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The Relationship of Bats (order Chiroptera) and Invertebrate Abundance with  
Habitat Availability along the Northern outskirts of Norwich  
with focus on the Barbastelle Bat (*Barbastella barbastellus*).

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By

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August 2021

In collaboration with:



Wild Wings Ecology and the University of East Anglia.

This is a dissertation thesis submitted to the University of East Anglia in partial fulfilment of the requirements for the degree of Master of Science: Applied Ecology and Conservation

"Vast areas of old forest have been cut, or chained down with bulldozers, to make way for cattle ranching and urban sprawl. People have planted orchards, established urban parks, landscaped their yards with blossoming trees, and created other unintended enticements amid the cities and suburbs. So, bats have decided that, as their native habitat is disappearing, as climate is becoming more variable, and their food source is becoming less diverse, it's easier to live in an urban area."

**– David Quammen, Spillover: Animal Infections and the Next Human Pandemic**

"Between me and the moonlight flitted a great bat, coming and going in great, whirling circles. Once or twice it came quite close, but was, I suppose, frightened at seeing me, and flitted away."

**– Bram Stoker, Dracula**

## Table of Contents

Abstract.....	4
Introduction .....	6
Norwich and Norfolk area.....	10
Aims and Objectives.....	11
Methods.....	12
Study Sites and Acoustic Data.....	12
Invertebrate Abundance and Biodiversity .....	13
Moth Abundance .....	14
Habitat .....	14
Results.....	15
Total Bat Activity .....	15
Barbastelle Bat Activity .....	16
Moth Abundance .....	17
Insect Abundance and Biodiversity.....	19
Tests Between Variables .....	21
Habitat .....	24
Discussion: .....	27
Limitations and Improvements .....	29
Conclusions .....	30
Future Conservation Recommendations: .....	32
Acknowledgments.....	34
References .....	35
Appendices.....	39
Appendix 1. ....	39

## Abstract

The aim of this study was to collate and provide better understanding of bat activity (with focus on the Barbastelle bat - *Barbastella barbastellus*) within likely foraging sites of the spanned areas of Ringland and Weston Longville to the full extent of the Broadland Northway, based along the north outskirts of the City of Norwich, Norfolk, UK. Insect abundance and biodiversity at these sites may also provide an indicator as to habitat richness; and Moth abundance, an insight into the food richness these bats are provided with. All these factors were utilised in producing a map of effective conservation areas, highlighting locations of already good habitat which should be preserved, as well as areas that need to be improved upon.

This study analysed a total of 71 sites over 35 1km<sup>2</sup> grids, across the overall study area, which is described above. These sites were surveyed for Acoustic Bat Activity, Invertebrate Abundance, Invertebrate Biodiversity, and Moth Abundance. Recorded acoustic activity from the Barbastelle Bat (*B. barbastellus*) has been compared to that of the conglomerate bat activity - which species included (but not limited to) Noctule (*Nyctalus noctule*), common pipistrelle (*Pipistrellus pipistrellus*) and the soprano pipistrelle (*Pipistrellus pygmaeus*).

The Barbastelle bat Activity was shown to be significantly greater at the Ringland and Weston Longville sites than at the Established Gantries ( $U_{33,18} = 192.0$ ,  $P = 0.037$ ); the Green Bridge ( $U_{33,6} = 36.0$ ,  $P = 0.013$ ); and randomly selected sites ( $U_{33,6} = 30.0$ ,  $P = 0.007$ ). This contrasts with the sum of Total bat activity, which was found to be significantly greater at the Green Bridge mitigation site than the Established Gantries ( $U_{6,18} = 18.0$ ,  $P = 0.016$ ); the Ringland and Weston Longville sites ( $U_{36,6} = 12.0$ ,  $P < 0.001$ ); and randomly selected sites ( $U_{6,6} = 0.0$ ,  $P = 0.003$ ).

In juxtaposition to the literature - which states that moth and invertebrate abundance is a good predictor for habitat richness and bat foraging activity, with one being a direct result of the other (Hunter. 2002; Farhig and Jonsen. 1998; Wickramasinghe, *et al.* 2004), Moth Abundance was found to be significantly greater at the Established Gantries compared to Ringland and Weston Longville Sites ( $U_{18,26} = 16.5$ ,  $P < 0.001$ ), as well as random sites ( $U_{18,6} = 10.0$ ,  $P = 0.003$ ). Similarly, Invertebrate abundance was found to be significantly greater at

the Established Gantries than at the Green Bridge ( $U_{18,6} = 22.5$ ,  $P = 0.033$ ); Ringland and Weston Longville Sites ( $U_{18,36} = 21.08$ ,  $P < 0.001$ ); and at the random sites ( $U_{18,6} = 12.0$ ,  $P = 0.005$ ). In addition, invertebrate biodiversity was found to be significantly greater at the Established Gantries than at the Green Bridge ( $U_{18,6} = 13.6$ ,  $P = 0.005$ ); and Ringland and Weston Longville sites ( $U_{18,36} = 91.5$ ,  $P < 0.001$ ). Potential causes for this discrepancy are addressed in the discussion and is believed to be explainable through factors untested here, and not a reliable representation to question the literature that has been previously alluded to.

No significant correlation was found between either Total Bat activity or *B. barbastellus* activity with Moth Abundance, Invertebrate Abundance, or Invertebrate Biodiversity; however, Moth Abundance was found to be correlated with Invertebrate Biodiversity ( $p_{61} = 0.571$ ,  $P < 0.001$ ).

Main habitat surroundings were tested (Woodland, Water Environments, and Urban Environments) for their impact on Total Bat Activity and Barbastelle Activity. Urban Environments showed no significant contribution, however Multiple regression Analysis indicated Woodland, and Water Environments explained 17.3% of the variance and that the model was a significant predictor of Barbastelle presence,  $F(2, 32) = 3.355$ ,  $P = 0.048$ . While Woodland areas contributed significantly to the model ( $B = 5.32 \times 10^{-5}$ ,  $P = 0.26$ ), Water habitats did not ( $B = 7.97 \times 10^{-5}$ ,  $P > 0.05$ ). Total Bat activity was too widely distributed to be predictable with the tested models.

The model map produced in ArcGIS will assist in the future conservation actions that have been recommended at the end of this paper.

## Introduction

There are believed to be 18 species of bats (order of Chiroptera) native to the UK, a number risen from the 16 previously thought, and each with their own distinguishing features (Hill and Greenaway. 2008). The most frequently abundant species found is the common pipistrelle (*Pipistrellus pipistrellus*) however rarer species are also witnessed on occasion such as the Bechstein's bat (*Myotis bechsteinii*) or the Barbastelle (*Barbastella barbastellus*) (Bellamy *et al.* 2013; Hill and Greenaway. 2008).

The rarity of the *B. barbastellus* can be attributed to multiple factors, as while many Chiroptera species have a high longevity (recently, the Bat Word Sanctuary commemorated the loss of Statler, a 34 year old fruit bat), bats also have a low level of fecundity – averaging with one off-spring a year, meaning that if conditions are adverse, populations can be met with rapid declines in number, with slow recovery rates if recovery is possible at all (Jan, *et al.* 2019).

The habitat availability of *B. barbastellus* varies widely across the UK, however their existence is believed to be concentrated within the south and central areas of England and Wales (Hill and Greenaway. 2014). Rather than developing roosts independently, many bats rely on pre-existing structures to protect their colonies, and throughout the time rearing their young, bats have been observed residing within building crevices and cracks in trees, and once grown, these nursery colonies may disperse, reconvening in late July (Hillen, *et al.* 2011; Willis, *et al.* 2003). In the meantime, *B. barbastellus* survive the winters cold via hibernating in caves, tunnels, and cellars, as well as between roof timbers, and hollow tree trunks, with Ancient Woodland believed to be among their habitats year-round (Kunz 1982; Altringham 1996; Kunz and Lumsden 2003). However, few breeding sites of the Barbastelle are known, so to preserve this IUCN “Nearly Threatened” red-listed species, it is important that these known sites of communal summer roosting and winter hibernation are well maintained (Ancillotto, *et al.* 2015). It is believed that the loss of deciduous woodland in the UK may be a great influence on the species rarity (Grindal and Bringham. 1999), along with global warming's constant impacts on habitats across the globe (Scheel, *et al.* 1996; LaVal 2004; Nagy, *et al.* 2017; Rebelo, *et al.* 2010), and the use of artificial fertilizer and pesticides that may cause indirect

poisoning through contaminated water and insects, and disrupt insect abundances for foraging (Korine, *et al.* 2016; Wickramasinghe, *et al.* 2004).

Foraging habits of many Chiroptera (the *B. barbastellus* amongst them), start by emerging early in the summer dusk sticking to the long shadows cast by the trees, these Barbastelles begin to forage, waiting till the light levels of the open areas match those of the canopies (Sierro and Arlettaz. 1997). Once the light levels are low enough, *B. barbastellus* are known to forage over a relatively extensive area (40 km), and drink from ponds or lakes by swooping down in flight (Sierro and Arlettaz. 1997).

The available data on *B. barbastellus* suggests they possess a singular method for prey detection. Firstly, they possess an unusual sonogram, with their calls displayed as a convex shape comparable to an inverted J, first suspected by Jones 1993 (Denzinger *et al.* 2007; Jones. 1993). Secondly, study of ultrasounds made during field work suggest two types of calls are made by *B. barbastellus*, at ca. 32 kHz and 42 kHz (Parsons and Jones. 2000). The large part of prey for the *B. barbastellus* consist of moths that possess auditory organs - commonly believed to be a coevolutionary trait to avoid predation by these bats (Roeder and Treat. 1957; Griffin. 1958; Fullard. 1988; Windmill, *et al.* 2006), and there are three main foraging tactics that bats follow for their capture (Neuweiler. 1984).

