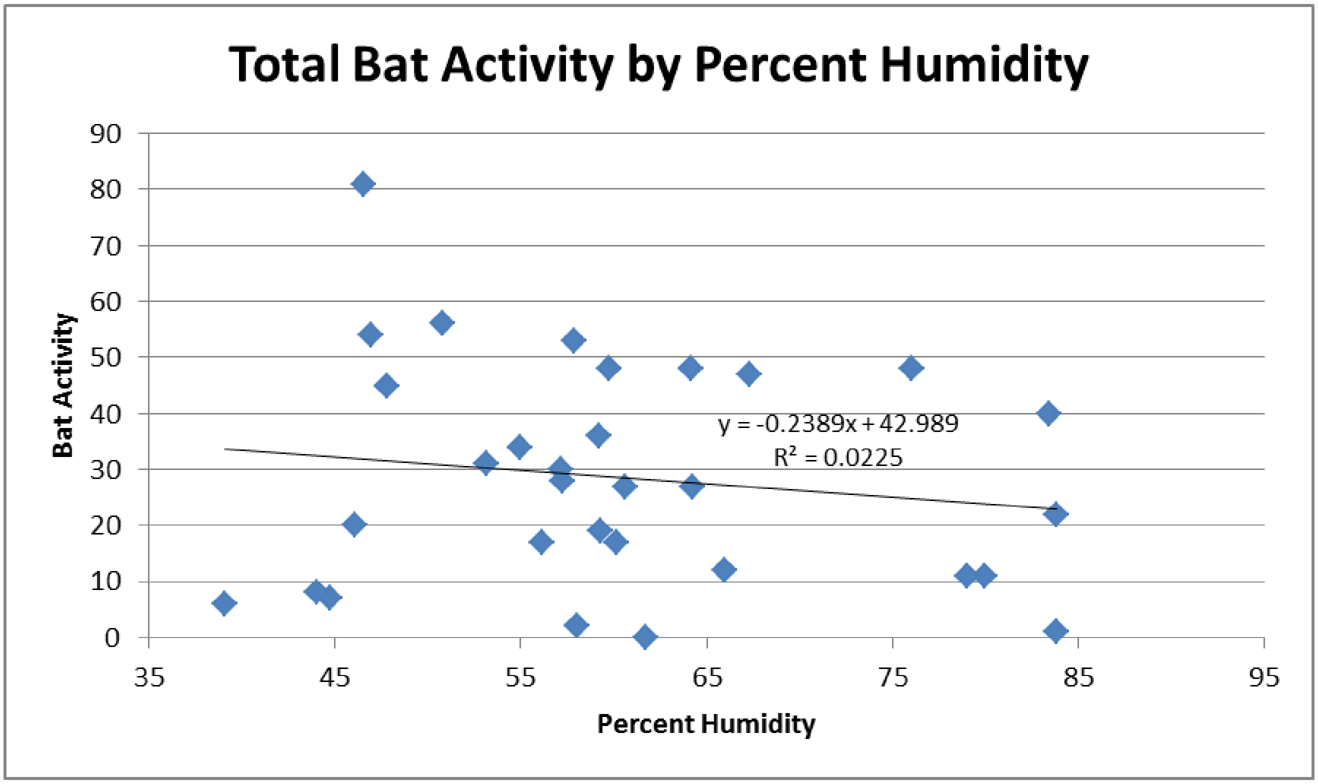

Figure 3: Total bat activity has a very weak negative correlation with percent humidity

