ABSTRACT

Bat Foraging Activity and Insect Abundance in Relation to Light Intensity
on Baylor University Campus

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The relationship between bats and urbanization is not yet well understood. Whereas bats are nocturnal and generally operate in darkness, insects tend to be drawn to illumination at nighttime. For this project, the relationships between bats and light and insects and light were being studied to determine how foraging activity of bats and insect abundance in an urban setting might vary in connection to different levels of artificial lighting. Echolocation signals were recorded over four weeks each night from 1900 hours to 0700 hours for five consecutive nights using ultrasonic detectors. The twelve locations on the Baylor University campus fall into groups of four based on the average nighttime light intensity due to the artificial lighting: low, medium, or high intensity. Insect abundance was tested once per week at each sampling location using non-toxic glue traps. To analyze the echolocation data, we utilized a program SONG SCOPE 4.0.7. An analysis of variance (ANOVA) revealed that bat foraging activity is significantly related to light intensity, and that foraging activity was higher in areas with higher light intensity ($P \leq 0.0001$). ANOVA of the insect abundance data showed that insect abundance was not significantly impacted by light intensity ($P \leq 0.733$).

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BAT FORAGING ACTIVITY AND INSECT ABUNDANCE IN RELATION TO LIGHT INTENSITY ON BAYLOR UNIVERSITY CAMPUS

A Thesis Submitted to the Faculty of

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In Partial Fulfillment of the Requirements for the

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By

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CHAPTER ONE

Introduction

Texas is not only one of the biggest states in the continental United States, but it also is home to an estimated 33 species of bats from four different families of Chiroptera (Schmidly 2004). McLennan County, where Waco is located in central Texas, is within the geographic range of at least six species of bats including the Mexican free-tailed bat (*Tadaria brasiliensis mexicana*), the eastern red bat (*Lasiurus borealis*), the cave myotis (*Myotis velifer*), the hoary bat (*Lasiurus cinereus*), the seminole bat (*Lasiurus seminolus*), and the big brown bat (*Eptesicus fuscus*) (Schmidly 2004). Of these six, the Mexican free-tailed bat is most studied in Waco with the majority of previous studies focusing on this species' use of man-made structures for roosts and roosting fidelity (Fraze and Wilkins, 1990; Scales 2002).

Previous research on *T. brasiliensis* in Waco makes it an ideal species to relate to this study of the significance of urbanization and light intensity on a species' foraging activity and food source. This species is one of the best known of the North American bats because of its widespread occurrence and abundance (Schmidly 1991; Wilkins 1989). *T. brasiliensis* is an insectivorous bat that has been known to play a significant ecological role of controlling insect populations. After successful summers of breeding, over 40 million of these bats are available to forage and consume between 6,000 and 18,000 metric tons of insects annually in Texas (Schmidly 2004). Although considered to primarily be a cave-dwelling species, *T, brasiliensis* is also considered to be a generalist, or 'house bat', species which has adapted to living in many environments from holes in forest trees to urban anthropogenic structures such as bridges (Schmidly 2004). In one study concerning the use of spatial features by foraging insectivorous bats in a large urban landscape like Mexico City, *T. brasiliensis* reportedly used urban areas such as large parks and illuminated areas. These bats, classified as molossids and fast fliers, can roost in urban habitats, and were observed to have benefited from the roosting places offered by urbanization and the insects that were attracted to the urban lights (Avila-Flores and Fenton, 2005). Their main diet consists of insects about 2-10 mm in length and includes moths (Lepidoptera), flying ants (Hymenoptera), June beetles and leaf beetles (Coleoptera), leafhoppers, and other true bugs (Hemiptera) (Schmidly 2004). The Mexican free-tailed bat uses echolocation to identify the majority of objects and is thought to have limited use of eyesight and poor visual acuity although no studies have been performed in that area yet (Schmidly 1991). When it finds food, its echolocation calls increase from about 5 per second to about 200 per second as it closes in on prey. This is known as a ‘feeding buzz’ and corresponds to foraging activity (Schmidly 1991). Their occurrence in urban landscapes and dependence on certain insects as food sources makes this species a good species to keep in mind while analyzing this particular study.

In general, bats will forage, or leave their roosts, to search for food. Foraging activity by bats can be connected to light intensity, insect abundance, and location. In rural areas with intense bat activity, the towns were illuminated and had some vegetation according to an article pertaining to studying foraging habitats by bats in a Mediterranean area which were determined by acoustic surveys (Russo and Jones, 2003). Lighting in certain areas also affects insect abundance which can then affect bat activity. Researchers in the Negev Desert discovered that bat activity was high around artificial lights and sewage ponds because of aggregation of insects (Karine and Pinshow, 2001). Increased vegetation and artificial light lamps in the Mexico City study both were found to increase insect abundance as well (Avila-Flores and Fenton, 2002).