The primary method is Aerial Hawking, where bats produce a low intensity call that is undetectable by their prey (Norberg. 1986). The *B. barbastellus* are especially adept to this style of hunting, producing an aerial hawking call that have amplitudes 10 to 100 times lower than other aerial hawking bats, providing a stealthy manner to exploit moth's echoes before their own detection (Sierro and Arlettaz. 1997). This leads onto the second method, passive acoustical cues, where bats rely on the sounds generated by their target prey as opposed to relying solely on their echolocation – however the predation of moths by bats have also been considered responsible for the evolution of secondary defences used by moths such as ultrasonic clicks, found to directly affect the success of the bats foraging (Jacobs and Bastian. 2016). The third method is called the allotonic frequencies hypothesis, where bats use the frequencies either above or below the predated moth's auditory sensitivity (Schoeman and Jacobs. 2003).

This foraging along their northern territories mostly consists of small moths (Lepidoptera) comprising of 97.5% of their food source, however alternative species consumed include other invertebrates such as small flies and beetles (Carr *et al.* 2020). The study performed by Carr *et al.* had also noted that 97% of the prey items *B. barbastellus* consume have larval stages that are dependent on plants found within the *B. barbastellus* foraging areas, and that worryingly, almost half of the moth species they had identified had been experiencing their own population declines (Carr *et al.* 2020). Within the Swiss Alps and Pamir Mountains, the foraging of *B. barbastellus* is also primarily focused on Lepidoptera (~99%), with a considerable quantity of tympanate moths (84%) sampled at the foraging sites (Sierro and Arlettaz. 1997). The considerably niche diet of the *B. barbastellus* in these regions, if replicated in other areas, could also account for the species' rarity.

Bats are known for maintaining use of the same foraging sites, both nightly and over longer periods (Zeale *et al.* 2012; Entwistle *et al.* 2001; Entwistle *et al.* 1996), however changes in agricultural practices result in a decrease in insect abundance once entering adult stages of maturity, reducing the bats food source availability, worsened by habitat fragmentation of all species (Entwistle *et al.* 2001).

Development of urban areas produce several risks alone for *B. barbastellus*, with increased light pollution effecting both bat and moth abundance, road development resulting in a loss of habitat, and interrupting linear flights - the 'barrier effect' (Fensom and Mathews. 2016). If some colonies refuse to cross these road developments, then with these smaller habitats the potential of isolation from other members of the species may develop, causing a build-up of genetic load within passing generations leading to the populations collapse through genetic diseases and overall loss of fitness (Kirkpatrick and James. 2000; Barclay, *et al.* 2003). Even if they do cross, *B. barbastellus* fly at heights of 0-4 meters above ground level, and travel at slow speeds (< 20 km an hour), and as such can become easy roadkill if either directly hit or get caught in a passing vehicle's slipstream (Altringham and Kerth. 2016). The development of large roads come with the side effects of the chemical, light, and noise pollutions that all accompany the cars using these roads – and the presence of which interferes with the isolation and predation of foraged species (Altringham and Kerth. 2016; Zurcher, *et al.* 2010).



While benefits of road developments on species such as *B. barbastellus* are few, road bridges over rivers can provide good roosting spots (Keeley and Tuttle. 1999). In addition, implementation of effective mitigation strategies can make the environment attractive to bat species but may provide a greater risk of collisions with traffic (Altringham and Kerth. 2016; Rydell and Baagøe. 1996). Similarly, lights may attract greater abundances of moths, leading to exploitation of open-air foraging for bats, however this is at a greater mortality risk as described above (Stone, *et al.* 2015; Altringham and Kerth. 2016; Zurcher, *et al.* 2010).

Bats are protected nationwide under the Conservation of Habitats and Species Regulations 2017 and the Wildlife and Countryside Act 1981 (with considered amendments made to both). As such, certain mitigation strategies are commonly put in use that theoretically assist in the bats continued use of the areas, such as gantries and green bridges. In practicality however, data collected over nine years have established bat gantries *in situ* do not help bats to cross the road safely (Berthinussen and Altringham. 2012), and green bridge overpasses can at times be found ineffective if poor nutrient levels are available for plants, and poorly managed by those that set them up (Von Haareen and Reich. 2006).

These mitigation strategies are not the only ones that can be developed, however. Biodiversity offsetting enforces companies to compensate for habitat damage by developing and managing other habitats for the same disrupted species elsewhere nearby, encouraging the identification of land nearby that contains most biodiversity for least money to conserve (Needham, *et al.* 2019). This can mean any number of things including restoring a pre-existing habitat by planting trees or removing threats to a species by giving it a protected status (Maron, *et al.* 2015). Unfortunately, most schemes have a 'no net loss' policy that can often be interpreted as maintaining the current rate of decline, which does nothing to help the species survive beyond expected measures (Robertson. 2000; Quétier, *et al.* 2014).

Studies with other species such as the Great Crested Newt, or *Triturus cristatus* (*T. cristatus*), has allowed development of a district licencing scheme, with consideration of biodiversity offsetting. Some areas the *T. cristatus* inhabit are also needed for building development and as such workers must wait for proper procedures to be completed before going forward with their construction. These procedures include hiring an ecologist to perform surveys to determine if there is a presence of *T. cristatus* eDNA - (environmental

DNA, DNA found within the environment such as ponds and soils) (Deiner, *et al.* 2017), and depending on how many ponds to be tested, may result in high costs (averaging at £250K), especially when there are delays, which site developers are charged for regardless of whether they can build on that site or not (Tew, *et al.* 2018). With the introduction of District Licencing, building commissions have become a lot easier to apply for by focusing on the conservation of *T. cristatus* populations rather than individuals, using a 4:1 ratio of new pond habitats built to pond habitats destroyed (Tew, *et al.* 2019), ensuring a net gain in *T. cristatus* habitats, as opposed to the common interpretation of 'no net loss'. An adaptation of this for the *B. barbastellus* may provide an alternative conservation to mitigate any losses for the barbastelle bat if a similar method of habitat evaluation can be produced.

### Norwich and Norfolk area

The largest known colony of *B. barbastellus* in the UK roosts within the Norfolk area, with the only known maternity roost, making this an optimal location to study their natural behaviours (Norfolk Wildlife Trust. 2020). Norfolk council released a *Norfolk Biodiversity Action Plan* regarding the Barbastelle Bat (Norfolk County Council. 2009) that listed their actions as studying sites across north and south Norfolk, as well as south Suffolk; Mist net studies at Swanton Novers NNR to assist with the local woodland management; a special planning zone within 10 km radius of Paston Barn (by North Walsham) with *B. barbastellus* being a key consideration for any planning applications; and continued monitoring of colonies.

Following development of the Northern Distributor Road (NDR), mitigations in the form of gantries and green bridges were developed to assist bats across the dual carriageway, however despite these mitigations, two out of three colonies of *B. barbastellus* along this route have been undetected since (Barkham. 2020). An extension to this road is planned (the Western Link), that passes through the Wensum Valley cutting between areas of Ringland and Weston Longville, raising concerns for the *B. barbastellus* colonies within that area (Barkham. 2020; Norfolk County Council. 2021).

## Aims and Objectives

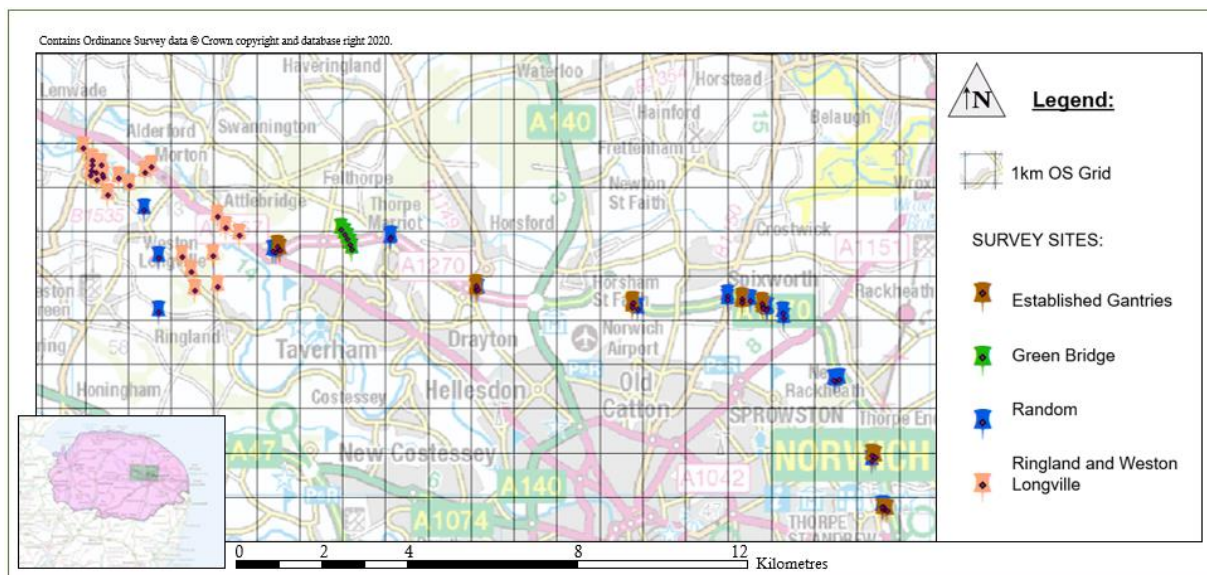
The aim of this study is to collate and provide better understanding of bat activity (with focus on the Barbastelle bat, *B. barbastellus*) within likely foraging sites of the spanned areas of Ringland and Weston Longville, to the full extent of the Broadland Northway, based along the north outskirts of the City of Norwich, Norfolk, UK. Insect abundance and biodiversity at these sites may also provide an indicator as to habitat richness; and Moth abundance, an insight into the food richness these bats are provided with. All these factors will be utilised in producing a map of effective conservation areas, highlighting locations of already good habitat which should be preserved, as well as areas that need to be improved upon. As such the hypotheses being tested are as follows:

