**Does Bat Activity vary with Weather Conditions?**

Cecilia Eason

300132804

EVS4009 – Research Project

Supervisor: Gabriel-Blouin-Demers

University of Ottawa

Department of Earth and Environmental Science

24 April 2024

# Abstract

As biodiversity declines, monitoring endangered species becomes an important part of conservation efforts. For monitoring to be effective, however, it must be completed during conditions suitable for the detection of the species of interest. Bat activity and detection can be impacted by weather variables such as temperature and precipitation. My goal was do determine how bat activity varies with weather conditions. Acoustic monitoring was completed in June and July of 2023 for fifty nights at seven sites within Gatineau Park, Canada. Multiple regression models were created for the total bat activity, as well as for the big brown bat/silver-haired bat and the *Myotis* phonic complexes and for hoary bat activity. Wind speed, precipitation, mean nightly temperature, atmospheric pressure and fraction of the moon illuminated were used as predictor variables. All bats, *Myotis* bats, and hoary bats were more active on nights with higher atmospheric pressure, while *Myotis* bats were less active on nights with precipitation. Hoary bats were more active on warmer nights and bats in the big brown bat/silver-haired bat complex were more active on windier night. All models only explained a small part of the variation in detected bat activity, indicating that variables other than those considered in this project have an impact on bat activity. However, these results do suggest that bat monitoring should be completed on nights with higher atmospheric pressure, a slight wind, and no precipitation.



**Key Words:** Bat Activity, Weather, Acoustic Monitoring, Conservation

## Acknowledgements

I am grateful to Gabriel Blouin-Demers for his guidance and feedback during every step of this project. I would also like to thank Carine Coté-Germain from the National Capital Commission for her support during the fieldwork portion of the project and Mitra Dadjoo for accompanying me during the fieldwork. Finally, thank you to all my family and friends for their continuing encouragement during this endeavour.

# Table of Contents

## Table of Figures



## List of Tables

## Introduction

Biodiversity declines around the world are currently one of the most pressing environmental issues. Important drivers of these declines include climate change, habitat loss and degradation, and invasive species (Pereira *et al.*, 2012). In 2023, over 44,000 species are threatened by extinction and are on the IUCN Red List of Threatened Species (IUCN, 2023). The increased rate of species extinctions in the last few decades has led scientists to consider the current biodiversity crisis as a mass extinction event (Ceballos *et al.*, 2017). In light of these biodiversity declines, conservation programs are extremely important.

Monitoring endangered species is a necessary part of conservation efforts. Monitoring provides vital information on the effectiveness of such efforts, such as observing trends in populations of threatened species, and in the development of management decisions (Buxton *et al.*, 2022). For monitoring to provide this information, however, the species of interest must be effectively detected. This can be a particular concern for species that are difficult to see or nocturnal (Borkin *et al.*, 2023). Passive acoustic monitoring is a method developed relatively recently, which offers an alternative to capture or visual methods. Acoustic monitoring has several advantages over other methods, notably that it can be used effectively in most weather conditions and at any time of day or night (Marques *et al.*, 2013). This method has been used to monitor a wide range of species including birds, amphibians,  and bats (Hoefer *et al.*, 2023). Passive acoustic monitoring can be more effective for sampling insectivorous bats than capture methods (MacSwiney G *et al.*, 2008).

Bats are one of the most widespread groups of mammals in the world, being found all around the world, except polar regions, and numbering over 1,300 species. Bats play a variety of important ecological roles, such as controlling insect populations which has been estimated to be worth millions of USD in pest control, as well as pollinators and seed dispersers. Bats are also bioindicators since they appear to be sensitive to habitat changes (Jones *et al.*, 2009; Voigt and Kingston, 2018).

Unfortunately, a large proportion of bat species are at risk. Causes for these declines include habitat loss and degradation, climate change, persecution due to superstition, and wind turbine mortality (Voigt and Kingston, 2018; Squires *et al.*, 2021).  In eastern North America, bat declines have been particularly severe due to white-nose syndrome, a disease caused by the fungus *Pseudogymnoascus destructans*. White-nose syndrome has led to over 90% decreases in the populations of bast in the *Myotis* genus and has altered bat communities (O'Keefe *et al.*, 2019; Faure-Lacroix *et al.*, 2020).  Monitoring bats is therefore of the utmost importance.

Bats are greatly affected by variation in weather because of both their capacity for powered flight and their use of echolocation to navigate. Flight is very energetically costly, and inclement weather such as rain can further increase those costs, by increasing the costs of thermoregulation and affecting the aerodynamics of the wings (Voigt *et al.*, 2011a). The small size of most bats and the large uninsulated area of their wings can also lead to thermoregulation challenges, and to increased energetic costs of activity during colder nights (Rummel *et al.*, 2019). The transmission of sound through air can be greatly impacted by the properties such as humidity, temperature, and atmospheric pressure. These factors can impact atmospheric attenuation of sound, which is the absorption of a sound's energy by air molecules. For example, higher atmospheric pressure can decrease sound attenuation, and increased relative humidity increases attenuation (Goerlitz, 2018).

My aim in this project is to confirm whether the activity of bats in Gatineau Park is also affected by meteorological conditions, including precipitation, wind speed, and temperature. Since insects that bats eat change their behavior based on lunar phases (Williams and Singh, 1951), and since it is possible that insectivorous bat species exhibit lunar phobia (Appel, *et al.*, 2017), moon phase and percent illumination will also be taken into consideration.