One way to study general bat foraging activity is through analyzing echolocation calls recorded by a device as the bats emerge from their roosts for feeding each night. By using bat detectors and walking for about a half hour or more after sunset, researchers in the London area were able to acoustically detect the activity of the bats and to determine which species were active at what times (Gaisler, et al.1998) Echolocation calls can be distinguished from other noises by their frequencies and patterns. Calls of different species can be distinguished by comparing known call recordings of each species previously recorded by other researchers and archived for future use. Furthermore, the two types of calls bats make, commuting calls and foraging calls, can be recognized by analyzing the shape of the call and the frequency at which it was produced. Discovering which bats are active and when in the Waco area based on their calls can help determine the feeding patterns of bats nearest to the city. This information, in turn, can be used to explore ways that urbanization of areas impacts species occupying other cities around the world.

Light intensity and insect abundance are factors that affect levels of bat foraging activity. In regards to light intensity, most species of bats are nocturnal and they emerge from roosts around sunset when the natural light intensity diminishes. However, artificial lights in particular areas may delay the emergence of the bats because the light intensity is still strong after sundown. In one study pertaining to the effects of anthropogenic light pollution on an endangered species in Britain, *Rhinolophus hipposideros,* the results showed that street lights affect the commencement of bat activity by causing them to emerge later than normal by about an hour, missing peak prey abundance time. It also causes them to either risk exposure to predators at night or take alternative foraging routes which cause increased energy expenditure and increased exposures to elements like rain and wind as the other routes provide less coverage when foraging (Stone, et. al, 2008). Increased light intensity could provide benefits to some bats though by attracting more insects. Human construction of artificial lights of different colors and lux, a unit referring to light intensity, attracts insects to the area, including insects that bats might prey upon. A London study showed scientists that mercury vapor lights (bluish-white) are more attractive to insects and therefore bats, as opposed to low pressure sodium lamps which emit a yellow-orange light and are being used to replace the mercury lights and decrease bat activity in certain areas (Gaisler, et al, 1998). Cities that continue to use mercury vapor lights may draw new species of bats to feed in urban locations because the bats' food source would be more abundant and easy to capture. It is also important to take insect abundance into consideration because the abundance of insects can not only affect foraging choice, but also the duration of foraging and even time of parturition in some species (Karine and Pinshow, 2001). A way to examine and confirm the relationship between insect abundance and light intensity in Waco is by collecting insects overnight near echolocation recording sites.

Other variables that might affect levels of bat foraging activity could be the presence of a water source near a recording location, and nightly weather conditions. Water is a necessity for all mammals for survival. Therefore, bats may be more drawn to certain areas simply because those areas have water and that water might also be surrounded by an environment for prey insects. Weather patterns may also affect the activity of bats because rainy days would diminish natural light levels, thus decreasing insect activity and making it unprofitable for bats to forage. Rain might also physically make it difficult for insects to fly, thus reducing the bats' food supply. Seasonal differences also probably influence which insect species are present at different times of the year, which can also influence when bats choose to forage (Russo and Jones, 2003).

A method combining acoustic detection of bats and insect abundance sampling was utilized for research on Baylor University's campus for this project. The purpose of this study is to further explore the relationships between bats, insects, and light intensity, and to find significant and related trends. By accumulating echolocation recordings and insect samples over a one month period, the results will help scientists further understand the human impact of urbanization on local bat species. Based on the collected data, if the foraging ratios of bats and insect abundance are significantly and directly related to light intensity, then bat foraging in part directly depends on insect abundance which directly depends on light intensity. This means that as light intensity increases, insect abundance increases, and therefore bat foraging activity increased. The null hypotheses state that there will be no significance difference between the foraging ratios of bats at different light intensities or between insect abundance and light intensity.

CHAPTER TWO

Materials and Methods

This study was conducted in Waco, McLennan County, Texas on the Baylor University campus. Echolocation recordings were recorded and the number of foraging call events per hour was used to indicate levels of bat feeding activity at different locations. Analyzing collected samples of the insect community at each area also showed the correlations between insects, bats, and light intensities. Echolocation recordings and insect collections took place at twelve locations (Fig.1). These sample sites represented three levels of nighttime light intensity. The high light intensity locations were comprised of areas by the soccer field (Fig. 2), on the top level of the Dutton Avenue parking garage (Fig. 3), behind the McLane Student Life Center (Fig. 4), and on the top level of the 5th Street parking garage (Fig. 5). The medium light intensity locations included locations near Robinson Tower (Fig. 6), the top level of the Speight Avenue parking garage (Fig. 7), the top level of the Daughtrey parking garage (Fig. 8), and on the side of the 8th Street parking garage (Fig. 9). The low light intensity sites were behind the Baylor Law School (Fig. 10), on the side of the Lewis Art Building (Fig. 11), behind the Browning Armstrong Library (Fig. 12), and near the Carroll Science Building in the middle of campus (Fig. 13).