- H<sub>1</sub> – Moth Abundance alters with footpath location
- H<sub>2</sub> – Insect Abundance and/or Biodiversity alters with footpath location
- H<sub>3</sub> – Total Bat Activity alters with footpath location
- H<sub>4</sub> – Barbastelle Bat Activity alters with footpath location
- H<sub>5</sub> – A relationship exists between Moth Abundance and Insect Biodiversity
- H<sub>6</sub> – A relationship between Moth Abundance and either Total Bat Activity and/or Barbastelle Bat Activity
- H<sub>7</sub> – A relationship exists between Insect Abundance and/or Biodiversity and Total Bat Activity
- H<sub>8</sub> – A relationship exists between Insect Abundance and/or Biodiversity and Barbastelle Bat Activity

## Methods

### Study Sites and Acoustic Data

A grid consisting of 1km<sup>2</sup> OS grids was superimposed upon the overall study sites, which spanned areas of Ringland and Weston Longville to the full extent of the Broadland Northway, based along the north outskirts of the City of Norwich, Norfolk, UK. Of the 231 1km<sup>2</sup> OS grids within the region highlighting north Norwich and the surrounding area in Figure 1, 35 were surveyed for bats. Sites were chosen at each established gantry, and the Marriott Way Green Bridge, both of which are mitigation strategies put in place to assist bat crossings over the Broadland Northway; Ringland and Weston Longville sites, as well as random locations across the spanned areas.



**Figure 1.** The Northern outskirts of the City of Norwich, Norfolk. The study area, based around Ringland and Weston Longville to the extent of the Northern Distributor Road, was superimposed with 1km<sup>2</sup> OS grids.

These independently chosen sites were surveyed for bats either on the same night or in close succession of each other. These bat surveys were conducted via *Song Meter SM4Bat FS Ultrasonic Recorders* (SM4Bat FS detectors), set to record continuously, and left at sites overnight. Averaging at 3-4 detectors being deployed each night, over the period of 23

surveying nights between the middle of June and the middle of July (due to a late development of the seasons) and resulting in 71 individual survey sites.

The *SM4Bat FS* detectors, produced by Wildlife Acoustics, were deployed with two types of omnidirectional microphone, the *SMM-U1 Ultrasonic Microphone*, and the *SMM-U2 Ultrasonic Microphone*, affixed and camouflaged amongst the surrounding area at a 1-meter height to allow discreet detection within the bat's flight path. Effectiveness of bat call detection is dependent on various factors, firstly from the surrounding environment, with weather conditions and various landscapes resulting in disruption in the soundwaves journey. Additionally, effective detection is dependent from the call itself, regarding the frequency and amplitude (with higher frequencies able to travel only shorter distances, and lower amplitudes being harder to pick up), as well as the direction the calls origin is facing in relation to the microphone. With these latter influences, detection is made more difficult with species-specific calls, many utilising their own frequencies, in addition to the variety in call types, as social calls and echolocation calls use different amplitudes (Lattenkamp, *et al.* 2021).

Sites within the same or within adjacent 1km<sup>2</sup> OS grids were placed at least 200 meters apart to ensure there was no simultaneous recordings from multiple *SM4Bat FS* detectors, as it has been noted that species such as the common noctule (*Nyctalus noctule* – *N. noctule*) have calls that can be heard up to similar distances (Russ. 2012). Out of the 71 sites surveyed, data from 8 sites were omitted, 1 of which due to a fault with the detector.

### Invertebrate Abundance and Biodiversity

The detectors were accompanied by a 20cm x 15cm yellow insect card trap, suspended at a 1-meter height using metallic garden stakes and protected by a cylindrical net of chicken wire, with gaps of 2.5 x 1.5 cm. The non-attractive resin allowed passive collection of invertebrate abundance, from which information regarding the site's invertebrate biodiversity could also be extracted. These traps were positioned along hedge rows and treelines, and other natural linear features where possible, using plausible routes for bat commutes. Deployed at the same time as the *SM4Bat FS* detectors, these were also collected the following morning. Total individual count provided an overall abundance per trap, whilst identification of species via the *Seek by iNaturalist* app provided the biodiversity scores per trap. All 71 sites surveyed for bat activity were accompanied by an insect trap as described above.

### Moth Abundance

Sites were surveyed for moth presence via walking transects, using a red LED to maintain night vision and to avoid unnecessary disturbance for any Bats present. Transects were performed by walking 50 meters and observing any Moth present in 15 feet in all directions. Three Moth walks were made a night, once at sunset, another 45 minutes afterwards, and again 45 minutes after that. A list of dates and times sunset occurred covering the survey period can be found in Appendix 1.

### Habitat

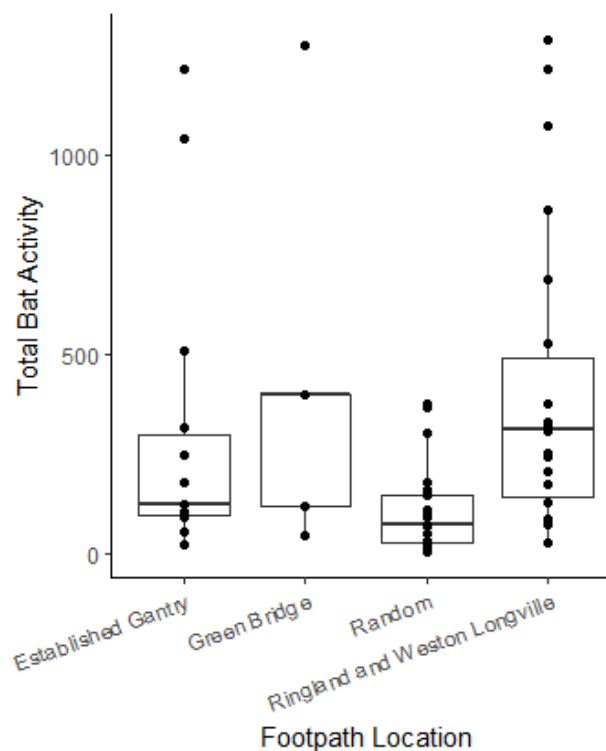
The EDINA DIGIMAP Environment provided the *Land Cover Map 2019 for Great Britain (Vector)*, which provided the freshwater, suburban and urban landcover data used in this study. This data, published in 2019, was polygonal type, and consisted of British National Grid (BNG) coordinates, scaling at 1:250,000. Ancient Woodland data was provided from Natural England Open Data's *Ancient Woodland (England)*, a BNG system of polygons at a 1:250,000 scale created in 2013 with revisions made in 2020.

Ensuring the coordinate systems maintained a consistency, all the ancient woodland layers were imported and merged, to then be intersected with the fishnet and spatially joined so that the total area of ancient woodland for each 10km<sup>2</sup> area could be used to calculate proportional relationship. The same was done for urban areas and freshwater sources, before these data could be exported through a singular table, allowing a correlation and logistic regression to be made for final habitat models.

## Results

### Total Bat Activity

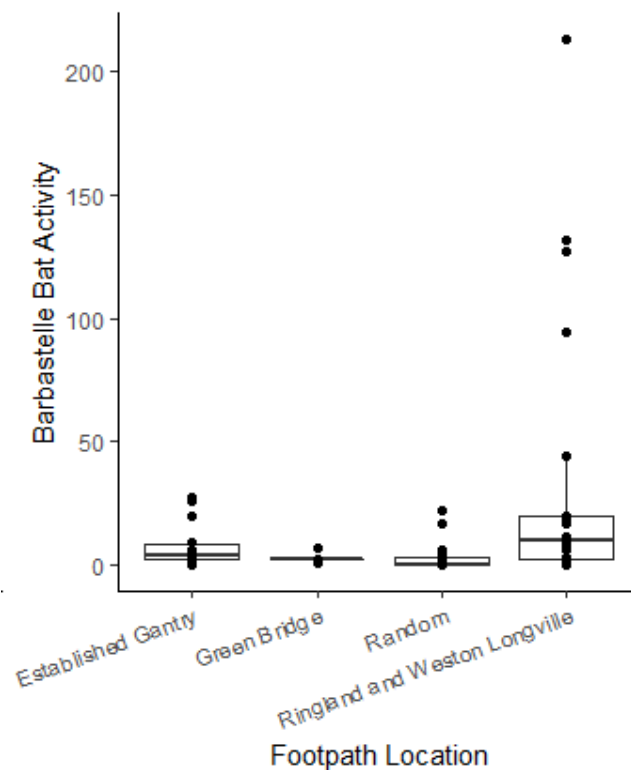
The median mark of the Total Bat Activity within different locations are displayed in figure 2. A Kruskal-Wallis test showed that there was a significant difference between the median scores. Greater Total Bat Activity was recorded in the Green Bridge sites than at the areas of Established Gentries, with medians of 399 and 125.5 respectively, with a Mann-Witney U test revealing these differences to be significant ( $U_{6,18} = 18.0, P = 0.016$ ). In addition, the Green Bridge showed greater median scores than those at the Ringland and Weston Longville sites, with medians of 399 and 310 respectively. A Mann-Witney U test revealed these differences to also be significant ( $U_{36,6} = 12.0, P < 0.001$ ). Similarly, significant differences between the Green Bridge and Random sites were also found, with medians of 399 and 75 respectively ( $U_{6,6} = 0.0, P = 0.003$ ).