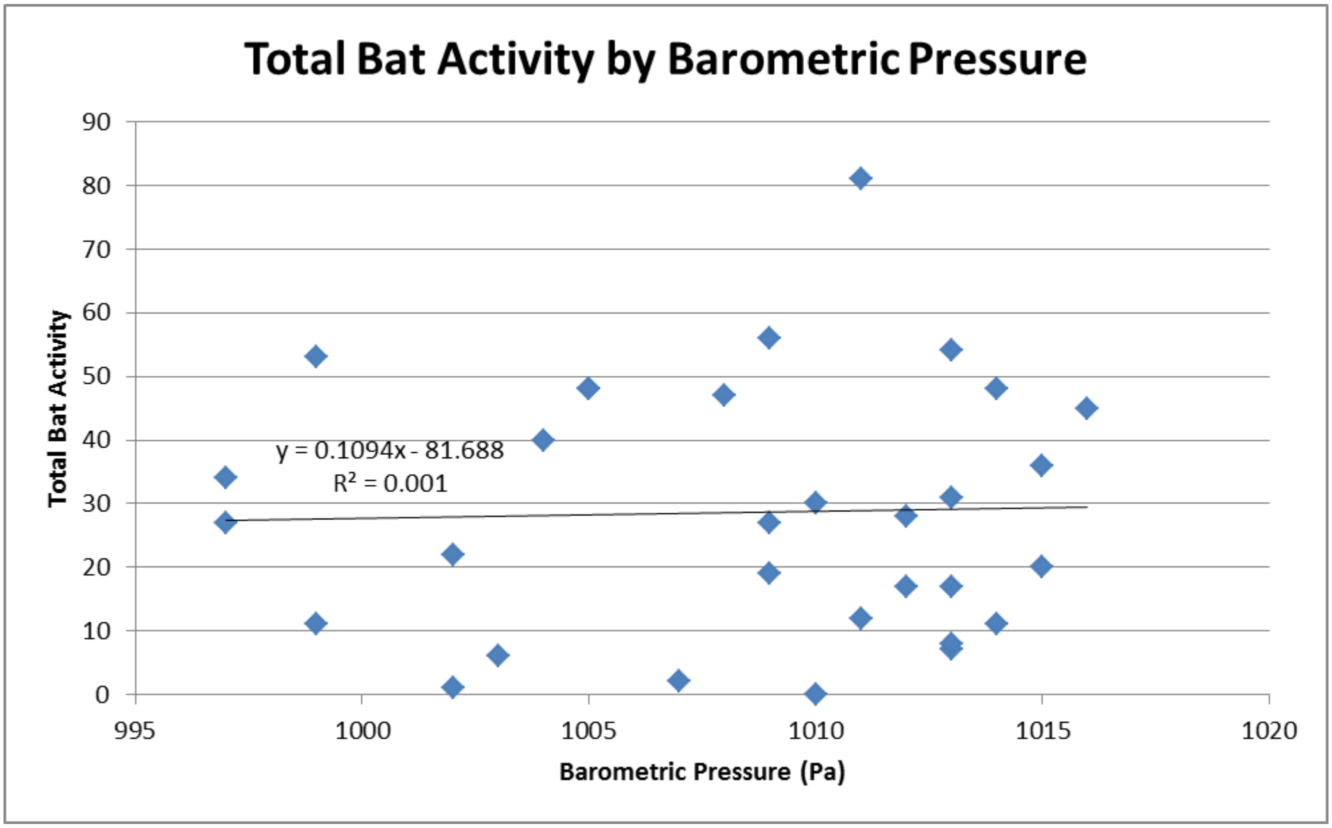

Figure 4: Total bat activity has no correlation with barometric pressure

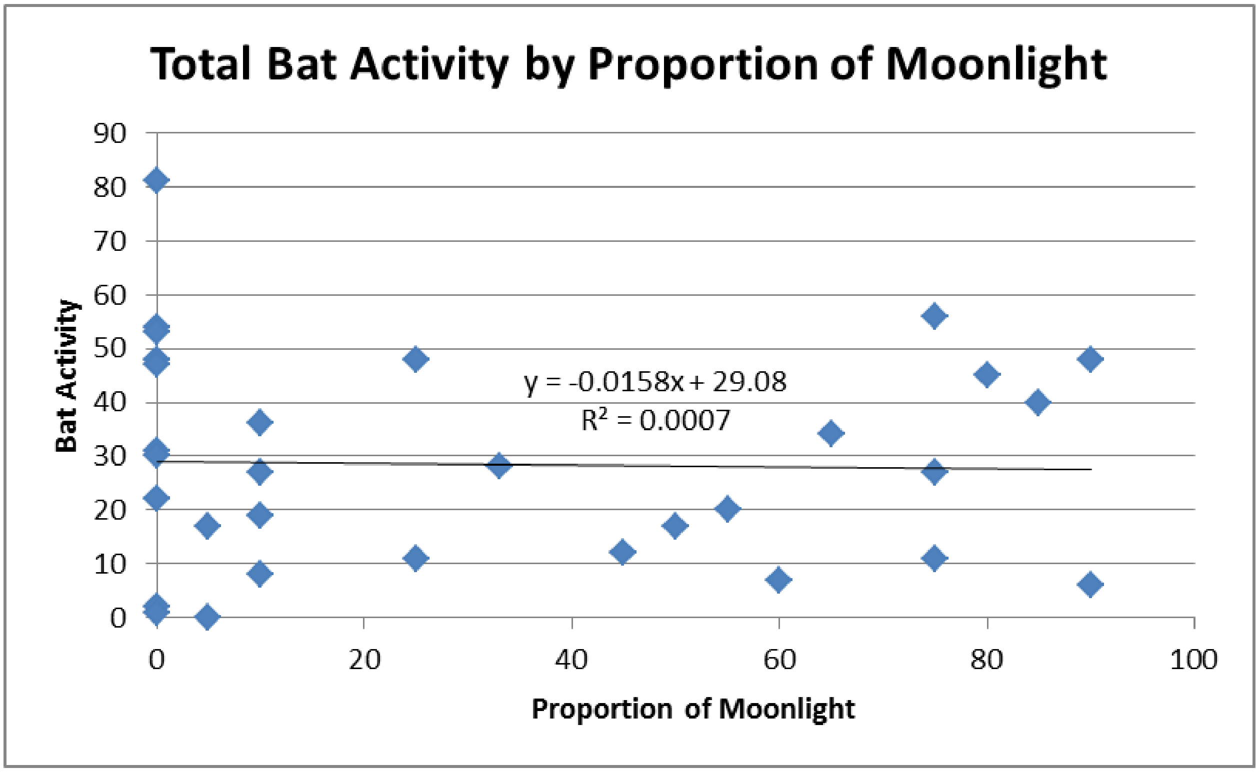

Figure 5: Total bat activity has no