All of the light intensities were previously determined by Biology doctoral student Han Li using an Extech Instruments Easy View 30 Light Meter. To determine which sites had high, medium, or low light intensities, light meter readings were

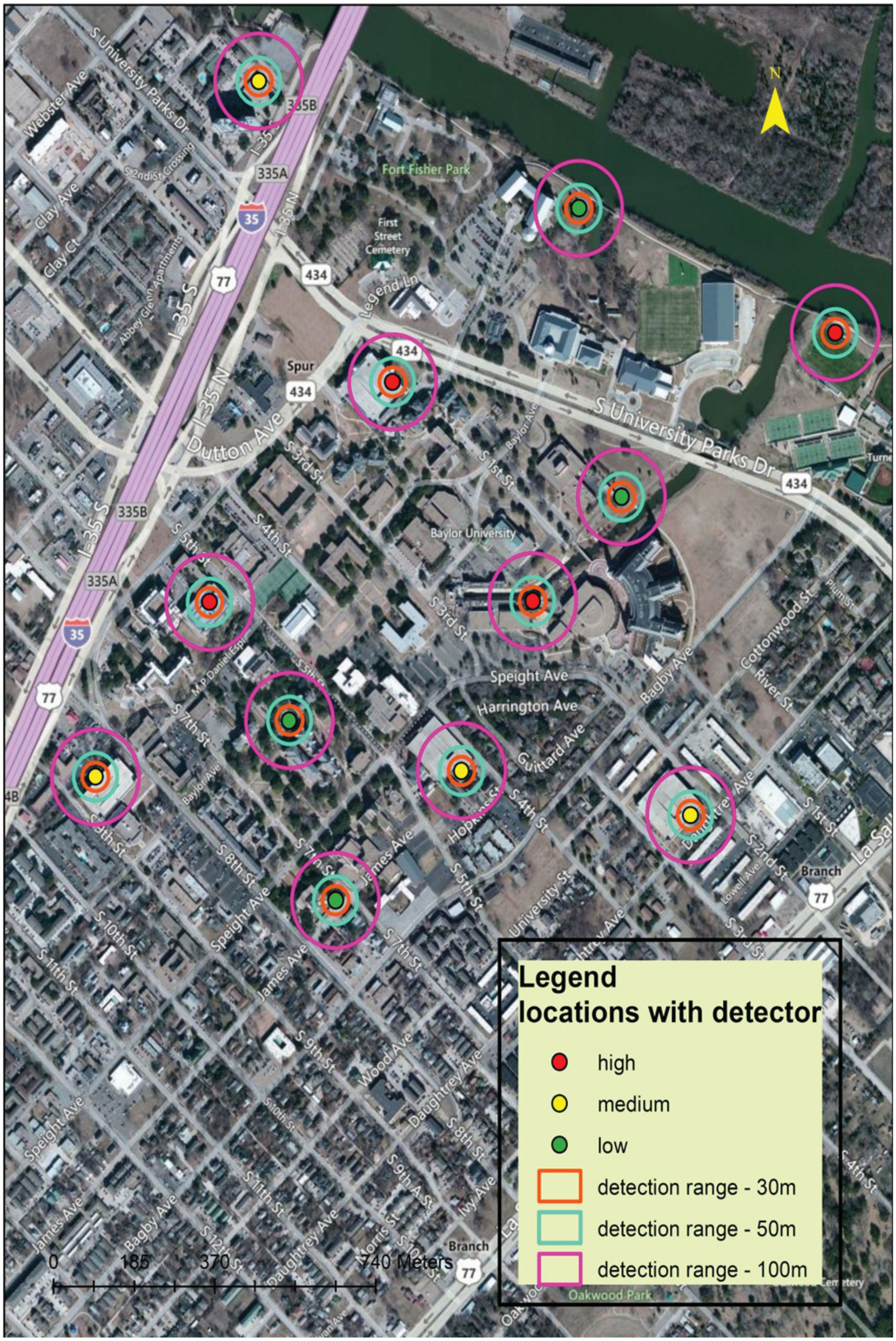

Figure 1: Map of the Baylor University campus, showing the twelve stations used for monitoring echolocation calls of bats and sampling insect abundance. Courtesy of Google Maps; created by Han Li.