**Figure 2.** The medians, quartiles, and range of Total Bat Activity across the different foraging site areas. The Green Bridge area showed a greater median of bat activity than any other area (see in-text for details).

### Barbastelle Bat Activity

The median mark of the Barbastelle Bat Activity within different locations are displayed in figure 3. A Kruskal-Wallis test showed that there was a significant difference between the median scores. Greater Barbastelle Bat Activity was recorded in the Ringland and Weston Longville sites than at the areas of Established Gantries, with medians of 10 and 4 respectively, with a Mann-Witney U test revealing these differences to be significant ( $U_{33,18} = 192.0$ ,  $P = 0.037$ ). In addition, the Ringland and Weston Longville sites showed greater median scores than those at the Green Bridge area, with medians of 10 and 2 respectively. A Mann-Witney U test revealed these differences to also be significant ( $U_{33,6} = 36.0$ ,  $P = 0.013$ ). Similarly, significant differences between the Ringland and Weston Longville sites and Random sites were also found, with medians of 10 and 0 respectively ( $U_{33,6} = 30.0$ ,  $P = 0.007$ ).

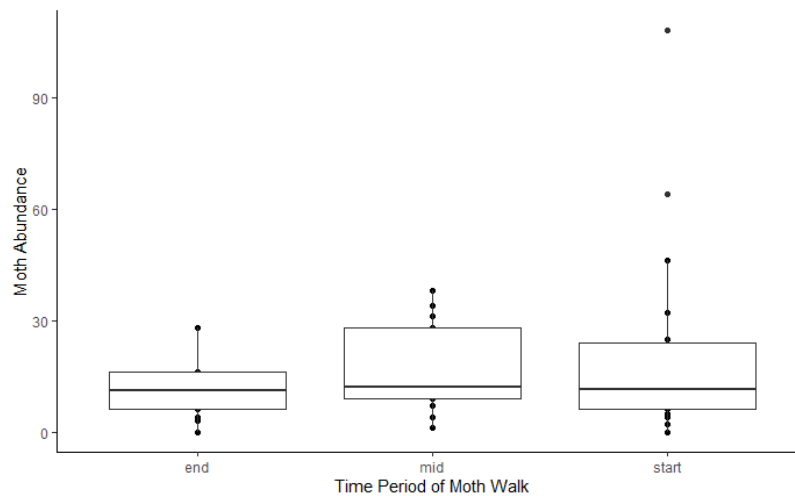


**Figure 3.** The medians, quartiles, and range of solely *B. barbastellus* (Barbastelle Bat) Activity across the different foraging site areas. The Ringland and Weston Longville area showed a greater median of *B. barbastellus* activity than any other area (see in-text for details).



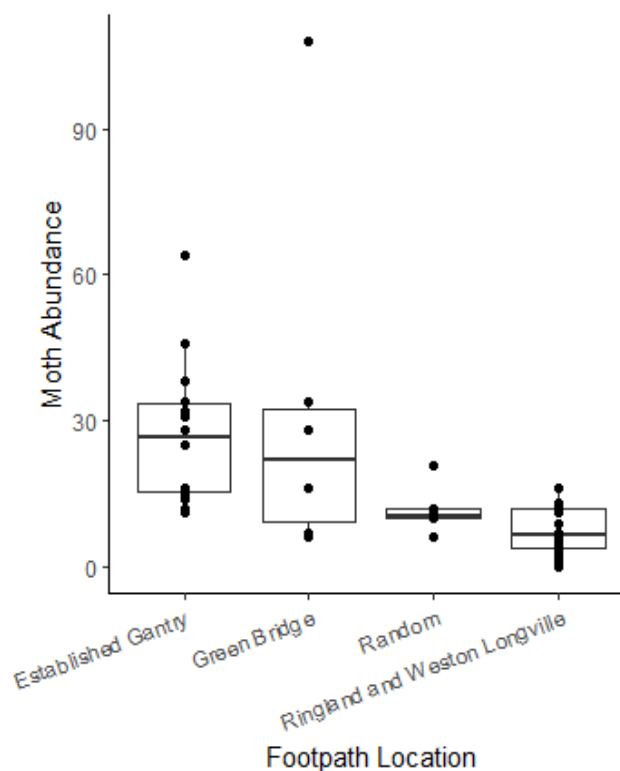
### Moth Abundance

The median mark of the Total moth Abundance during different times of the night following dusk are displayed in figure 4. A Kruskal-Wallis test showed that there was no significant difference between the median scores (Start = 11.5; Middle = 12; End = 11). As no significant difference was found, any data involving moth abundances just used one value per site, those recorded at sunset as foraging begins for *B. barbastellus*.



**Figure 4. Moth Abundance at different times of the night. Start times begin at sunset for the day of study, with middle studies being done 45 mins past sunset and end studies 90 mins past midnight (Exact times these would have occurred is available in Appendix 1). No significance was found throughout these data, meaning that moth abundance was not affected by the progression of nightfall between sunset and the following 90 mins (usually ending by 23:00).**

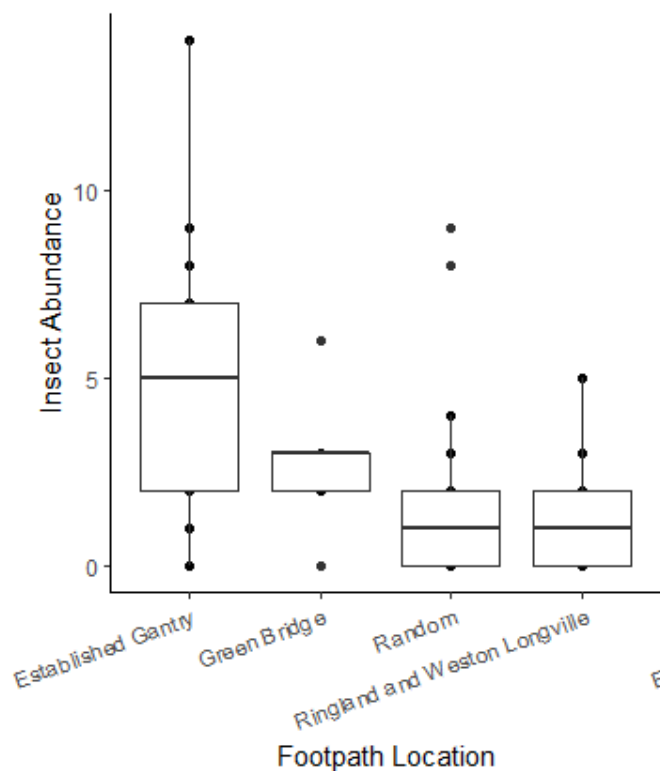
The median mark of the total moth abundance within different locations are displayed in figure 5. A Kruskal-Wallis test showed that there was a significant difference between the median scores. More moths were found in the areas of Established Gantries than Ringland and Weston Longville sites, with medians of 26.5 and 22 respectively. A Mann-Witney U test revealed these differences to be significant ( $U_{18, 26} = 16.5$ ,  $P < 0.001$ ). Similarly, significant differences between the Established Gantries and Random sites were found, with medians of 26.5 and 10.5 respectively ( $U_{18, 6} = 10.0$ ,  $P = 0.003$ ).



**Figure 5. The medians, quartiles, and range of Moth Abundance across the different foraging site areas. The areas with Established Gantries showed a greater median of Moth Abundance than Ringland and Weston Longville Sites, as well as Randomly selected sites (see in-text for details).**

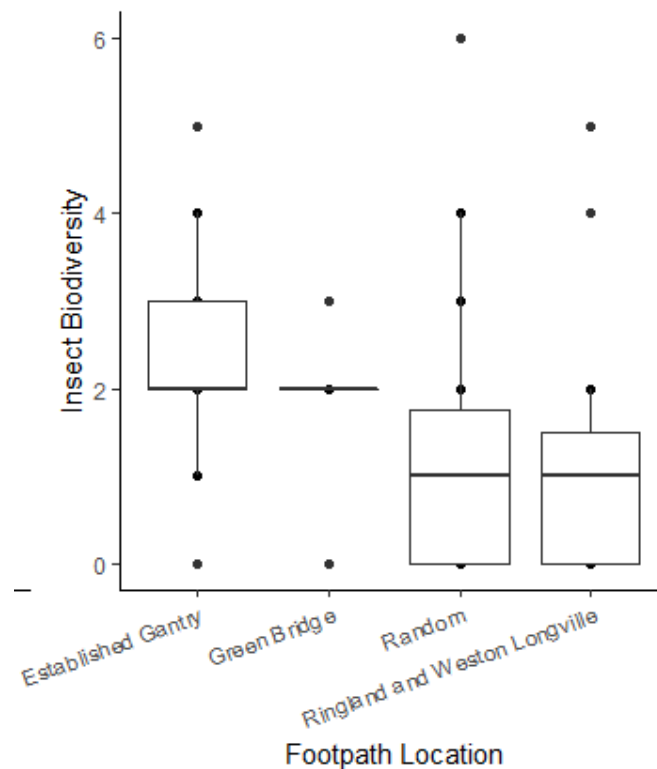
### Insect Abundance and Biodiversity

The median mark of the total invertebrate abundance within different locations are displayed in figure 6. A Kruskal-Wallis test showed that there was a significant difference between the median scores. More invertebrates were captured in the areas of Established Gantries than at the Green Bridge, with medians of 5 and 3 respectively, with a Mann-Witney U test revealing these differences to be significant ( $U_{18,6} = 22.5$ ,  $P = 0.033$ ). In addition, the Established Gantries showed greater median scores than those at the Ringland and Weston Longville sites, with medians of 5 and 1 respectively. A Mann-Witney U test revealed these differences to be significant ( $U_{18,36} = 21.08$ ,  $P < 0.001$ ). Similarly, significant differences between the Established Gantries and Random sites were found, with medians of 5 and 1 respectively ( $U_{18,6} = 12.0$ ,  $P = 0.005$ ).



