ANNUAL AND TEMPORAL POPULATION CHARACTERISTICS OF *TADARIDA BRASILIENSIS* AND *MYOTIS VELIFER* AT THE OLD TUNNEL WILDLIFE MANAGEMENT AREA, KENDALL COUNTY, TEXAS

THESIS

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by

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ANNUAL AND TEMPORAL POPULATION CHARACTERISTICS OF *TADARIDA BRASILIENSIS* AND *MYOTIS VELIFER* AT THE OLD TUNNEL WILDLIFE MANAGEMENT AREA, KENDALL COUNTY, TEXAS

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The Old Tunnel Wildlife Management Area (OTWMA) bat population is considered a pseudomaternal colony and very little is known about this type of roost. Two species reside at OTWMA, the Mexican free-tailed bat (*Tadarida brasiliensis*) and the cave myotis (*Myotis velifer*). A harp net was used to capture bats. In 2003, my objectives were to 1) observe and document the netting night (annual) and time of netting night (temporal) activity patterns of this pseudomaternal colony of *Tadarida brasiliensis* and *Myotis velifer*, 2) measure and document changes in weights, gender, reproductive status, and age of *T brasiliensis* and *M velifer* throughout the night and time of night,

and 3) observe and approximate the timing of parturition and arrival of juvenile *T. brasiliensis* from nearby maternity colonies. Gender, age, reproductive status, and weight were analyzed. Preliminary capture data showed a skewed sex ratio for almost all trapping efforts with females outnumbering males 2:1 in both species. Results showed no correlations of the dependent variables to the regressions. Dependent variables included weight, bats per second, and the ratio of reproductive to non-reproductive adults. A two factor ANOVA was used for two categories, netting night and netting time class. Both categories were analyzed with the dependent variables and blocked for either gender or reproductive class accordingly. Finally, temporal autocorrelations were conducted to determine appropriate regression model statements, with or without time series correlations.

CHAPTER I

INTRODUCTION

In 1913, workers took approximately 10,873 m^3 of rock out of Big Hill, Kendall County, Texas, to create a 280 meter railroad tunnel for The San Antonio-Fredericksburg & Northern Railroad (Schmidt 1973). In 1991, a nearly 41,683 m^2 tract of land surrounding the southern entrance of the railroad tunnel was acquired by Texas Parks and Wildlife, eventually becoming The Old Tunnel Wildlife Management Area (OTWMA). The OTWMA is located in the Edwards Plateau Ecological region. Today, it is a non-game management area created to protect the population of bats residing in the tunnel. The resident bat population consists of the Mexican free-tailed bat (*Tadarida brasiliensis*) and cave myotis (*Myotis velifer*) (Tanner 1999, Hein 2001). This is not unusual because these two species are often found in close association at other roosting sites (Twente 1955). In OTWMA their numbers peak at an estimate of three million bats (end of July through August) (Wallace and Lawyer 1996).

The OTWMA bat population is unlike that of any cave, bridge, or even bat house maternal colonies in that it is considered a pseudomaternal colony (Bailey 1993, Wallace and Lawyer 1996, Harper 1997, Tanner 1999). There are no known records of pups within the tunnel, however, pregnant and lactating females make up a large portion of the summer population along with a small number of males (Tanner 1999, Hein 2001). From inspections of the ceiling and walls of the tunnel, there has been no evidence that females actually raise young here but instead use this as an alternative roosting site or as a night roost (Bailey 1993, Wallace and Lawyer 1996, Harper 1997, Tanner 1999). This datum was reemphasized from personally inspecting the ceiling and walls of the tunnel in July 2003, when lactating females were most abundant and before any volant juveniles were captured.

There is substantial information about the Mexican free-tailed bat but little on the cave myotis (Schmidly 1991, J. Kennedy, Texas Speological Association and Bat Conservation International, personal communication, and M. D. Tuttle, Bat Conservation International, personal communication). The cave myotis is found in colonies ranging from hundreds to thousands (Fitch et al. 1981); whereas, the Mexican free-tailed bat can be found in colonies consisting of millions (Wilkins 1989). Males usually stay in Mexico, although a few male bachelor colonies have been found north of Mexico (Davis et al. 1962, Villa and Cockrum 1962). Davis et al. (1962) and Villa and Cockrum (1962) found Mexican free-tailed females migrate to locations north of Mexico during the summer birthing season. Fluctuating ratios of males are seen at transient colonies with most males consisting of only the present year male offspring before they are fully mature (Cockrum 1969). Adult females also occur at transient roosts and their ratios fluctuate as well (Cockrum 1969); however, they are more abundant at OTWMA (Tanner 1999, Hein 2001).