conducted at each location and then related to the number of lights was counted within a 50 meter radius around each detector. This radius was previously determined by the use of a measuring tape. The intensity of light at each detector was the average of three light meter readings. The stations with the brightest illumination averaged approximately 200 klux, corresponding to approximately 50 lights within the radius surrounding each detector. The stations with medium illumination averaged about 100 klux, corresponding to about 20 lights within the radius surrounding each detector. The lowest illumination stations averaged approximately 50 klux, corresponding to approximately 10 lights within the radius surrounding each detector. These light illumination values correspond to high, medium, and low light intensity areas which were used to determine the correlations between bat activity and light intensity, as well as between insect abundance and light intensity.

Figure 2: Outside of the soccer field

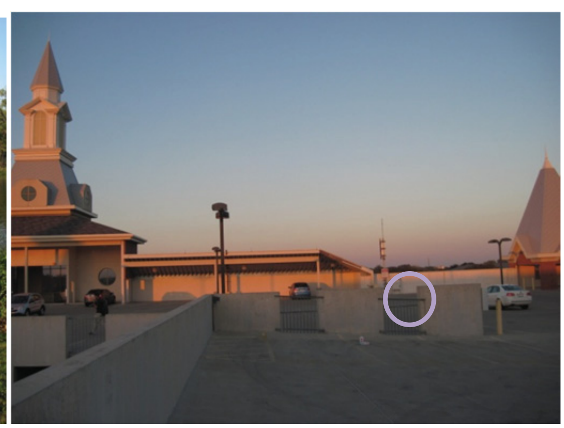

Figure 3: Dutton Avenue Parking Garage

Figure 4: Behind the Student Life Center

Figure 5: 5th Street Parking Garage

Figure 6: Robinson Tower Parking Garage

Figure 7: Speight Parking Garage

Figure 8: Daughtrey Parking Garage

Figure 9: Side of 8th Street Parking Garage

Figure 10: Behind Baylor Law School

Figure 11: Armstrong Browning Library

Figure 12: Side of Lewis Art Building

Figure 13: Carroll Science Building

To accomplish the survey of bats and foraging activity at the aforementioned sites, echolocation detectors were placed at each site in weekly cycles of four sites at a time. Four randomly selected locations from Fig. 1 were chosen for the placement of the detectors each week, and the detectors were set out on Mondays and collected on Saturdays. Each detector was placed in a metal box that was either attached via metal screws to the concrete siding of a building, or attached to a 1.22 meter metal rod (Fig. 14). The metal boxes have only one opening through which the detector microphone protruded and had removable lids that were secured to the boxes by screws (Fig.15).

Figure 14: Echolocation detector apparatus attached to a rod

Microphone covered by plastic wrap ↓

Figure 15: Metal box with echolocation detector inside and microphone protruding outward

The microphones were covered with a sheet of plastic wrap to avoid ruining the microphone tops should there be any rainfall during recording weeks. The apparatuses composed of metal boxes and rods were created and conceptually devised by Han Li and the Baylor Grounds Crew. After installing four D2 batteries, each detector was set to turn on at 1900 hours and off at 0700 hours each night for Monday through Friday, and the data were recorded onto a 16 GB Secure Digital, or ‘SD,’ card. The data were transferred to a lab computer each week to enable analysis of echolocation call data using specialized software.

Echolocation signals were recorded from Monday, September 26, 2011, to Friday, October 14, 2011, representing one 4-week sampling session. A method utilizing stratified randomness within each light intensity group allowed for the random selection of four sites including at least one site of high, medium, and low light intensity for each weekly sampling interval. The Song Meter SM2BAT (Wildlife Acoustics, Inc., Concord, MA) echolocation recordings were analyzed using a program called SONG SCOPE 4.0.7 (Wildlife Acoustics Inc., Concord, MA). This program shows the frequency of activity recorded in kHz over time in milliseconds. The analyst can see and play the recordings on the system to record the call time, duration of each call, and type of call onto a Microsoft Excel spreadsheet. To obtain manageable data from the analysis of the echolocation recordings using SONG SCOPE 4.0.7, any group of three or more bat calls was determined to be a viable set of calls and could be used in the call event count for each location. Calls were distinguished by the analyst from other interference signals by looking for a low frequency (20 kHz-40 kHz), flat, recurring, box-shape for commuting calls (Fig.16), or for a high frequency (40 kHz-60 kHz), recurring L-shape for foraging calls (Fig.17). Once the total call events had been manually counted and labeled as commuting or foraging for each location for each recording night, the total call events for each site in one night were divided by the total number of recording hours in the night, which was always 12 hours. This yielded the call events per hour for each site for each recording night. Then all of the foraging call events were totaled and divided by 12 hours to get the number of foraging call events per hour for each location for each recording night. The foraging ratio was calculated by dividing the foraging call events per hour by call events per hour for each location on each recording night.