**Figure 6. The medians, quartiles, and range of Insect Abundance across the different foraging site areas. The areas with Established Gantries showed a greater median of Insect Abundance than any other area (see in-text for details).**

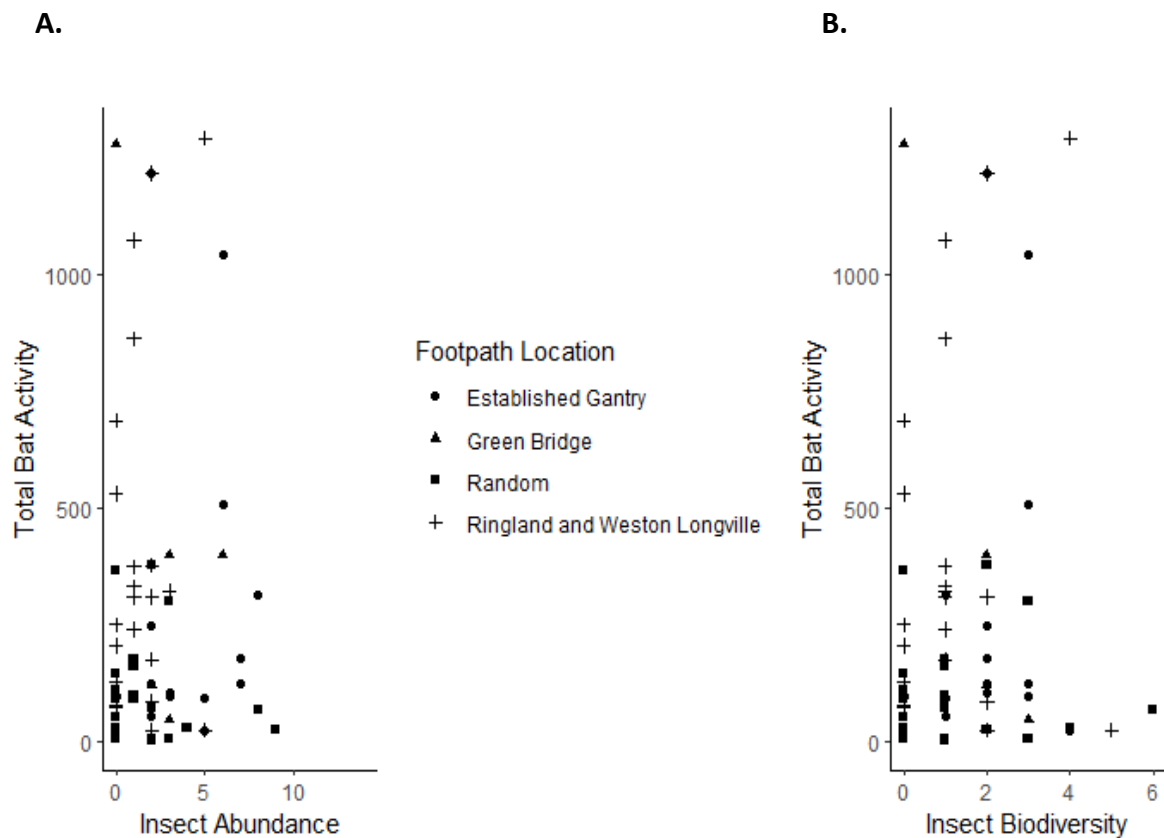
The median mark of the invertebrate biodiversity within different locations are displayed in figure 7. A Kruskal Wallis test showed that there was a significant difference between the median scores. Greater Biodiversity was captured in the areas of Established Gantries than at the Green Bridge, with medians of 2 and 2 respectively, with a Mann-Witney U test revealing these differences to be significant ( $U_{18,6} = 13.6$ ,  $P = 0.005$ ). In addition, the Established Gantries showed greater median scores than those at the Ringland and Weston Longville sites, with medians of 2 and 1 respectively. A Mann-Witney U test revealed these differences to also be significant ( $U_{18,36} = 91.5$ ,  $P < 0.001$ ).



**Figure 7. The medians, quartiles, and range of Insect Biodiversity across the different foraging site areas. The areas with Established Gantries showed a greater median of Insect Biodiversity than the Green Bridge, and Ringland and Weston Longville sites (see in-text for details).**

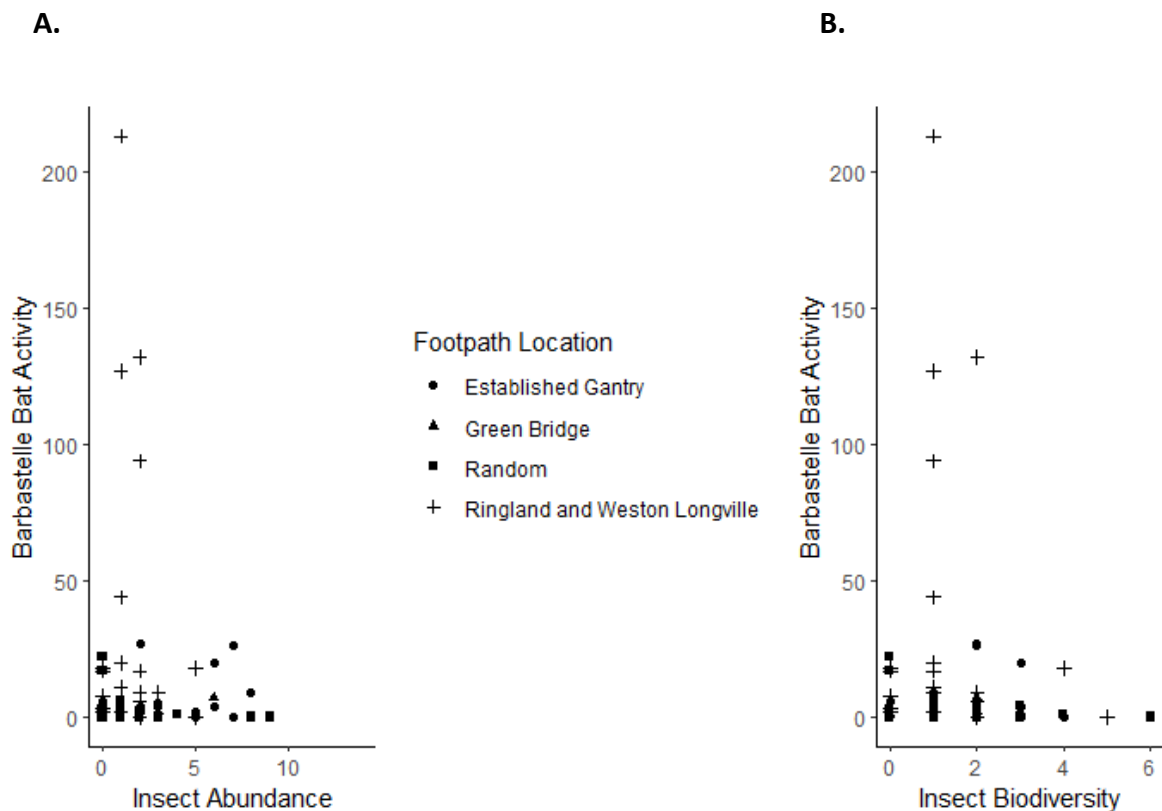


The relationship between Insect Abundance and Total Bat Activity is given in figure 9a. A Spearman rank correlation showed that there was no significant relationship between the two ( $p_{61} = 0.101$ ,  $P = 0.433$ ). Similarly, the relationship between Insect Biodiversity and Total Bat Activity is given in figure 9b. A Spearman rank correlation showed that there was no significant relationship between the two ( $p_{61} = 0.190$ ,  $P = 0.881$ ).