correlation with proportion of moonlight

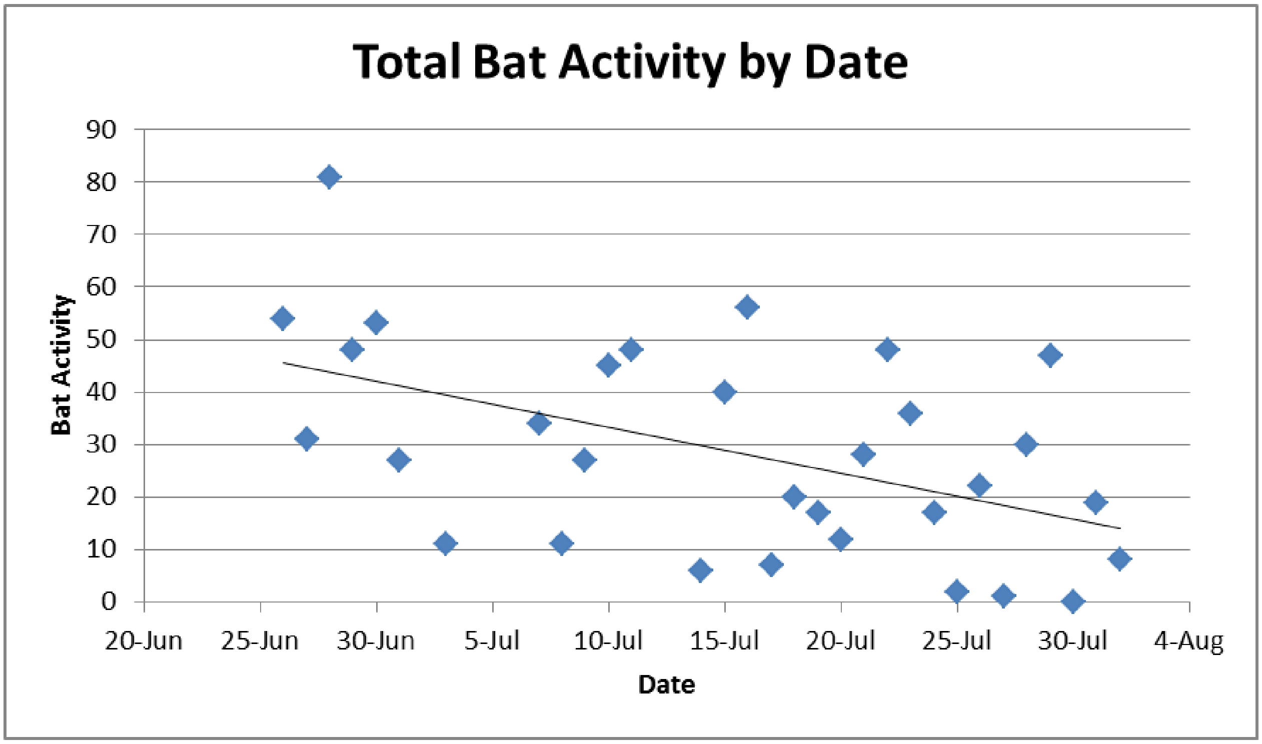

Figure 6: Total bat activity has a non-significant negative correlation with date over the 2014 summer period