I hypothesize that given that temperature and wind speed can affect the energy required for flight, and that atmospheric pressure and temperature can affect the atmospheric attenuation of echolocation calls, nightly weather conditions will impact bat activity. Furthermore, I predict that bat activity will decrease as precipitation and wind speed increase, since these variables will increase the energy costs of flight, and since rain will increase the atmospheric attenuation of echolocation calls. I also predict that bat activity will increase as temperature and barometric pressure increase, since increased temperature will reduce metabolic costs and barometric pressure could lower atmospheric attenuation of echolocation. I also predict that bat activity will decrease as the fraction of the moon illuminated increases.

## Methods

### *Study area*

I collected data for this project in Gatineau Park from 13 June to 28 July 2023. I recorded bat activity at seven points throughout the park (Figure 1). I selected sites from a list of sites evaluated for another study in 2018 based on their suitability for bats. I also chose sites which were distributed throughout the park and in different habitats in the hope to record all eight bat species present in the study area. Five out of seven of the sites were in or adjacent to wetlands. The other three sites were located in forest clearings.

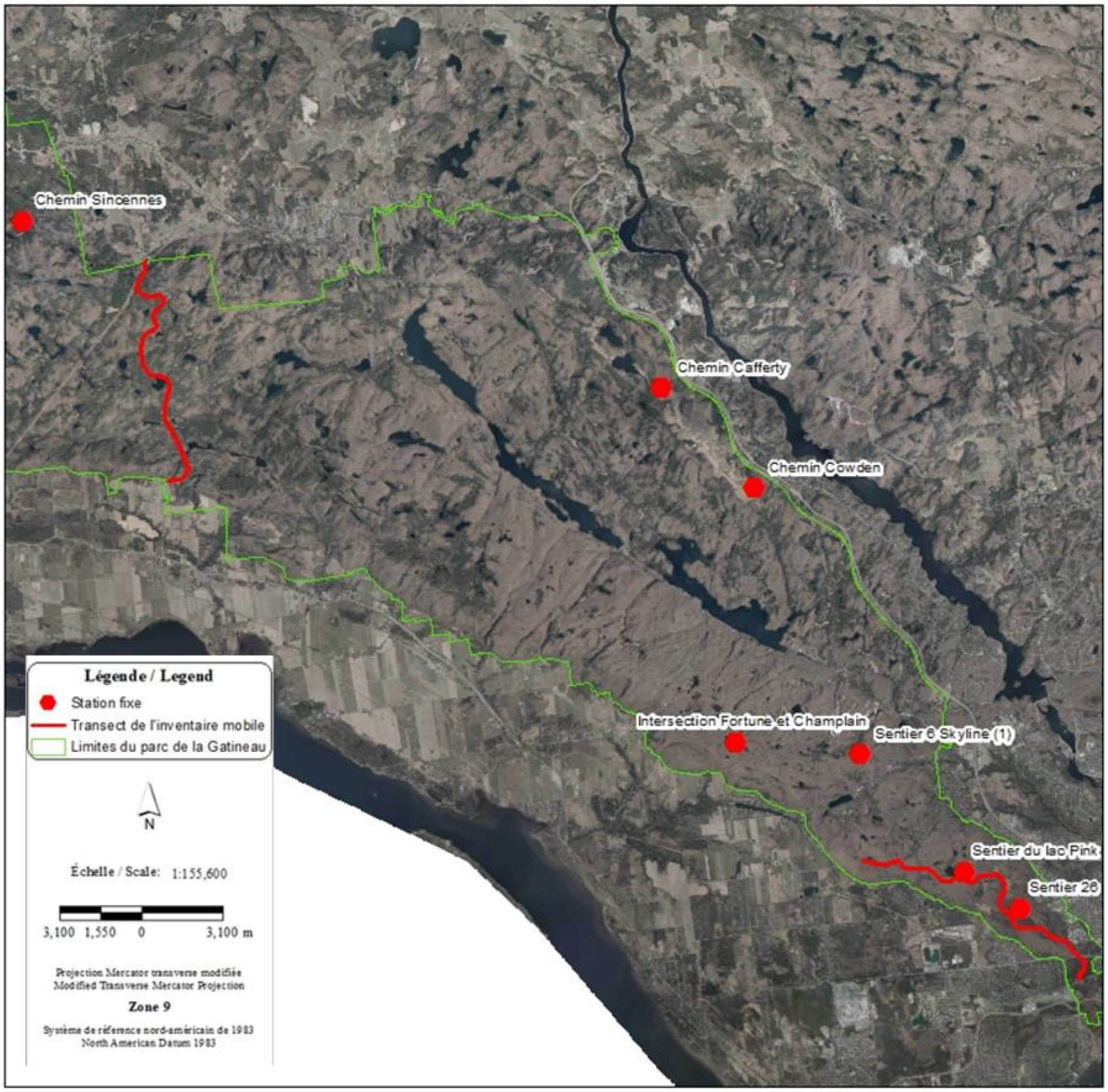


***Figure 1*** *- Map of study Sites with red points representing each site. Seven sites within Gatineau Park were selected as being suitable for use by bats. The bat detector was placed at each site for seven nights.*

## *Bat Activity*

I deployed an SM4Bat FS bat detector from Wildlife Acoustics at each site for seven consecutive days. I used an external U2 ultrasonic microphone for the SM4 and I attached it to a painter's pole which was approximately 2 m long to be raised off the ground and away from objects that could block or reflect bat calls such as leaves. I programmed the SM4 bat to record each night from 30 minutes before sunset until 30 minutes after sunrise.