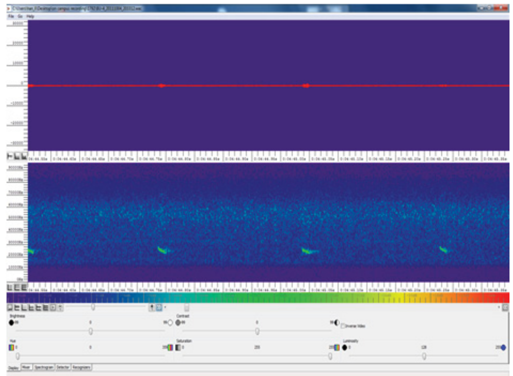

Figure 16: Typical commuting call event

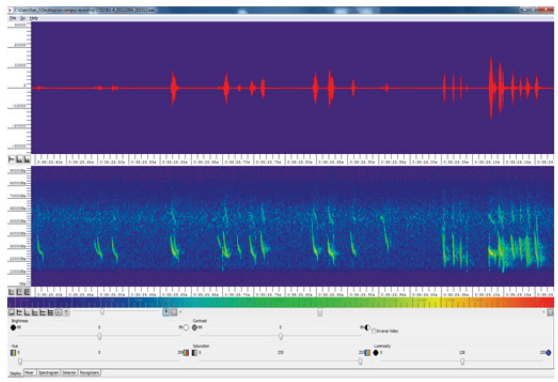

Figure 17: Typical foraging call event

A statistical method called ANOVA (Analysis of Variance) is used to test for differences between mean values. A p-value ≥ 0.05 means that the result of the test has a strong possibility of being influenced by coincidences or other factors outside of the two variables being compared. If the p-value is < 0.05, then the result is most likely not due to coincidence. ANOVA was used to compare the mean values of total call events per hour at the various light intensities, as well as for mean foraging ratio (foraging call events per hour/total call events per hour) and light intensity. Using this test will show whether bat foraging activity is significantly related to light intensity.

Another aspect of this experiment includes sampling the insect variety and abundance at each of the twelve locations. This was done by securing one CatchMaster

Replacement Board (non-toxic glue traps for a 911 Flying Insect Light Trap) about 20 cm by 41 cm long to a nearby pole or to the apparatus itself if no nearby pole was available. Orange surveyor's tape about 3 cm wide was used to secure the fly paper to the poles. The fly paper was set out once a week at 1900 hours on nights that seemed promising for good weather and bat activity at the four randomly selected sites and was collected at 0700 hours the next day. Then the papers were analyzed using a stereo microscope and insect identification books to determine the types of insects (to the level of order), their size to the nearest millimeter, and their abundance on the paper. The sizes of the insects were measured using a ruler and their abundance was recorded by size. Small insects were considered to be smaller than 1 mm, and large insects anything greater than 1 mm. ANOVA was run to compare small insect abundance and light intensity. Pie charts were used to show the abundance of orders of large insects in relation to light intensity. Analysis of this data examined whether insect abundance and order was significantly related to light intensity, and if that, in turn, may play a role in the possible relationship between bat foraging activity and light intensity.

CHAPTER THREE

Results

During the interval between September 26 and October 14, 2011, a total of 76 night recordings were made for the 12 sites at low, medium, and high intensities. Table 1 presents the light intensities, dates of recording, number of recording nights, and number of call events recorded for each of the sampling sites.

Table 1-Recording Locations on Baylor University Campus with Light Intensity, Dates of Sampling, Number of Nights Echolocation Calls were Recorded, and Number of Call Events Recorded

Site	Light Intensity	Sampling Dates	Number of Recording Nights	Number of Call Events Recorded
8th Street Parking Garage	M	9/26-9/29	4	221
Browning Library	L	9/26-9/29	4	228
McLane Student Life Center	H	9/26-9/29	4	244
Daughtrey Parking Garage	M	9/26-9/29	4	221
Speight Avenue Parking Garage	M	9/30-10/6	7	387
Law School	L	9/30-10/6	7	399
Soccer Field	H	9/30-10/6	7	427
5th Street Parking Garage	H	9/30-10/6	7	427
Robinson Tower	M	10/7-10/14	8	442
Carroll Science Building	L	10/7-10/14	8	455
Dutton Parking Garage	H	10/7-10/14	8	488
Art Building	L	10/7-10/14	8	455

More than 4390 call events were recorded for all sites over the whole sampling period; the average number of call events per hour, average number of foraging call events per hour, and foraging ratio were calculated for each site (Table 2).