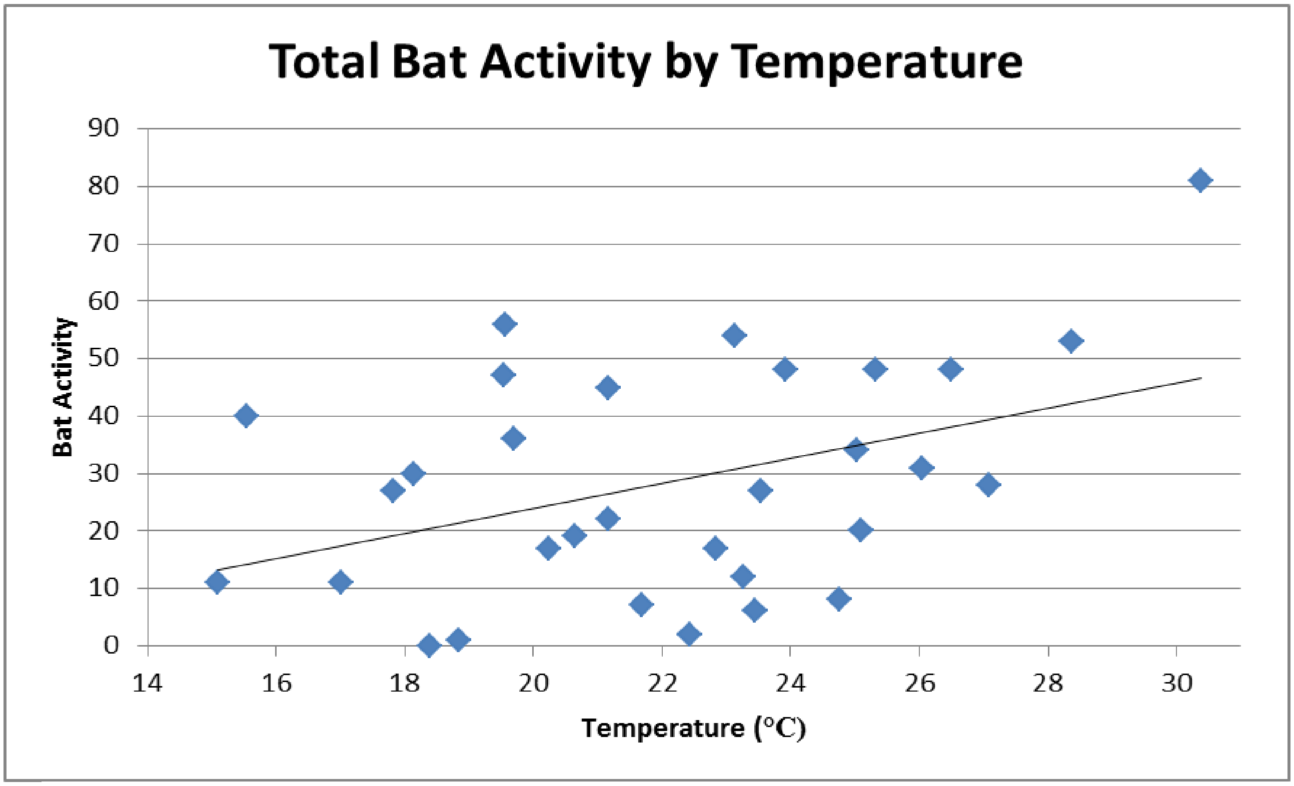

Figure 7: Total bat activity has a significant positive association with temperature (p=0.34)