I analyzed recordings using the Kaleidoscope Pro software from Wildlife acoustics version 5.6.2. This software removed noise and included an automatic identification, which allowed for a preliminary identification of recordings. Since there is a certain amount of error with automatic identification, I manually validated recording identification using the Kaleidoscope viewer. Since there is a high rate of misidentification between the silver-haired bat (*Lasionycteris noctivans*) and the big brown bat (*Eptesicus fuscus*) and between the three *Myotis* species (*M. Lucifugus, M. leibii, M. septentrionalis*) (Personal communication, Francois Fabianek, 2022), I placed these species into two phonic complexes for analysis referred to as the EPNO and MYSP complexes.

I measured bat activity as the number of bat passages during a given night, where one bat passage was the series of two or more echolocation pulses captured by a recording. I counted recordings including two species or complexes as two bat passages. While it is possible that one bat could be responsible for more than one bat passage, measuring passages should still be an acceptable proxy for bat activity. Recordings were identified by Kaleidoscope's auto-identification or during validation as not containing any bat calls were excluded from analysis.

### *Meteorological data*

I downloaded meteorological data for nightly precipitation, temperature, atmospheric pressure and wind speed from the Environment and Climate Change Canada website for the Ottawa CDA RCS weather station. This weather station is approximately 15 km from the study area and was selected as it was the closest weather station with complete hourly data for June and July 2023. I calculated data for the fraction of the moon illuminated in R using the suncalc package (Thieurmel & Elmarhraoui, 2022).

*Statistical analyses*

Statistical analyses were performed in R version 4.2.1 (R Core Team, 2022). A correlation matrix was used to ensure that there was no collinearity between predictor variables. The Variance Inflation Factors were also calculated to test for multicollinearity. Univariate analyses were performed to rule out variables which had a p-value greater than 0.25 because of the relatively small sample size. A multiple regression was performed with total bat activity as the response variable, as well as separately with the EPNO and the MYSP complex activity and with hoary bat (*Lasiurus cinereus*) activity. The total bat activity model included wind speed, mean temperature, and atmospheric pressure. The model for the EPNO complex included the predictors wind speed and atmospheric pressure. The MYSP complex model included nightly precipitation, mean temperature, atmospheric pressure, and fraction of the moon illuminated as predictor variables. The final hoary bat model was constructed using the predictor variables, mean temperature, and atmospheric pressure. A natural logarithmic transformation was applied to the response variable in order to meet the assumption of normality. A base 10 logarithmic transformation and a square root transformation were also attempted and achieved similar results. The Performance package in R (Lüdecke *et al*., 2021) was used to check model assumptions.

# Results

In total, 10,239 bat passes were recorded during the 50 nights of recording. Of these, 7,140 were from the big brown bat/silver-haired bat complex, 2,151 were from hoary bats, and 290 were from *Myotis* bats. Only one night occurred without any bats being recorded. All predictor variables had a variance inflation factor close to 1, indicating that there were no issues with multicollinearity.

Barometric pressure was a significant predictor for all models except the EPNO model. *Myotis* bats ($t_{45}$ = 2.087; p = 0.0426), hoary bat ($t_{47}$ = 2.125; p = 0.0389) and bats ($t_{46}$ = 2.170;p = 0.0352; Figure 2), all species considered together, were more active on nights with higher barometric pressure. Bats of all species considered together ($t_{46}$ = 2.381; p = 0.0215) and bats in the EPNO complex ($t_{47}$ = 2.753; p = 0.0084; Figure 3) were more active on windier nights.