Table 2-Descriptive Statistics (Mean, Standard Deviation, Minimum and Maximum values) for Bat Echolocation Calls Recorded on Baylor University Campus

Light Intensity	Number of Sites	Number of Recording Nights	Call Events/Hour				Foraging Call Events/Hour				Foraging Ratio			
			Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
L	4	27	4.74	1.84	0.00	7.60	1.72	0.77	0.00	2.50	0.39	0.15	0.00	0.57
M	4	23	4.60	1.97	0.00	8.60	2.10	1.34	0.20	5.60	0.42	0.17	0.00	0.70
H	4	26	5.08	1.63	0.10	9.30	2.89	1.17	0.00	5.00	0.55	0.16	0.00	0.89

The number of call events per hour ranged from 4.60 at medium-intensity sites to 5.08 at high-intensity sites. The intermediate value of 4.74 call events per hour was at the sites with lowest light intensities. ANOVA demonstrated that these means were not significantly related to light intensity. There were two degrees of freedom for this test, and the F-statistic was 0.455. The p-value for total call events per hour in relation to light intensity was > 0.05 at 0.636, so there was no significant difference between sites for this variable.

The foraging ratio is the result of dividing mean foraging call events per hour by mean total call events per hour for each light intensity group. This variable ranged from 0.39 at low-intensity sites to 0.55 at high-intensity sites. The median of the means was 0.42 at medium-intensity sites. ANOVA showed that the foraging ratio means are significantly different from each other. There were two degrees of freedom and the F-statistic was 11.027. The p-value was < 0.05 at 0.001, which means that the differences in foraging ratios were significantly different.

When comparing the results of the call events per hour, foraging call events per hour, and foraging ratio, the most notable difference between the three is which light intensity group has the lowest mean. The medium light intensity group had the lowest mean total call events per hour at 4.60, but had the middle mean values for foraging call events per hour and foraging ratio at 2.10 and 0.42 respectively. There is no overall trend for the mean total call events per hour versus light intensity, but there is an overall increasing trend from the low light intensity mean to the high light intensity mean for foraging ratio (Fig. 18, 19). This means that bat feeding activity increased on average as light intensity increased, but that the total calls the bats make in an area may not be related to light intensity since there was no observable trend among the averages.