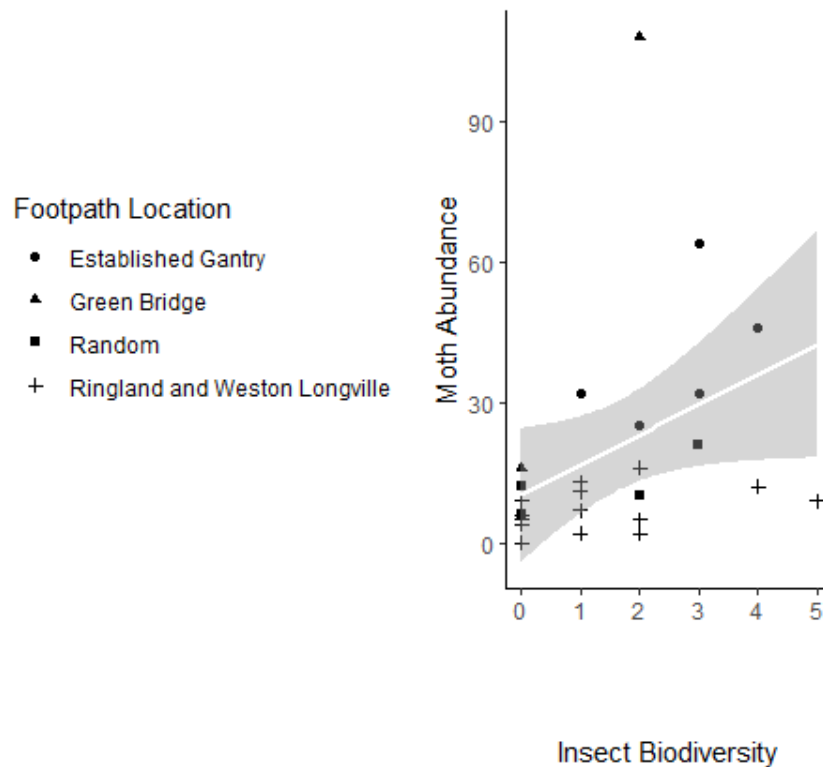
**Figure 9. The relationship between Total Bat activity and A). Insect Abundance and B). Insect Biodiversity, across the different foraging sites. No significant correlation was found between either variable in both relationships (see in-text for details).**

The relationship between Insect Abundance and Barbastelle Bat Activity is given in figure 10a. A Spearman rank correlation showed that there was no significant relationship between the two ( $p_{61} = 0.139$ ,  $P = 0.276$ ). Similarly, the relationship between Insect Biodiversity and Barbastelle Bat Activity is given in figure 10b. A Spearman rank correlation showed that there was no significant relationship between the two ( $p_{61} = 0.104$ ,  $P = 0.417$ ).



**Figure 10. The relationship between *B. barbastellus* activity and A). Insect Abundance and B). Insect Biodiversity across the different foraging sites. No significant correlation was found between either variable in both relationships (see in-text for details).**

The relationship between Insect Biodiversity and Moth Abundance is given in figure 11. A Spearman rank correlation showed that there was a significant relationship between the two ( $p_{61} = 0.571$ ,  $P < 0.001$ ).



**Figure 11.** The relationship between Moth abundance and Insect Biodiversity across the different foraging sites. A significant correlation was found between the two variables (see in-text for details), with select random sites showing greater number of moths than other sites.

### Habitat

A multiple regression analysis was carried out to investigate whether Urban, Water, and Woodland environments could significantly predict either Barbastelle, or overall Bat activity. The results of the regression showed Urban environments displayed the least effect on Barbastelle bat presence, and produced no significant combined effect, and so was



eliminated. The results of the updated regression indicated Woodland, and Water Environments explained 17.3% of the variance and that the model was a significant predictor of Barbastelle presence,  $F(2, 32) = 3.355$ ,  $P = 0.048$ . While Woodland areas contributed significantly to the model ( $B = 5.32 \times 10^{-5}$ ,  $P = 0.26$ ), Water habitats did not ( $B = 7.97 \times 10^{-5}$ ,  $P > 0.05$ ). The final predictive model for Barbastelle Bat Presence was produced and is replicated in Equation 1.

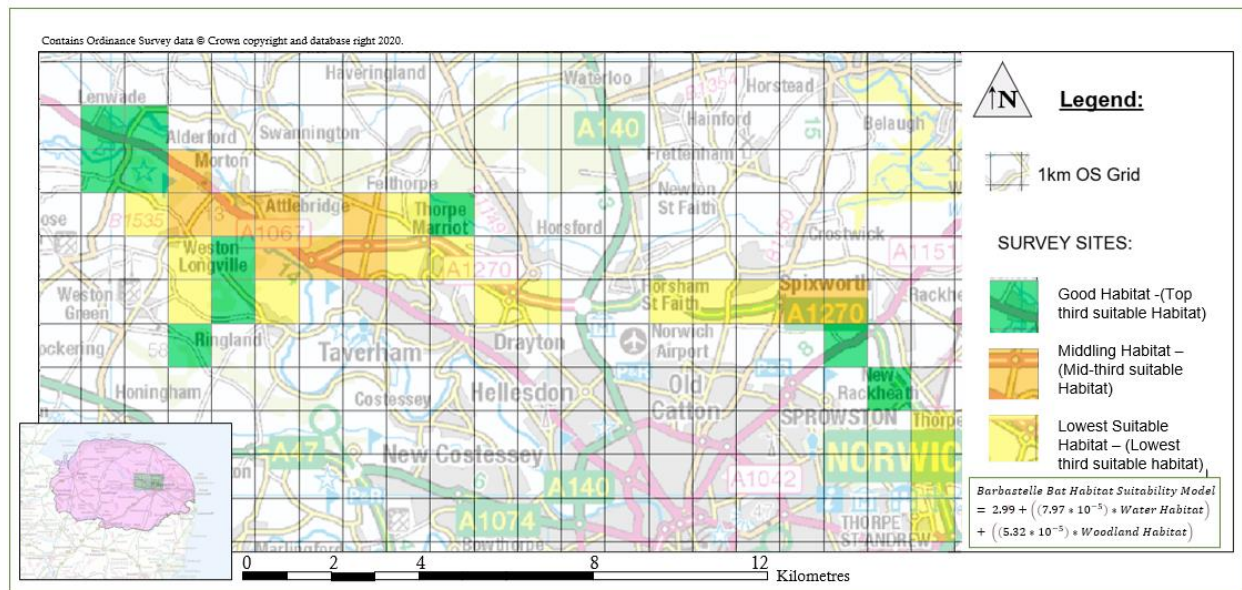
**Equation 1. Prediction of Barbastelle Bat (*B. barbastellus*) presence based on a multiple regression analysis of habitat data and recorded *B. barbastellus* activity at selected sites.**

*Barbastelle Bat Presence*

$$= 2.99 + ((7.97 \times 10^{-5}) * \text{Water Habitat}) + ((5.32 \times 10^{-5}) * \text{Woodland Habitat})$$

Using this predictive model, an assessment of landcover was made in each of the surrounding areas of the study sites (Figure 12), and using ArcGIS, were divided into thirds, and coloured in accordance with the best fitted (Green), to the worst fitted (Yellow). The 10 green areas are shown to be areas with greater woodland. At the west this shows areas around Ringland and Weston Longville, as well as the areas around Lenwade and Alderford, with woodland behind Thorpe Marriot at the centre. To the East of the map there are two more green areas around New Rackheath. Middling habitat areas (10), shown in orange, are concentrated to the west of the map between Lenwade, Thorpe Marriot, and Ringland (mostly following the river Wensum), with additional areas in the east, by Spixworth. The lowest suited habitat areas (15) in yellow, comprise the rest of the area and are more spread across the map. These yellow sites are the ones that the model indicates need the most conservation development to ensure an enriched environment for *B. barbastellus* to regain a foothold in the current ecosystem.

An additional model was tested for inclusion of Invertebrate abundance and Biodiversity (Table 1), however this was not seen to hold any significant effect in a GLM, thus the previously described habitat model was kept in its place.



**Figure 12.** Barbastelle habitat suitability in the Northern outskirts of the City of Norwich, Norfolk. The study area, based around Ringland and Weston Longville to the extent of the Northern Distributor Road, was superimposed with 1km<sup>2</sup> OS grids. The model produced in Equation 1 has been superimposed to provide evidence of habitat suitability within these different 1 km<sup>2</sup> OS grids. Green Squares are rich in woodland and water habitats, giving *B. barbastellus* the cover and hydration needed. Yellow habitats have the least amount of woodland and water habitats providing the least benefit.

**Table 1.** Output for full model tested. This model includes the addition of Invertebrate Abundance and Biodiversity (This model was rejected in favour of the better fitting habitat model shown in equation 1).

	B	Std. Error	Beta	t	sig
<b>Barbastelle Bat Activity (Constant)</b>	-.096	9.532		-.010	.992
<b>Urban</b>	234906.629	245827.604	.168	.956	.347
<b>Water</b>	6.902E-5	.000	.137	.758	.455
<b>Woodland</b>	5.968E-5	.000	.422	2.256	.032
<b>Invertebrate Abundance</b>	1.445	3.751	.164	.385	.703
<b>Invertebrate Biodiversity</b>	-2.006	5.792	-.152	-.346	.732

## Discussion:

The aim of this study was to collate and provide better understanding of bat activity (with focus on the Barbastelle bat – *B. barbastellus*) within likely foraging sites of the spanned areas of Ringland and Weston Longville to the full extent of the Broadland Northway, based along the north outskirts of the City of Norwich, Norfolk, UK. Insect abundance and biodiversity at these sites may also provide an indicator as to habitat richness; and Moth abundance, an insight into the food richness these bats are provided with. All these factors were utilised in producing a map of effective conservation areas (Figure 12), highlighting locations of already good habitat which should be preserved, as well as areas that need to be improved upon.

The survey had captured 17730 bat calls at the selected sites from 13 different species, providing an in depth look at the spanned area, with insights on the bat coverage of Ringland and Weston Longville to the full extent of the Broadland Northway. While only the *B. barbastellus* bat species was analysed separately from the total recorded activities, discussion will refer to other species that were detected within the overall bat activity surveys.

The initial results as shown in Figure 2 show that the location has significant influence on the total bat activity, with greater occurrence at the green bridge, as well as *B. barbastellus* bat activity, shown in figure 3, displaying a greater occurrence happening within the Ringland and Weston Longville sites. The differences between *B. barbastellus* and total bat activities is likely due to the greater adaptability to varying habitats that the other bats possess. Within the sets of data, the common pipistrelle (*P. pipistrellus*) and the soprano pipistrelle (*Pipistrellus pygmaeus*) were the most frequently detected bat species throughout all surveyed sites; both species are widespread across the UK and have become adapted to the Urban environment that has developed considerably over the past few centuries (Altringham and Kerth. 2016). The *B. barbastellus* in comparison has been found, both in this study (Figure 12) and within the relevant literature, to be far better adapted to woodland areas (Zurcher, *et al.* 2010; Kunz 1982; Altringham 1996; Kunz and Lumsden 2003)). It is also interesting to note that other rare species of Chiroptera were detected, with a full list of species identified at each site provided within the supplementary materials folder accompanying this report.