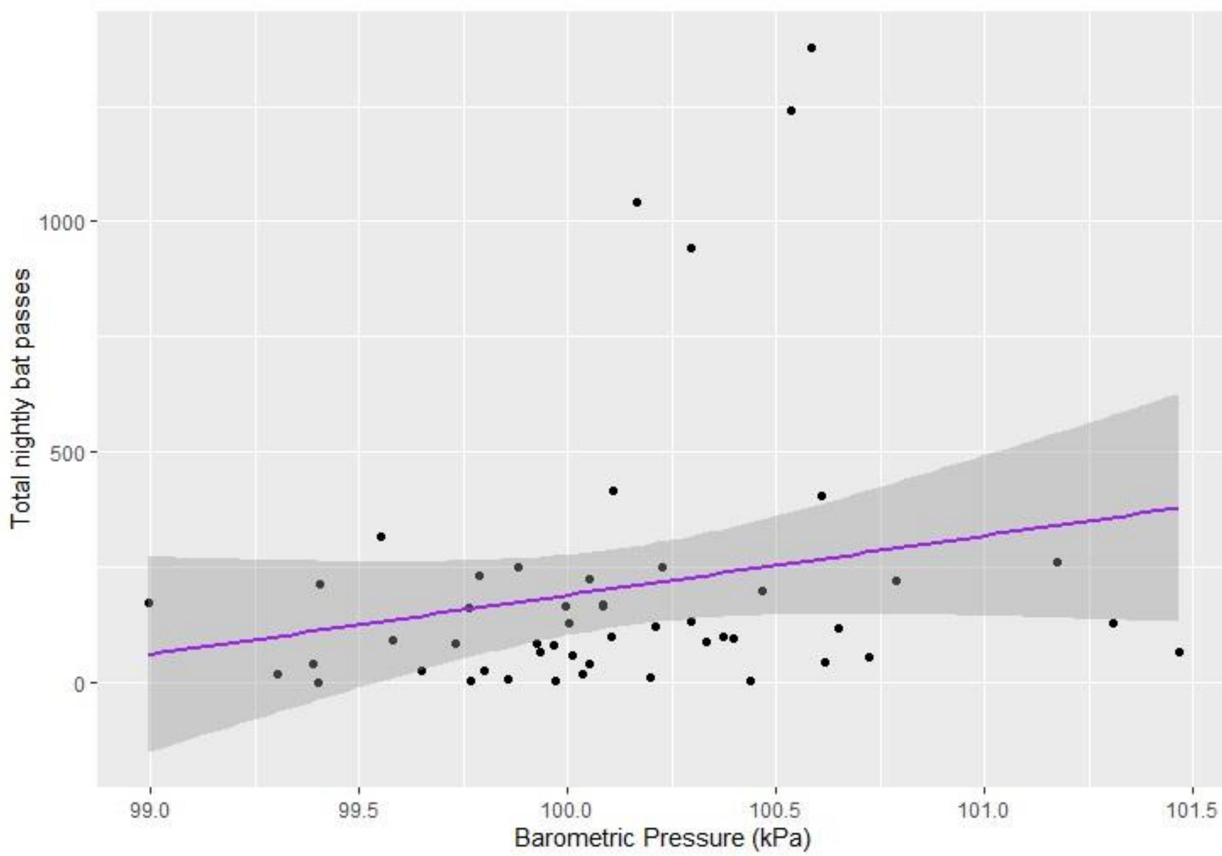


***Figure 2.Total nightly bat activity in relation to barometric pressure.*** *Most bat detections occurred on nights with an average nightly barometric pressure greater than 99.5 kPa. The nights with the highest amounts of bat passes detected had a barometric pressure greater than 100 kPa.*

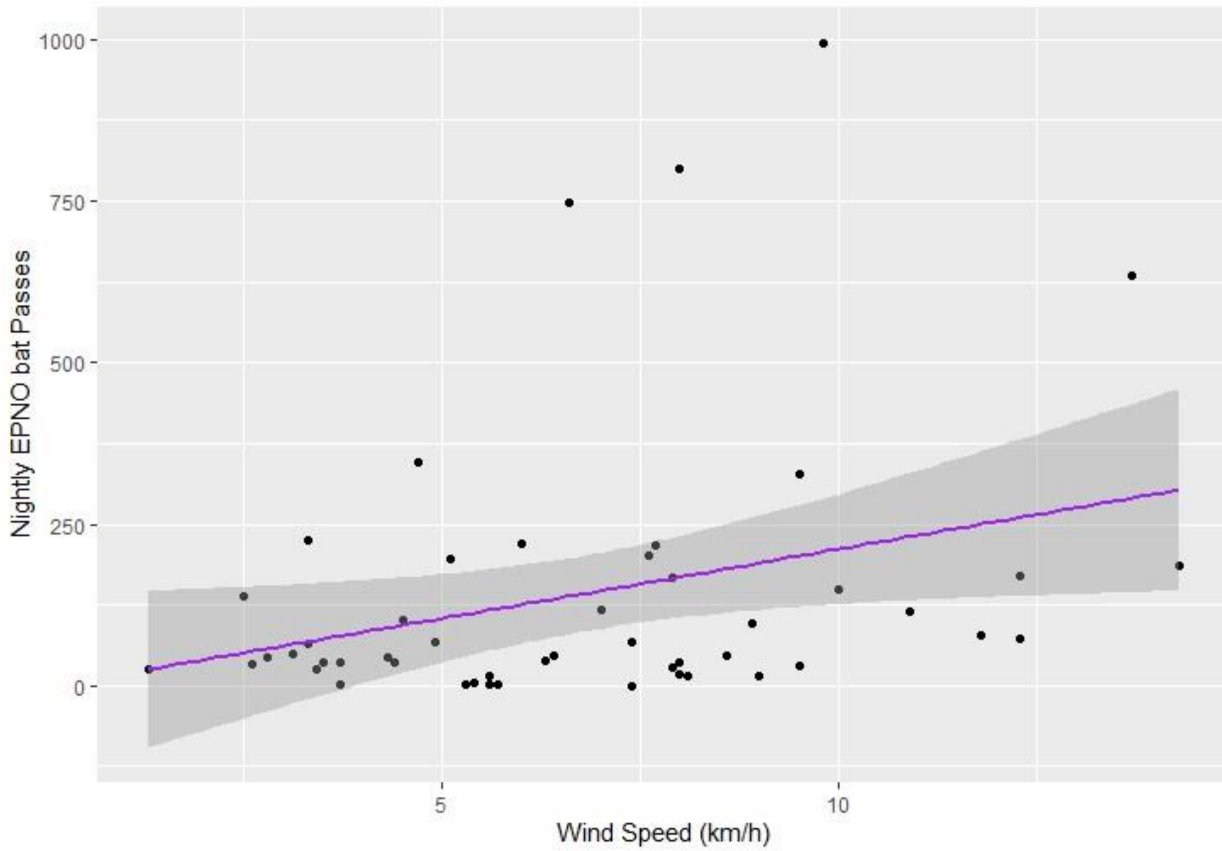


***Figure 3. Nightly activity 4of the big brown bat/silver-haired bat complex in relation to wind speed. Nights with the most detections had an average wind speed greater than 5km/hr.***

Precipitation was only a significant predictor in the *Myotis* model. *Myotis* bats were far less active on nights without rain ($t_{45}$ = -2.084; p = 0.0429), with 95% of *Myotis* passes recorded on nights without precipitation.