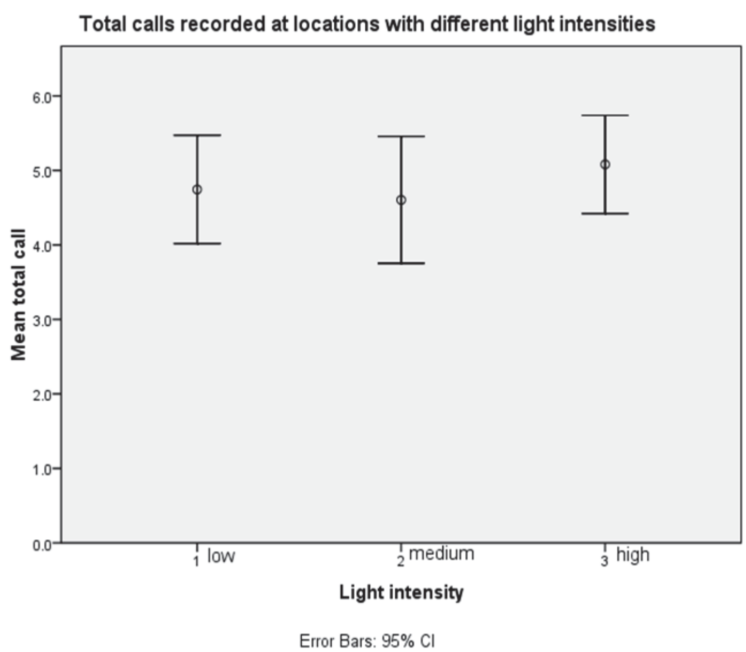

Figure 18: Comparison of the mean total call events and light intensity

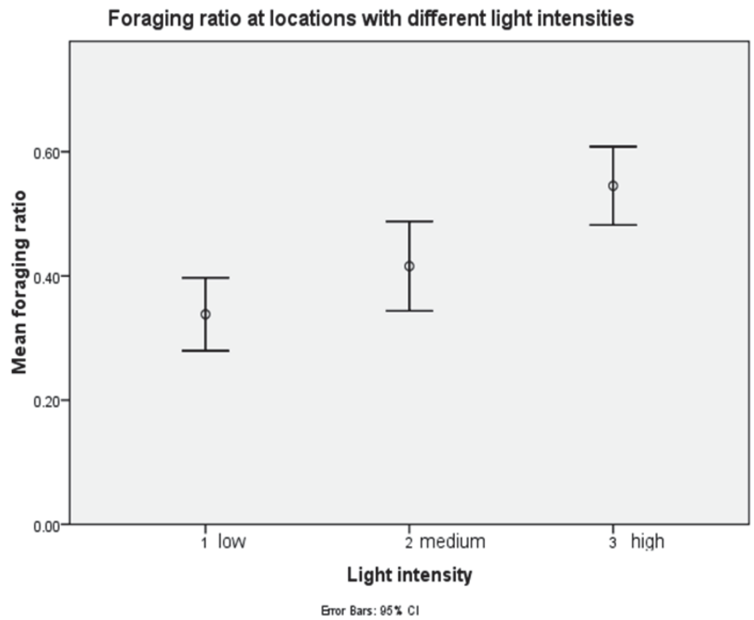

Figure 19: Comparison of the mean foraging ratios and light intensity

Insects were sampled at all 12 sampling sites to determine if either abundance or diversity of insects varied with levels of light intensity. Sampling produced a large number of small insects (< 1 mm in body length) at all three light intensity groups (Table 3). The pattern of absence and presence of different orders of insects suggests that light intensity may affect different orders variably. For example, order Blattodea was only present in low light intensity locations, whereas order Coleoptera was only found at high light intensities. For other orders like Diptera and Ephemeroptera, light may not be a significant factor because they were present at all three light intensity groups. Lepidoptera and Hymenoptera both could experience variable results since they were found in two of the three light intensity groups.

To determine if small insect abundance was significant in relation to light intensity, the means of the three light intensity groups were tested using ANOVA. The

Table 3- Orders of Insects and Small Insect Average at High, Medium, and Low Light Intensities

Group	Moth, Butterfly	Bee, Wasp, Ant	Fly	Beetle	Termites	Mayfly	Small insect average
Order	Lepidoptera	Hymenoptera	Diptera	Coleoptera	Blattodea	Ephemeroptera	N/A
High	P	A	P	P	A	P	86
Medium	A	P	P	A	A	P	76
Low	P	P	P	A	P	P	60

overall average of small insects was the greatest for the high light intensity group at 86 insects and smallest for the low light intensity group at 60. The medium light intensity group had the median mean value with average of 76 insects. The comparison between the small insect means compared to the three light intensity groups can be seen in Figure 20. For the analysis of variance test, the degrees of freedom were 2, and the F-statistic was 0.328. The p-value was 0.733, which is greater than 0.05. This means that there was no statistical significance found in the differences in small insect abundance values in comparison to varying light intensity.

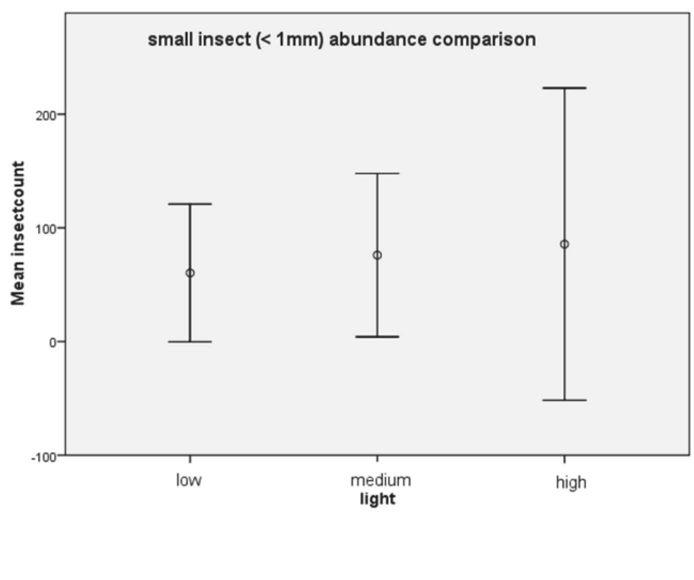

Figure 20: Mean small insect abundance in relation to light intensity

CHAPTER FOUR

Discussion and Conclusions

This study examined the relationship of levels of bat activity and insect abundance with variation in intensity of nighttime lighting. Foraging ratio averages significantly differed based on light intensity, whereas total call event averages and small insect abundance did not significantly relate to light intensity based on this study. Based on these results, the null hypothesis of no difference in bat foraging ratio in relation to varying levels of light intensity can be rejected. However the null hypothesis can be accepted for insect abundance in this study, as no statistical significance was found for the means at different light intensities. All three variables of bat activity, insect abundance, and light intensity are intertwined, but the relationship between bats and light intensity seems to be most important when it comes to determining where bats will forage.