Moth abundance, Invertebrate abundance, and Invertebrate Biodiversity were all recorded to be greatest at the established gantries (as shown in Figure 5, Figure 6, and Figure 7 respectively). This data seems to juxtapose the literature collected on invertebrate abundance being used as a predictor for habitat richness in various location types. This literature states that moth and invertebrate abundance is a good predictor for habitat richness (Hunter. 2002; Farhig and Jonsen. 1998) and bat foraging activity, with one being a direct result of the other (Wickramasinghe, *et al.* 2004). It has been found that weather impacts the presence of these groups, for example, Aquatic insects respond to thermal regimes, which are composed of patterns of absolute temperatures, diel and seasonal Amplitudes. Along with rates of change (Ward and Stanford. 1982). As such, the temperatures and climate conditions must be accounted for in parallel to those of the bats for a strong enough data set to oppose this, if such results present themselves.

An assessment of landcover was made in each of the surrounding areas of the study sites in Figure 12 using the model described in Equation 1, and using ArcGIS, were divided into thirds, and coloured in accordance with the best fitted (Green), to the worst fitted (Yellow). The 10 green areas shown to have greater woodland, and in the west, this shows areas around Ringland and Weston Longville, as well as the areas around Lenwade and Alderford. While a gap exists between these areas in the West, it is likely that there is flight between these two rich areas, thus making the area between vitally important to conserve and if possible, to enrich, encouraging the development of *B. barbastellus* presence. At present, plans for a Western Link to the NDR are in development for the area (Barkham. 2020). As has been previously discussed, current mitigation plans used within the Norwich area such as the gantries are not effective (Berthinussen and Altringham. 2012), and a disruption to a continuous habitat such as this could be devastating to both the foraging and roosting habits of *B. barbastellus*.

An area of woodland behind Thorpe Marriot, known as Drayton Woods, appears to be another area of suitable habitat, as are two areas to the East of the map, around New Rackheath. If a development of habitat suitability models such as the Great Crested Newts Habitat Suitability Index was to be developed, then these areas should also be scouted for specific factors such as quantities of ancient woodland for roosting, and other factors that directly affect barbastelle presence in either a positive or negative way (Grindal and Brigham.

1999; Keeley and Tuttle. 1999; Stone, *et al.* 2015; Altringham and Kerth. 2016; Zurcher, *et al.* 2010).

Middling habitat areas (10), shown in orange, are concentrated to the west of the map between Lenwade, Thorpe Marriot, and Ringland (mostly following the river Wensum), with additional areas in the east, by Spixworth. With effort these areas could be developed to enrich *B. barbastellus* presence, however, as much of this area is occupied by main roads and targeted for development of the prior mentioned western link, these habitats are likely to decline in suitability if not effectively mitigated and planning stopped. The lowest suited habitat areas (15) in yellow, comprise the rest of the area and are more spread across the map. These yellow sites are the ones that the model indicates need the most conservation development to ensure an enriched environment for *B. barbastellus* to regain a foothold in the current ecosystem. These areas being more spread out make them difficult to manage effectively, and any increase in urban developments in these areas will only worsen their effective use.

### Limitations and Improvements

This study has certain limitations in its method and execution which can be improved upon in future studies. Firstly, time constraints due to a late seasonal change led to the inability to fully regulate climate controls; while weather was controlled for bat activity, not collecting data on days below 18°C or when there is rainfall, as these times bats stay within their roosts, further regulations in data collection time slots must be made to account for invertebrate and moth presences. It has been found that weather impacts the presence of these groups, and as such, the optimal temperatures and climate conditions must be accounted for in parallel to those of the bats for a more relevant and representative model to be produced.

Secondly, while the insect traps used work well enough to prove effective, damage to these traps in the form of punctures, were noticed and are believed to be a result of long slender beaks still managing to access the traps from behind the chicken wire mesh. While the BTO pipeline was able to identify that bird species were present during these studies, exact species names were unable to be identified, but as a precautionary measure, an

increase in radius from the sticky trap card may prove an effective countermeasure and allow better biodiversity and abundance estimates in future. With a current circumference of 90 cm, a radius of 14.32 cm can be calculated; a new radius of 30 cm will mean that the circumference of the new trap will have to be 188.49 cm – a suggested starting point for testing this countermeasure's effectiveness.

Thirdly, moth abundance data were collected by subjective means, and any discrepancies in night-vision, depth perception, or situational awareness can provide different results for any individuals collecting the data. To standardise this in future studies, equipment must be used to collect better surveying data. Thermal imaging camera traps are useful in short periods, but they run similar risks as acoustic detectors in that multiple counts of a singular individual can be made, causing skewed results. Another alternative would be the D-Vac, which can act as a simultaneous replacement for sticky traps in invertebrate abundance and biodiversity measurements, as it collects all the individuals into a box – alive and free to redistribute after data is collated. This however comes with another setback- as the D-Vac produces considerable noise, any nearby bats in either roosts or perhaps in flight may be disturbed by such noises. Active moth traps seem an obvious choice, however any light produced may disturb the bats roosting and daylight estimates causing them to return from foraging (and perhaps disorientating them away from the roost mistaking the source of light for the sun).

## Conclusions

In conclusion, the Barbastelle bat has greater presence within woodland areas by water sources, ideal for roosting and keeping hydrated. Presence of other bat species are greatly widespread across the surveyed areas and thus are harder to create a working predictive model for in this study. Greater activities of Barbastelles were found around the Ringland and Weston Longville areas, where woodland was most dense, however, to maintain their presence in these areas, as well as cultivation in the surrounding areas, a list of conservation practices need to be implemented, focused on development of woodland and preservation of existing areas (see below). Further study within this area is needed for

accurate invertebrate biodiversity and abundance data, preferably a long-term study allowing a spatial-temporal display of any disturbances. This would especially be useful if development of the NDR's Western link continues – as negative changes in bat habitats are sure to occur if this happens, and studies of change in behaviour may assist in their recuperation elsewhere, but as the largest known *B.barbastellus* colony in the UK, a loss this big may mean an irreversible decline for their species in the UK. The habitat suitability model produced through this study may act as a precursor for a thorough widespread assessment strategy, paralleling effective measures put in place for other species.

This study aimed to test several hypotheses; out of them the following were accepted:

- H<sub>1</sub> – Moth Abundance alters with footpath location
- H<sub>2</sub> – Insect Abundance and/or Biodiversity alters with footpath location
- H<sub>3</sub> – Total Bat Activity alters with footpath location
- H<sub>4</sub> – Barbastelle Bat Activity alters with footpath location
- H<sub>5</sub> – A relationship exists between Moth Abundance and Insect Biodiversity

With the current data available, the following hypotheses were turned down in favour for their null hypothesis equivalents.

- H<sub>6</sub> – A relationship between Moth Abundance and either Total Bat Activity and/or Barbastelle Bat Activity
- H<sub>7</sub> – A relationship exists between Insect abundance and/or biodiversity and Total bat activity
- H<sub>8</sub> – A relationship exists between Insect Abundance and/or Biodiversity and Barbastelle Bat Activity

### Future Conservation Recommendations:

Conservation management for the Barbastelle bat needs account for surrounding habitats, the communication of which must involve targeted landowners and councils understanding the real risks the species are under in their areas. This study will assist in the communication of areas needing protection and areas needing further enrichment to the relevant parties in a long-term conservation scheme. As such, this study highlights the following areas for informed conservation management:

- The maintained presence of important woodland, especially ancient woodland, as crucial roosting sites of multiple species of bats, especially the IUCN's 'near threatened' classified *B. barbastellus* bat. The maintenance, and, ideally, growth of these areas will assist the continuation of not just these species, but other species such as Brown Hare (*Lepus europaeus*), whose populations are declining throughout the UK (Ancillotto, *et al.* 2015).
- The subsidising of farmers to utilise agricultural environment schemes that promote less destructive practices to alleviate any possible strain faced by bats when foraging for insects in these areas (Entwhistle *et al.* 2001).
- The activity of calls spanning the site areas can be used to reveal known roost locations, however one of the sites within the Ringland and Weston Longville area paralleled these numbers. While investigations into this site continues, it highlights the plausibility of other roosts in areas that have not yet been studied and emphasises that a lack of detected presence is not always the same as an absence. Therefore, destruction of suitable habitats on the basis that no *B. barbastellus* individuals have been detected should be discouraged, especially if they are known to exist within a wider area.
- Caution and care must be taken when using the sum of data generated within this study. While this data would at first suggest that the invertebrate population has little



effect upon the habitat richness or distribution of bats, other studies would lend themselves to other trains of thought, and discrepancies are likely due to altering weather conditions that were not controlled for (Hunter. 2002; Farhig and Jonsen. 1998; Wickramasinghe, *et al.* 2004).

- Habitat models for the *B. barbastellus* can be used for alternative mitigation strategies such as a similar approach to Biodiversity Offsetting as the district licencing scheme put in place for *T. cristatus*, that has been proving effective as a species centric model for developing new habitats in avoidance of common interpretations of no-net-loss policies (Tew, *et al.* 2019).

## Acknowledgments

Considerable thanks must firstly go out to Abbie Conner, who made data collection both timely and enjoyable, and without whom data collection for this project would have been a much more arduous task.