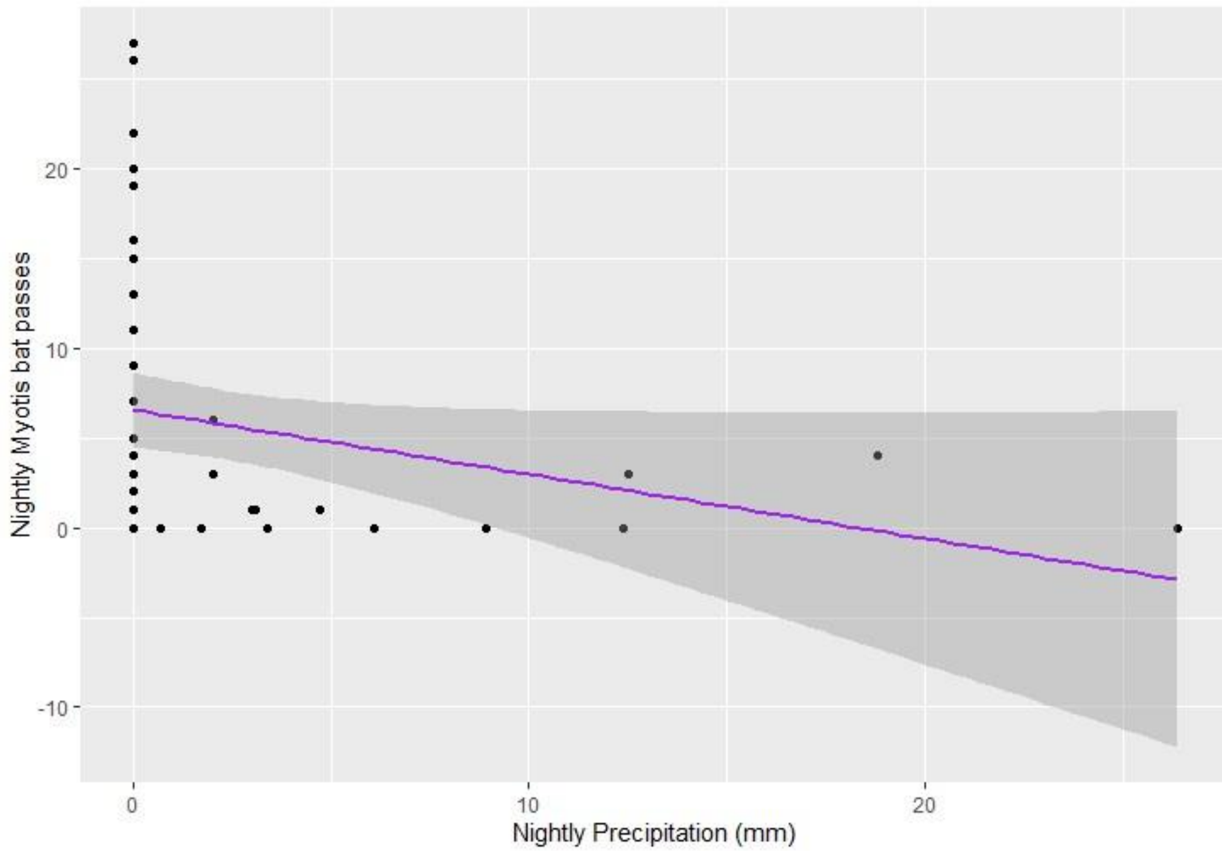


***Figure 4. Nightly Myotis activity in relation to nightly precipitation.*** *Most Myotis detections occurred on nights without precipitation and no detections occurred when precipitation exceeded 20 mm.*

The hoary bat model was the only model in which temperature was a significant predictor. For this species, bats were more active on warmer nights ($t_{47} = 3.661$; $p = 0.0006$; Figure 5).