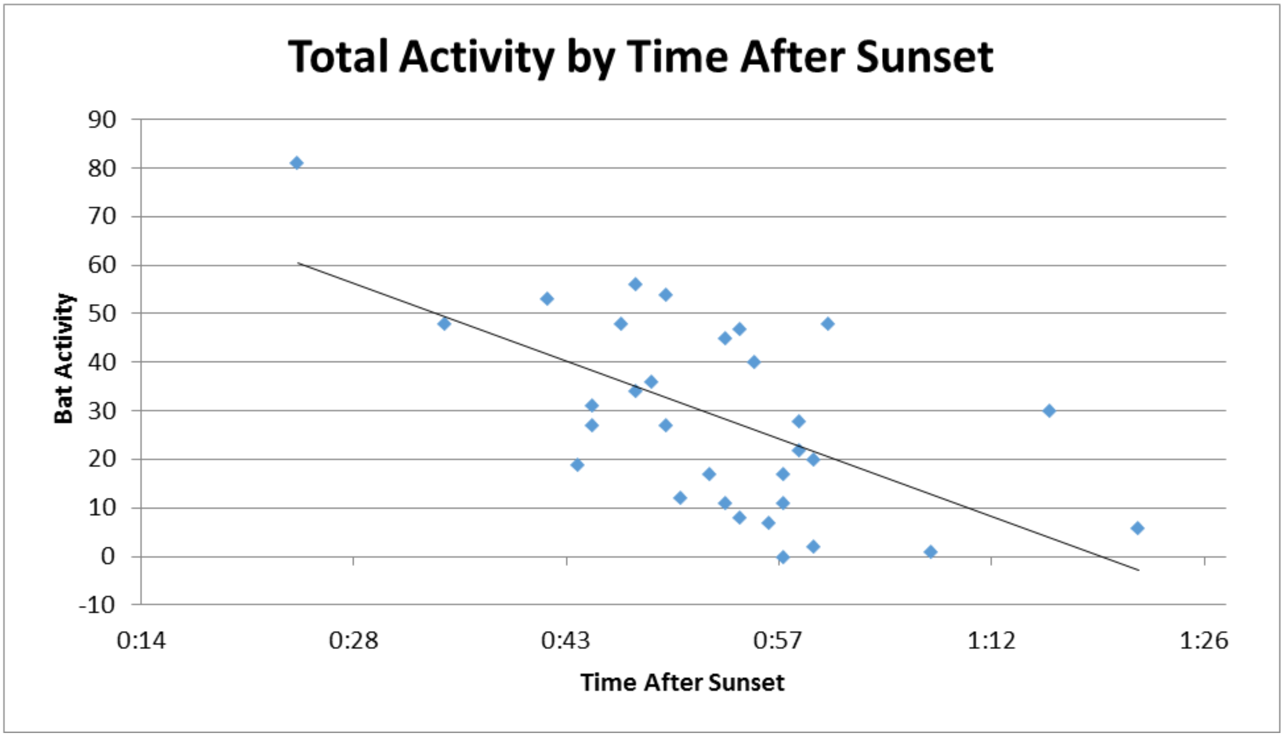

Figure 8: Total bat activity has a significant negative association with time after sunset ($p<0.001$)