Studying entire seasonal and nightly activity patterns of the OTWMA bat population was needed to further understand the full extent of roosting requirements of these two species. Several species of bats have been found to require more than one type of roosting site and/or habitat in one season (Anthony et al. 1981), which necessitates studying other types of roosts along with prominent and commonly studied maternal colonies. There also is a need to study site-specific populations of bats, so that they can be managed properly with changes in populations monitored over an extended time.

My objectives were to 1) observe and document the netting night (annual) and time of netting night (temporal) activity patterns of this pseudomaternal colony of *Tadarida brasiliensis* and *Myotis velifer*, 2) measure and document changes in weights, gender, reproductive status, and age of *T. brasiliensis* and *M. velifer* throughout the night and time of night, and 3) observe and approximate the timing of parturition and arrival of juvenile *T. brasiliensis* from nearby maternity colonies.

CHAPTER II

MATERIALS AND METHODS

The Old Tunnel Wildlife Management Area is located in Kendall County, Texas (30°06.037' 98°49.250') south of Fredericksburg and north of Comfort on Old #9 Highway (Fig. 1). The tunnel itself is 280 m long, 6 m high, and 5 m wide (Bailey 1993). During construction, a hole was bored into the middle of the tunnel to provide fresh air for workers (Schmidt 1973). This allowed water to seep from the ground and run along the ceiling a short distance, eventually falling on the tunnel floor. It is beyond this halfway point from the tunnel bore-hole continuing to the northern entrance (leads onto private property) where bats congregate, covering the ceiling and upper portions of the walls. When emerging, bats fly out the southern entrance, using the distance from their roosting location on the tunnel ceiling to gain enough momentum to spiral out and immediately climb out of the 12 m vertical cliffs.

Research commenced on 21 March 2003, when the first signs of flying bats were observed. Activity was based on whether any bats flew out the southern entrance of the tunnel. Research was concluded on 18 October 2003, when bat activity became unpredictable.

A harp net was the main instrument used to capture bats (Constantine 1958, Tuttle 1974, Kunz and Kurta 1988). The net used was 1.8 x 2 m and double framed with each