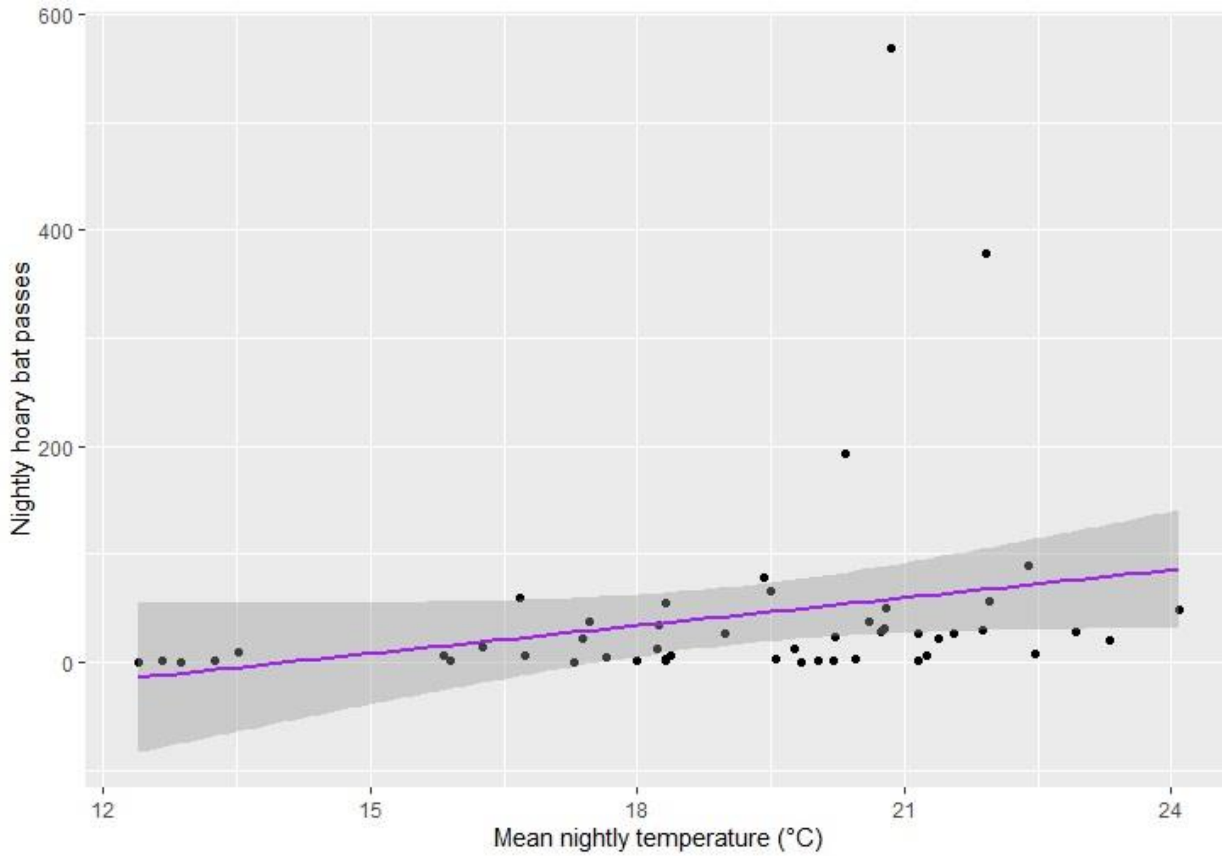


***Figure 5. Hoary bat activity in relation to nightly temperature.*** *Almost all detections were made on nights with a mean nightly temperature greater than 15 °C. Nights with the most detections had mean nightly temperatures greater than 18 °C.*

## Discussion

As expected, nightly weather conditions did affect bat activity. These results suggest that bat monitoring should be performed on warm nights with higher barometric pressure, a light wind, and no precipitation.

The relationship between bat activity and barometric pressure is still unclear, with certain studies reporting a positive relationship, as was seen here (Berková and Zukal, 2010; Bender and Hartman, 2015), and others reporting a negative relationship (Baerwald and Barclay, 2011; Squires *et al.*, 2021). It has been suggested that increased barometric pressure may decrease flight costs, due to the fact that increased pressure may increase the lift and thrust forces during flight. However, this relationship is not well understood (Bender and Hartman, 2015). Another possibility is that, since atmospheric pressure is inversely related to temperature and humidity, there is less attenuation of echolocation calls on nights with higher pressure, since increased humidity and temperature increase atmospheric attenuation of sound (Goerlitz, 2018).

Contrary to predictions, increased wind speed led to increased total bat activity and EPNO activity. These results also disagree with those of previous studies which found that bat activity decreases with increased wind speed (Squires *et al.*, 2021; Ellerbrok *et al.*, 2024). However, the maximum windspeed recorded during the study period was 14.3 km/h, and it has been noted that bat activity only decreases strongly once wind speeds reach approximately 20 km/h (Ellerbrok *et al.*, 2024).  Therefore, it is possible that the wind speeds during the recording period for this project were not high enough to observe this negative relationship. All study sites were located in forest clearings or at forest edged, which could have acted as windbreaks. Furthermore insect activity is greater near windbreaks (Lewis, 1970). It is possible that, if the sites were indeed located along windbreaks, bat activity was greater on the windier nights to take advantage of both those sheltered sites and the increased insect abundance.

Precipitation only had a significant impact on *Myotis* activity, which decreased on night with precipitation. This is consistent with previous studies which have generally found that fewer bats are detected on nights with precipitation (Erickson and West, 2002; Squires *et al.*, 2021). It is interesting that only *Myotis* bats were significantly affected since these studies have generally observed decreased in general bat activity. It is also surprising that the other groups were not affected given that rain negatively impacts thermoregulation and increases the costs of flight (Voigt *et al.*, 2011b). It is possible that *Myotis* bats are more impacted by precipitation than other species, due to their smaller size and due to the high frequencies, which they use for echolocation. Higher frequency calls experience greater attenuation in humid conditions (Goerlitz, 2018). This could indicate that *Myotis* bats are less active due to less effective echolocation. Another possibility is that *Myotis* bats adjust their echolocation calls in humid conditions, as has been observed in other bats, and that those calls have subsequently been misidentified (Snell-Rood, 2012).

As predicted, warmer nightly temperatures led to increased detections. However, the effect was only significant for the hoary bat. This result is generally consistent with previous studies (cite), though as was the case with precipitation most studies generally found effects across most species. Furthermore, Baerwald and Barclay (2011), found that hoary bats were less affected by temperature than other species, notably the silver-haired bat which in this study was not significantly affected by temperature. The hoary bat, unlike the little brown myotis or the big brown bat, does not roost in colonies over the summer, and instead roosts alone. Hoary bats may face more thermoregulatory costs during the day, and therefore may require higher temperatures at night in order to lower energetic costs when foraging (Klug and Barclay, 2013).

Moon illumination did not significantly affect activity for any of the groups. While it has been shown to have an impact on bat activity for some species (Appel *et al.*, 2017), it is possible that merely using the fraction illuminated as the variable without including time of moonrise and moonset did not properly capture the effect. It has also been hypothesized that bats change their habitat use during nights with greater moon illumination (Erickson & West, 2002), and as the sites used in this project were mostly in forest clearings, which would have provided shadows, bats may have continued using this habitat even on nights with more moonlight.

The results from this project did not always align with results from previous studies. This is not altogether surprising as there is little consensus in the literature particularly regarding the effect of atmospheric pressure. Reasons for these differences can include the shorter study duration, as well as differences in analysis, such as using a nightly scale as opposed to an hourly scale or different measures of bat activity. For example, some studies use intervals of time with detections, such as ten minutes intervals in which bats are detected or not, as the unit of measurement, rather than bat passages (Brabant *et al.*, 2021). Bat activity is not constant throughout the night, instead occurring in waves (Squires *et al.*, 2021). If inclement weather occurs before or after the peak of bat activity, it will have a far smaller impact than is assumed at a nightly scale.