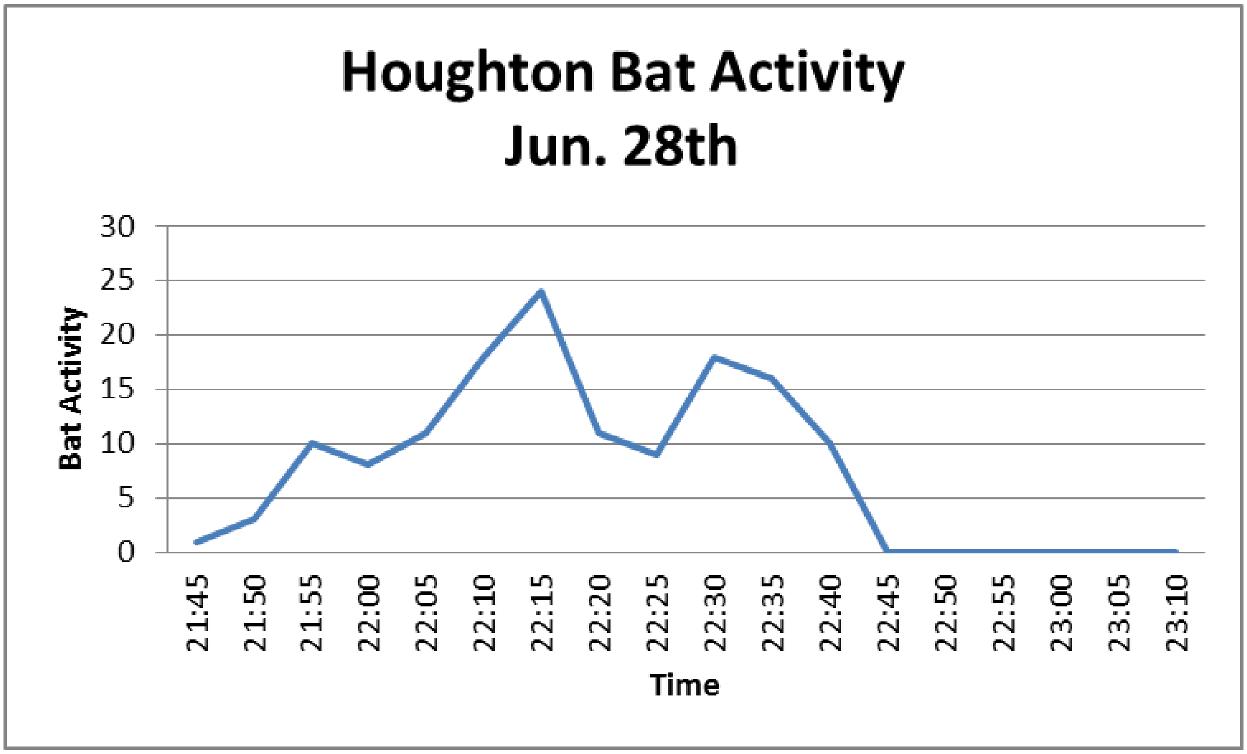

Figure 9: Bat activity at Houghton Laboratory on June 28th shows peaks at 22:15 and 22:30, 50 and 65 minutes after sunset respectively