These findings suggest that urbanization may play an important role in affecting the food source of insectivorous bats, and also, therefore, on the behavior of insectivorous bat species as a whole. Based on the orders of insects accumulated from sampling, four of the six can be directly linked to *T. brasiliensis* as part of its main food source. This may suggest that lights in Waco are attracting the food source of *T. brasiliensis*, and may therefore also attract this bat species. Because the high light intensity areas attract a multitude of insects, this should enable nearby foraging bats to feed efficiently. What this suggests is that it is energetically profitable for bats to travel to a high light intensity area, like those in cities, in order to fulfill the majority of their food requirements with the congregations of insects flying in highly illuminated areas. It seems that bats have evolved to forage efficiently in order to save energy, stay near the roost, and ultimately persevere. It would seem that the adaptation of taking advantage of opportunities to feed on insects that are drawn to the high light intensities provided by city lights best meets both needs of bats because both their food source and there roost are found in one location. Also, if the bats roost in the city, which is common for species such as *Tadarida brasiliensis* in Waco, then a suitable food source is not that far from their roost.

Since this study is solely based on one sampling round, continued data collection and analysis would benefit this study by confirming with greater statistical confidence that indeed bat foraging activity is directly related to light intensity, and that insect abundance may be significantly and directly related to light intensity. Also, further studies investigating the role bats' visual ability may play in their foraging behavior would help to further understand if certain light intensities can also help bats to see their prey better, and would therefore be favored locations for foraging.

Further analysis and development of a program comparing call structures and patterns to archived calls of certain species would be able to confirm which species of bats were actually recorded. However, since no such program exists yet, it was not possible to identify with confidence which species of bats, including *T. brasiliensis*, were actually recorded during this experiment.

Other factors concerning urban ecology could be more thoroughly investigated to ensure that they are not greatly affecting the results of variables in this study such as the temperature which changes with the seasons, weather events like rain or high winds, water availability near the sites, location of roosts, interspecies competition within the same area for a food source, and intraspecific competition should there be large numbers of one species competing for the same local food source.

For this 4-week study, the temperatures were fairly constant and warm with only a few weather events, so the insect populations and foraging opportunities likely were not greatly affected by the relatively steady temperatures. Also, water availability would probably not be of extreme significance because Waco has many ponds, lakes, rivers, and streams within easy reach of *T. brasiliensis*, the primary species in the immediate area. *T. brasiliensis* is a high-flying bat which travels long distances each night, so greater distance between food and water sources might not pose a difficulty. Also according to one study, lights will give the high-flying bats a consuming advantage since they will be able to fly higher and reach the insects that are also higher in the air (Longcore and Rich, 2004)

Interspecific competition could be a factor that influences bat foraging activity because the Mexican free-tailed bat and at least five other insectivorous species potentially live in the Waco area. Intraspecific competition could be another significant factor because the Mexican free-tailed bat tends to have roosts with large numbers of bats, so they would compete for food nearest to the roost to avoid flying too far away.

Development of a more reliable and accurate way to sample insect abundance in an area would also greatly benefit future projects of this type. Using fly paper might have skewed the results of insect abundance in the area because it has chemoattractants that specifically lure flies, bees, butterflies, and some other insects that might respond the same as if these chemicals were coming from flowers. Projects that focus more on species of bats and the specific types and sizes of insects that they feed on would also be beneficial in understanding if urbanization is affecting the food sources of particular species by either promoting or eliminating certain insects in the area.

Ultimately, coming to understand the relationships between urbanization and the ecology of bats and insects is very useful. Knowing how urbanization and additional light installation can affect the food source and feeding activity of bats will help biologists to further understand human impact on bat species and share that knowledge with those controlling urban development. Also, understanding how only some species can adapt well to feeding and living in urbanized conditions will help people to better predict the ecological impacts on any species of bat near an urban area including endangered species. These concepts are essential to understand how urbanization can affect mammals like bats in a world that is becoming urbanized at an exponential rate. Better understanding the relationships between light intensity, insect abundance, and bat foraging activity will better equip government leaders to know how their building plans affect the bat species and their food sources in those areas. This will help to avoid unknowingly urbanizing areas in which less-adaptable bats feed and roost to help preserve those species, and to also better understand how urbanization can affect adaptable bat communities in what could be considered a positive way. A widespread study of this kind could help to show how human actions through urbanization can affect all species of bats and to what degree, as well as help government leaders better protect and preserve the current diversity of bat species in the future.

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