It is also possible that trends in this study were not as clear as they might have been since weather data were obtained from a weather station approximately 15 km away from the study area. It is therefore plausible that the data recorded by the weather station were not identical to the weather which actually occurred at each site. A future study should preferably record meteorological data from each site.

Only as small portion of variation was explained by the meteorological variables in each model. This indicates that there are other factors which impact nightly bat activity. One of these could be differences in habitat at each site. Bat species have been shown to have different habitat preferences. For example, the *Myotis* species prefer closed habitats with denser forests, while hoary bats prefer more open habitats (Jung *et al.*, 1999). Given that only one recorder was used for this project, all recordings from a given night were recorded at a single site. Therefore, species habitat preferences have not been considered and may explain some of the remaining variation in bat activity.

These results indicate that not only is bat activity affected by weather, but the effects can also vary by species or complex. It could therefore be difficult to extrapolate them to other regions or to other species. Future analyses should aim to cover a longer period of time, as well as consider the effects of habitat.

## References

APPEL, G., A. LÓPEZ-BAUCELLS, W. E. MAGNUSSON, and P. E. D. BOBROWIEC. 2017. Aerial insectivorous bat activity in relation to moonlight intensity. Mammalian Biology. 85: 37–46.

BAERWALD, E. F., and R. M. R. BARCLAY. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. The Journal of Wildlife Management. 75: 1103–1114.

BENDER, M. J., and G. D. HARTMAN. 2015. Bat Activity Increases with Barometric Pressure and Temperature during Autumn in Central Georgia. Https://Doi-Org.Proxy.Bib.Uottawa.ca/10.1656/058.014.0203. 14: 231–242.

BERKOVÁ, H., and J. ZUKAL. 2010. Cave visitation by temperate zone bats: effects of climatic factors. Journal of Zoology. 280: 387–395.

BORKIN, K., J. GIEJSZTOWT, J. MCQUEEN-WATTON, and D. SMITH. 2023. Influence of weather on long-tailed bat detection in a North Island exotic forest. New Zealand Journal of Ecology.

BRABANT, R., Y. LAURENT, B. J. POERINK, and S. DEGRAER. 2021. The relation between migratory activity of pipistrellus bats at sea and weather conditions offers possibilities to reduce offshore wind farm effects. Animals. 11: 3457.

BUXTON, R. T., S. HAMIT, J. J. W. GEAUVREAU, S. DAVIS, P. A. SMITH, and J. R. BENNETT. 2022. Balancing research, monitoring, and action to recover Canada's species at risk. Environmental Science & Policy. 132: 198–205.

CEBALLOS, G., P. R. EHRLICH, and R. DIRZO. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proceedings of the National Academy of Sciences of the United States of America. 114: E6089–E6096.

ELLERBROK, J. S., N. FARWIG, F. PETER, and C. C. VOIGT. 2024. Forest bat activity declines with increasing wind speed in proximity of operating wind turbines. Global Ecology and Conservation. 49: e02782.

ERICKSON, J. L., and S. D. WEST. 2002. The influence of regional climate and nightly weather conditions on activity patterns of insectivorous bats. ACTA CHIROPTEROLOGICA. 4: 17–24.

FAURE-LACROIX, J., A. DESROCHERS, L. IMBEAU, and A. SIMARD. 2020. Long-term changes in bat activity in Quebec suggest climatic responses and summer niche partitioning associated with white-nose syndrome. Ecology and Evolution. 10: 5226–5239.

GOERLITZ, H. R. 2018. Weather conditions determine attenuation and speed of sound: Environmental limitations for monitoring and analyzing bat echolocation. Ecology and Evolution. 8: 5090–5100.

HOEFER, S., D. T. MCKNIGHT, S. ALLEN-ANKINS, E. J. NORDBERG, and L. SCHWARZKOPF. 2023. Passive acoustic monitoring in terrestrial vertebrates: a review. Bioacoustics. 32: 506–531.

JONES, G., D. S. JACOBS, T. H. KUNZ, M. R. WILIG, and P. A. RACEY. 2009. Carpe noctem: The importance of bats as bioindicators. Endangered Species Research. 8: 93–115.

JUNG, T. S., I. D. THOMPSON, R. D. TITMAN, and A. P. APPLEJOHN. 1999. Habitat Selection by Forest Bats in Relation to Mixed-Wood Stand Types and Structure in Central Ontario. The Journal of Wildlife Management. 63: 1306.

KLUG, B. J., and R. M. R. BARCLAY. 2013. Thermoregulation during reproduction in the solitary, foliage-roosting hoary bat (Lasiurus cinereus). Journal of Mammalogy. 94: 477–487.

LEWIS, T. 1970. Patterns of distribution of insects near a windbreak of tall trees. Annals of Applied Biology. 65: 213–220.

MACSWINEY G, M. C., F. M. CLARKE, and P. A. RACEY. 2008. What you see is not what you get: the role of ultrasonic detectors in increasing inventory completeness in Neotropical bat assemblages. Journal of Applied Ecology. 45: 1364–1371.

MARQUES, T. A., L. THOMAS, S. W. MARTIN, D. K. MELLINGER, J. A. WARD, D. J. MORETTI, D. HARRIS, and P. L. TYACK. 2013. Estimating animal population density using passive acoustics. Biological Reviews. 88: 287–309.