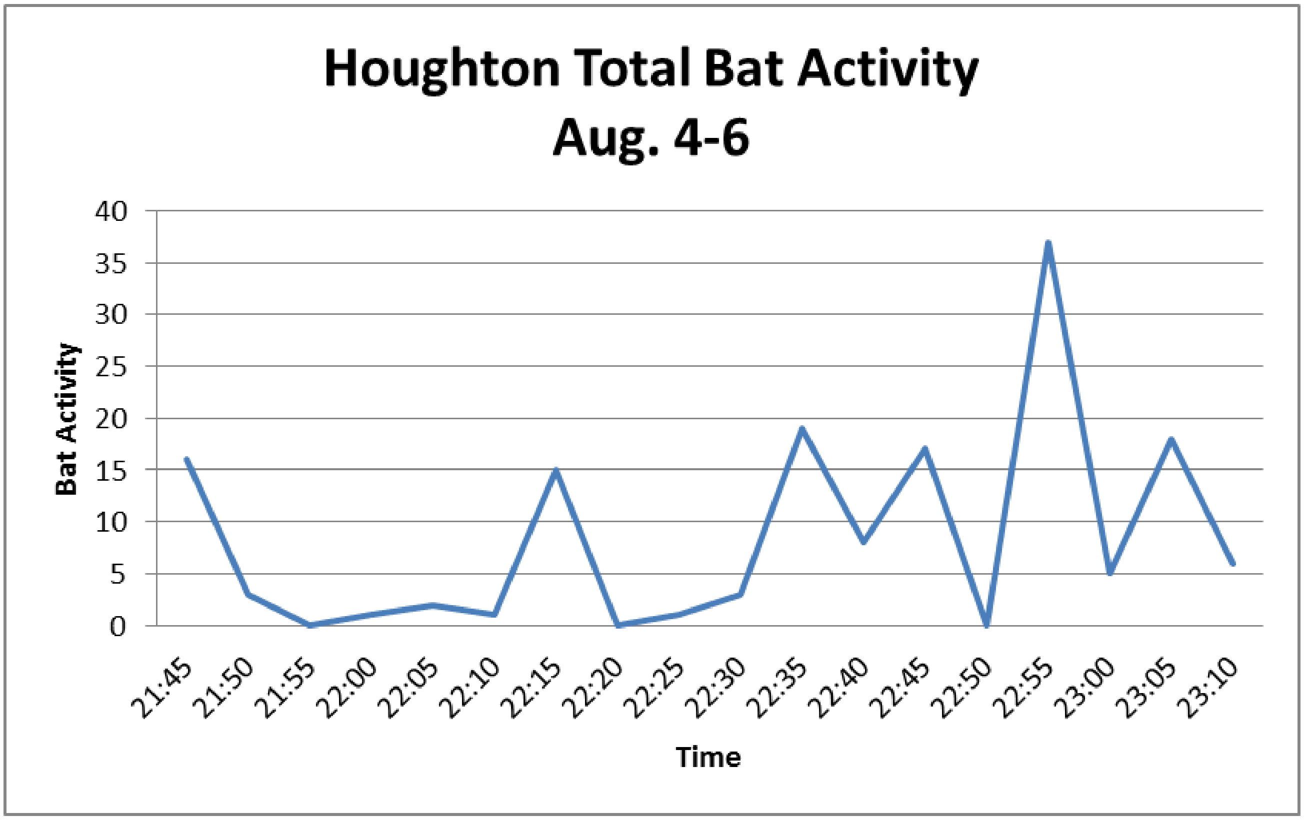

Figure 10: Total bat activity at Houghton Laboratory from August 4-6 shows a peak at 22:55, 117 minutes after sunset.