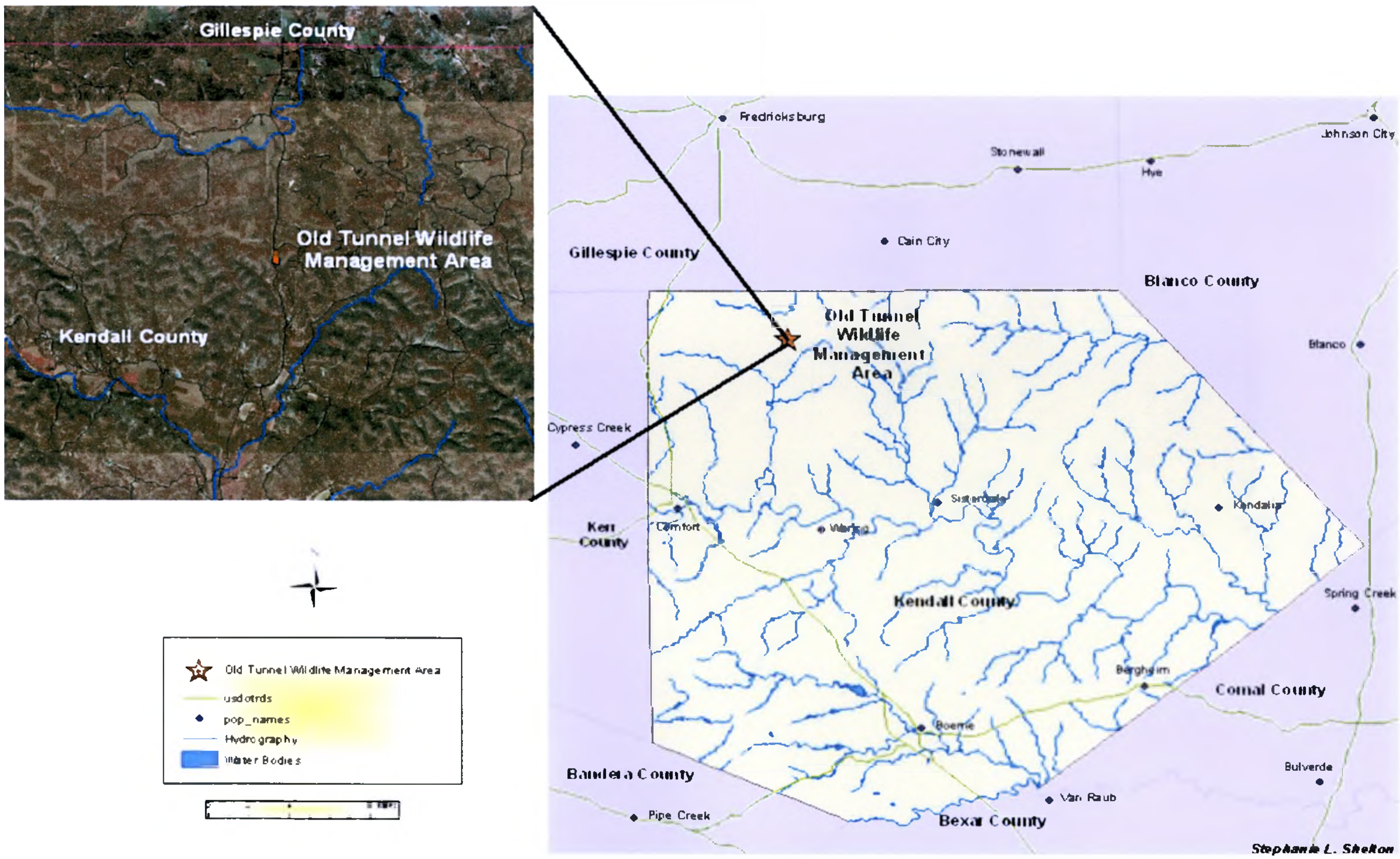

Figure 1. Location of Old Tunnel Wildlife Management Area in reference to the cities of Fredericksburg and Comfort, Texas.

monofilament line offset from one another. A large number of bats can be captured in a harp net and quickly removed so that stress to the bat is minimized. The net was suspended from a metal pole in front of the tunnel's southern entrance. The net covered the middle and upper portions of the entrance where a majority of bats fly in and out of the tunnel. At the beginning of the season, a 1.22 x 5.49 m four-shelved mist net was suspended underneath the harp net. The mist net was used because of the small number of bats present in the tunnel, and some avoided the harp net. The mist net captured bats that successfully evaded the harp net.

Trapping efforts were broken down into hourly segments from emergence until the majority of bats had presumably arrived back at OTWMA to roost the following morning. I ceased catching bats just before sunrise because, many times, they became disoriented and flew in the opposite direction of the tunnel entrance once released. To keep disturbances and predation on bats at a minimum, bats were processed and quickly released in the morning. After sunrise, no further nettings took place, even if bats were still flying into the tunnel.

Each hourly trapping effort required anywhere from a few seconds to a maximum of about 10 minutes. The lack of standardization for hourly capture was based on the unpredictable nature of the emergence and number of bats in the emergence, which could exceed thousands of bats within seconds at certain times of the season. During large emergences, the harp net was down for seconds with the majority of the post-emergence trapping lasting no longer than 10 minutes.

Once bats were obtained each hour, they were put into muslin bags. The age (Anthony 1988), gender, reproductive status (Racey 1988) and weight (using an Ohaus model HH320 electronic scale, Ohaus Corporation, NJ, USA, with a 30g Pesola spring scale, Pesola AG, Switzerland, for backup) of the Mexican free-tailed bats and cave myotis were recorded. Reproductive status consisted of four reproductive classes, which were blocked in statistical analyses. These classes consisted of pregnant, lactating, juvenile, and non-reproductive adults. Non-reproductive adults included adult males and non-reproductive adult females. The juvenile class was composed of volant juveniles lacking the epiphysial plate in their fourth metacarpal phalangial joint.

Interior environmental conditions of the tunnel were taken with a HOBO H8 Pro Series data logger (Onset Computer Corporation, MA, USA). Temperature and relative humidity were recorded from 12 February until 15 June, 2003. Minimum, average, and maximum temperatures and relative humidifies were listed (Table 6).

For statistical analyses, *Myotis velifer* captured were not included in group totals. Their minimal presence, as well as minute amount of data, were treated separately. Most analyses were based on *Tadarida brasiliensis* captured because they made up the majority of the bat sample population at OTWMA.

Analyses were conducted using S-PLUS statistical package for windows operating systems (Insightful Corporation, WA, USA). Analyses were categorized as netting night or netting time class. Nights were not blocked by seasons because there was no defined cutoff for the beginning or end of these periods within the year, only approximations. However, netting times were blocked into netting time classes. Time classes were based on one hour intervals, designated in military time. The genders of bats were analyzed separately when looking at the response variables weight, and ratio of bats per second. Weight and ratio of bats per second were analyzed for variation in netting night and then netting time class. Finally, the ratio of non-reproductive adult bats to reproductive and juvenile bats was analyzed for variation in netting night and then time class.