O'KEEFE, J. M., J. L. PETTIT, S. C. LOEB, and W. H. STIVER. 2019. White-nose syndrome dramatically altered the summer bat assemblage in a temperate Southern Appalachian forest. Mammalian Biology. 98: 146–154.

PEREIRA, H. M., L. M. NAVARRO, and I. S. MARTINS. 2012. Global biodiversity change: The Bad, the good, and the unknown. Annual Review of Environment and Resources. 37: 25–50.

RUMMEL, A. D., S. M. SWARTZ, and R. L. MARSH. 2019. Warm bodies, cool wings: regional heterothermy in flying bats. Biology Letters. 15.

SNELL-ROOD, E. C. 2012. The effect of climate on acoustic signals: Does atmospheric sound absorption matter for bird song and bat echolocation? The Journal of the Acoustical Society of America. 131: 1650–1658.

SQUIRES, K. A., B. G. THURBER, J. R. ZIMMERLING, and C. M. FRANCIS. 2021. Timing and weather offer alternative mitigation strategies for lowering bat mortality at wind energy facilities in Ontario. Animals. 11: 3503.

VOIGT, C. C., and T. KINGSTON. 2018. Bats in the Anthropocene: Conservation of Bats in a Changing World. Bats in the Anthropocene: Conservation of Bats in a Changing World. 606.

VOIGT, C. C., K. SCHNEEBERGER, S. L. VOIGT-HEUCKE, and D. LEWANZIK. 2011a. Rain increases the energy cost of bat flight. Biology Letters. 7: 793–795.

VOIGT, C. C., K. SCHNEEBERGER, S. L. VOIGT-HEUCKE, and D. LEWANZIK. 2011b. Rain increases the energy cost of bat flight. Biology Letters. 7: 793–795.

WILLIAMS, C. B., and B. P. SINGH. 1951. Effect of Moonlight on Insect Activity. Nature 1951 167:4256. 167: 853–853.

# Appendix 1. Summary tables of linear multiple regression models

**Table 1.** Linear multiple regression model for nightly total bat activity in relation to weather conditions over 50 nights in Gatineau Park. A star indicates p-values less than 0.05. The model had an adjusted $r^2 = 0.153$.

| Variable | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|
| Wind speed (km/h) | 0.16182 | 0.06798 | 2.381 | 0.0215 * |
| Mean Temperature (°C) | 0.10176 | 0.07292 | 1.396 | 0.1695 |
| Atmospheric pressure (kPa) | 0.93542 | 0.43102 | 2.170 | 0.0352 * |

**Table 2.** Linear multiple regression model for nightly activity of bats in the big brown bat/silver-haired bat complex in relation to weather conditions over 50 nights in Gatineau Park. Two stars indicates p-values less than 0.01. The model had an adjusted $r^2 = 0.132$.

| Variable | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|
| Wind speed (km/h) | 0.18950 | 0.06883 | 2.753 | 0.00836 ** |
| Atmospheric pressure (kPa) | 0.85211 | 0.42663 | 1.997 | 0.05160 |

**Table 3.** Linear multiple regression model for nightly Myotis activity in relation to weather conditions over 50 nights in Gatineau Park. A star indicates p-values less than 0.05. The model had an adjusted $r^2 = 0.212$.

| Variable | Estimate | Std. Error | t-value | p-value |
|---|---|---|---|---|
| Nightly Precipitation (mm) | -0.05724 | 0.02747 | -2.084 | 0.0429 * |
| Mean Temperature (°C) | 0.06696 | 0.04883 | 1.371 | 0.1771 |
| Atmospheric pressure (kPa) | 0.60117 | 0.28808 | 2.087 | 0.0426 * |
| Fraction of the moon illuminated | 0.15726 | 0.10475 | 1.501 | 0.1402 |

**Table 4.** Linear multiple regression model for nightly hoary bat (Lasiurus cinereus)activity in relation to weather conditions over 50 nights in Gatineau Park. A star indicates p-values less than 0.05, and three star indicate a p-value less than 0.001. The model had an adjusted $r^2 = 0.292$.

| **Variable** | **Estimate** | **Std. Error** | **t-value** | **p-value** |
|---|---|---|---|---|
| Mean Temperature (°C) | 0.24625 | 0.06727 | 3.661 | 0.000636 *** |
| Atmospheric pressure (kPa) | 0.81979 | 0.38587 | 2.125 | 0.038916 * |

# Appendix 2

**Table 5.** Location and description of the seven recording sites located in Gatineau Park.

| Site | Coordinates (MTM zone 9, nad83) | Habitat Description |
|---|---|---|
| Chemin Sincennes | X : 332093 Y : 5055740 | Wetland adjacent to the road leading to the Lac la Pêche beach. |
| Chemin Cafferty | X : 350523 Y : 5050859 | Small Wetland adjacent to trail 72, located in the Meech Creek Valley. Approximately 1km away from highway 5. |
| Chemin Cowden | X : 353191 Y : 5047930 | Forest’s edge adjacent to trail 45 in the Meech Creek Valley. In proximity of Meech Creek. |
| Sentier 6 (Skyline) | X : 356219 Y : 5040149 | Clearing adjacent to trail 6. |
| Coin Fortune Champlain | X : 352659 Y : 5040507 | Wetland near the intersection of the Fortune and Champlain Parkways. Approximately 100m from the parkway. |
| Lac Pink | X : 359217 Y : 5036705 | Wetland in proximity to Pink Lake |
| Sentier 26 | X : 360832 Y : 5035630 | Wetland adjacent to trail 26, in the Folly bog valued habitat |