Thanks also go out to the stakeholders and landowners of all the sites described in this study, who were all very accommodating and supportive in providing access to their land to conduct surveys, often during unsociable hours. For the few met in-person during these hours, extra thanks are extended in the genuine interest and enthusiasm earnestly displayed towards this study.

Additional gratitude goes out to Stuart Newson from BTO for timely help with the Acoustic Pipeline when an error occurred, and Ronald Ennos for writing *Statistical and Data Handling Skills in Biology*, a book that proved tremendously helpful when it came time to analysing the collected data.

Many obligations go out to the many friends and members of family who have provided continued and unwavering support throughout the duration of this project.

Finally, immeasurable thanks go out to Dr Iain Barr of UEA for both his continued support, advice, and assistance, and for providing the means to develop and recognise the tools needed for furthering independence. His supervision in this project has helped produce this entire dissertation, and without whom this project would not have been possible.

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## Appendices

### Appendix 1.

List of Day-length Times and associated times in which fieldwork commenced throughout the study period. Used primarily during Moth Abundance Transect Walks (See Methods for Details).

	<b>DATE</b>	<b>SUNRISE</b>	<b>SUNSET (START)</b>	<b>DAY LENGTH</b>	<b>MIDDLE (START + 45 MINS)</b>	<b>END (START + 90 MINS)</b>
	<b>1ST JUNE</b>	04:49	<b>21:08</b>	16h 18m	<b>21:53</b>	<b>22:38</b>
	<b>2ND JUNE</b>	04:49	<b>21:09</b>	16h 20m	<b>21:54</b>	<b>22:39</b>
	<b>3RD JUNE</b>	04:48	<b>21:10</b>	16h 22m	<b>21:55</b>	<b>22:40</b>
	<b>4TH JUNE</b>	04:47	<b>21:11</b>	16h 23m	<b>21:56</b>	<b>22:41</b>
	<b>5TH JUNE</b>	04:46	<b>21:12</b>	16h 25m	<b>21:57</b>	<b>22:42</b>
	<b>6TH JUNE</b>	04:46	<b>21:13</b>	16h 26m	<b>21:58</b>	<b>22:43</b>
*	<b>7TH JUNE</b>	04:45	<b>21:14</b>	16h 28m	<b>21:59</b>	<b>22:44</b>
	<b>8TH JUNE</b>	04:45	<b>21:14</b>	16h 29m	<b>21:59</b>	<b>22:44</b>
	<b>9TH JUNE</b>	04:44	<b>21:15</b>	16h 30m	<b>22:00</b>	<b>22:45</b>
	<b>10TH JUNE</b>	04:44	<b>21:16</b>	16h 32m	<b>22:01</b>	<b>22:46</b>
	<b>11TH JUNE</b>	04:44	<b>21:17</b>	16h 33m	<b>22:02</b>	<b>22:47</b>
	<b>12TH JUNE</b>	04:43	<b>21:17</b>	16h 34m	<b>22:02</b>	<b>22:47</b>
	<b>13TH JUNE</b>	04:43	<b>21:18</b>	16h 34m	<b>22:03</b>	<b>22:48</b>
	<b>14TH JUNE</b>	04:43	<b>21:19</b>	16h 35m	<b>22:04</b>	<b>22:49</b>
	<b>15TH JUNE</b>	04:43	<b>21:19</b>	16h 36m	<b>22:04</b>	<b>22:49</b>
	<b>16TH JUNE</b>	04:43	<b>21:20</b>	16h 36m	<b>22:05</b>	<b>22:50</b>
	<b>17TH JUNE</b>	04:43	<b>21:20</b>	16h 37m	<b>22:05</b>	<b>22:50</b>
	<b>18TH JUNE</b>	04:43	<b>21:20</b>	16h 37m	<b>22:05</b>	<b>22:50</b>
	<b>19TH JUNE</b>	04:43	<b>21:21</b>	16h 38m	<b>22:06</b>	<b>22:51</b>
	<b>20TH JUNE</b>	04:43	<b>21:21</b>	16h 38m	<b>22:06</b>	<b>22:51</b>
	<b>21ST JUNE</b>	04:43	<b>21:21</b>	16h 38m	<b>22:06</b>	<b>22:51</b>
	<b>22ND JUNE</b>	04:43	<b>21:22</b>	16h 38m	<b>22:07</b>	<b>22:52</b>
	<b>23RD JUNE</b>	04:44	<b>21:22</b>	16h 38m	<b>22:07</b>	<b>22:52</b>
	<b>24TH JUNE</b>	04:44	<b>21:22</b>	16h 37m	<b>22:07</b>	<b>22:52</b>
	<b>25TH JUNE</b>	04:44	<b>21:22</b>	16h 37m	<b>22:07</b>	<b>22:52</b>
	<b>26TH JUNE</b>	04:45	<b>21:22</b>	16h 37m	<b>22:07</b>	<b>22:52</b>
	<b>27TH JUNE</b>	04:45	<b>21:22</b>	16h 36m	<b>22:07</b>	<b>22:52</b>

	<b>28TH JUNE</b>	04:46	<b>21:22</b>	16h 35m	<b>22:07</b>	<b>22:52</b>
	<b>29TH JUNE</b>	04:46	<b>21:21</b>	16h 35m	<b>22:06</b>	<b>22:51</b>
	<b>30TH JUNE</b>	04:47	<b>21:21</b>	16h 34m	<b>22:06</b>	<b>22:51</b>
	<b>1ST JULY</b>	04:47	<b>21:21</b>	16h 33m	<b>22:06</b>	<b>22:51</b>
	<b>2ND JULY</b>	04:48	<b>21:21</b>	16h 32m	<b>22:06</b>	<b>22:51</b>
	<b>3RD JULY</b>	04:49	<b>21:20</b>	16h 31m	<b>22:05</b>	<b>22:50</b>
	<b>4TH JULY</b>	04:50	<b>21:20</b>	16h 30m	<b>22:05</b>	<b>22:50</b>
	<b>5TH JULY</b>	04:50	<b>21:19</b>	16h 28m	<b>22:04</b>	<b>22:49</b>
	<b>6TH JULY</b>	04:51	<b>21:19</b>	16h 27m	<b>22:04</b>	<b>22:49</b>
	<b>7TH JULY</b>	04:52	<b>21:18</b>	16h 25m	<b>22:03</b>	<b>22:48</b>
	<b>8TH JULY</b>	04:53	<b>21:17</b>	16h 24m	<b>22:02</b>	<b>22:47</b>
	<b>9TH JULY</b>	04:54	<b>21:17</b>	16h 22m	<b>22:02</b>	<b>22:47</b>
	<b>10TH JULY</b>	04:55	<b>21:16</b>	16h 21m	<b>22:01</b>	<b>22:46</b>
	<b>11TH JULY</b>	04:56	<b>21:15</b>	16h 19m	<b>22:00</b>	<b>22:45</b>
	<b>12TH JULY</b>	04:57	<b>21:14</b>	16h 17m	<b>21:59</b>	<b>22:44</b>
	<b>13TH JULY</b>	04:58	<b>21:14</b>	16h 15m	<b>21:59</b>	<b>22:44</b>
	<b>14TH JULY</b>	04:59	<b>21:13</b>	16h 13m	<b>21:58</b>	<b>22:43</b>
<b>**</b>	<b>15TH JULY</b>	05:00	<b>21:12</b>	16h 11m	<b>21:57</b>	<b>22:42</b>
	<b>16TH JULY</b>	05:02	<b>21:11</b>	16h 8m	<b>21:56</b>	<b>22:41</b>
	<b>17TH JULY</b>	05:03	<b>21:10</b>	16h 6m	<b>21:55</b>	<b>22:40</b>
	<b>18TH JULY</b>	05:04	<b>21:08</b>	16h 4m	<b>21:53</b>	<b>22:38</b>
	<b>19TH JULY</b>	05:05	<b>21:07</b>	16h 1m	<b>21:52</b>	<b>22:37</b>
	<b>20TH JULY</b>	05:07	<b>21:06</b>	15h 59m	<b>21:51</b>	<b>22:36</b>
	<b>21ST JULY</b>	05:08	<b>21:05</b>	15h 56m	<b>21:50</b>	<b>22:35</b>
	<b>22ND JULY</b>	05:09	<b>21:04</b>	15h 54m	<b>21:49</b>	<b>22:34</b>
	<b>23RD JULY</b>	05:11	<b>21:02</b>	15h 51m	<b>21:47</b>	<b>22:32</b>
	<b>24TH JULY</b>	05:12	<b>21:01</b>	15h 48m	<b>21:46</b>	<b>22:31</b>
	<b>25TH JULY</b>	05:13	<b>21:00</b>	15h 46m	<b>21:45</b>	<b>22:30</b>
	<b>26TH JULY</b>	05:15	<b>20:58</b>	15h 43m	<b>21:43</b>	<b>22:28</b>
	<b>27TH JULY</b>	05:16	<b>20:57</b>	15h 40m	<b>21:42</b>	<b>22:27</b>
	<b>28TH JULY</b>	05:18	<b>20:55</b>	15h 37m	<b>21:40</b>	<b>22:25</b>
	<b>29TH JULY</b>	05:19	<b>20:54</b>	15h 34m	<b>21:39</b>	<b>22:24</b>
	<b>30TH JULY</b>	05:21	<b>20:52</b>	15h 31m	<b>21:37</b>	<b>22:22</b>
	<b>31ST JULY</b>	05:22	<b>20:51</b>	15h 28m	<b>21:36</b>	<b>22:21</b>

\*Denotes Start Date for Field Work

\*\*Denotes End Date for Field Work