Some of my data were represented by a time series data set, which innately lacks independence from one week to the next. This data set was further confounded because observations were taken in a different time frame throughout the year, therefore, a straightforward time series analysis could not be used in some cases. For those that could not be analyzed using a simple correlation, a Euclidean spatial correlation was conducted (Pinheiro and Bates 2000). There was the potential for seasonal and temporal autocorrelations, therefore, each response variable factor analysis set was analyzed by ANOVA as serially correlated data and as uncorrelated data. To compare regression model statements, I used the log likelihood ratio (Draper and Smith 1998). Both model statements were compared with Aikiake weights for linear, quadratic, and cubic relationships to find the best fit regression model for the relationship. To determine where the differences in variation occurred in the factors, averages of each response variable were used to run a two factor ANOVA.

Further tests were conducted on the Mexican free-tailed sample population to examine sex ratios as well as separate juvenile sex ratios, ratios of pregnant and lactating females, and ratios of reproductive classes as compared to the entire population. A G-test was conducted on the Mexican free-tailed juvenile population to determine if their numbers deviated from an expected 1:1 sex ratio (Davis et al. 1962, Wilkins 1989, Kunz and Robson 1995, Hein 2001). Finally, sex ratios for the cave myotis population were determined.

CHAPTER III

RESULTS

A total of 7,647 *T. brasiliensis* and *M. velifer* were captured, measured, and released in 2003. Of the total number of bats netted, 2,260 were males and 5,387 were females, giving this population a skewed sex ratio of approximately 1:2. However, most females were non-reproductive meaning they were neither pregnant nor lactating. In the total female collection, 1,019 were lactating and only 662 were pregnant, possibly indicating that the environment of this tunnel is inappropriate as a maternal colony but may be a night roost for resting bats (J. T. Baccus, Texas State University-San Marcos, personal communication). A total of 1,040 bats were volant juveniles with an almost 1:1 sex ratio, and the rest (6,607) were adults.

The OTWMA bat population consists mostly of Mexican free-tailed bats. A total of 7,569 (99%) bats were this species. As a result, this sample's sex ratio closely follows the sex ratio for the entire bat sample population. Specifically, 2,235 were males and 5,334 were females with a sex ratio of approximately 1:2 (Table 1). Because of this, data for cave myotis were handled separately. From this point forward, the results apply only to Mexican free-tailed bats unless otherwise indicated.

From 18 April through 18 August, females from the pregnant (661) and lactating (1,010) reproductive classes were netted; a total of 4,864 bats were netted in all. During this time, a total of 4,864 bats were netted. These numbers were compared to the total number of bats from the population netted during this time frame. Pregnant bats composed 13.6% of the bat population and lactating bats 20.8% during 2003 (Table 2).

From 16 July through 12 September, bats could accurately be designated as juvenile or adult. During this time, 2,755 bats were netted with 1,032 being juveniles. Specifically, the juvenile sample was composed of 506 males and 526 females. Juvenile males made up 18.5% of the bat population and juvenile females 19.1% during 2003 (Table 3). Juveniles had close to a 1:1 sex ratio as expected. The ratios were analyzed against an *a priori* knowledge of a juvenile sex ratio of 1:1 (Davis et al. 1962, Wilkins 1989, Kunz and Robson 1995). Using the G-test, there was no significant difference in the sex ratio of volant juveniles (Table 3).

In the netting night category, the frequency of bats (bats/s) netted had a positive trend over the season (Fig. 2). There was a substantial peak during the first part of August, which was expected because of newly volant juveniles joining the adult population. However, regression analyses showed a very low correlation between the frequency in number of bats and netting night ($r^2 = 0.1366$). For both genders, the regression was explained by a linear regression model statement. The data were not serially correlated (Female: $x^2 = 0.075$, $p = 0.784$, Male: $x^2 = 0.711$, $p = 0.399$).

The average number of bats in the annual category compared to the netting night also had a slightly positive trend with low correlations (Fig. 3). For females the r^2 was 0.2432 and for males it was 0.374. The ANOVA was blocked for gender to account for

Table 1 Total number of *Tadarıda brasılıensıs*, wıthout respect to age, netted each nettıng nıght at Old Tunnel Wıldlıfe Management Area, Kendall County, Texas, 2003 Relatıve proportıons of males vs females for each nıght ıs shown ın parentheses

Date	Males		Females		Total
21-Mar	0		1	(100)	1
1-Apr	48	(17 9)	220	(82 1)	268
4-Apr	120	(32 2)	263	(67 8)	383
11-Apr	46	(33 3)	92	(66 7)	138
18-Apr	64	(26 2)	180	(73 8)	244
25-Apr	48	(24 9)	145	(75 1)	193
2-May	93	(26 3)	261	(73 7)	354
9-May	41	(16 1)	213	(83 9)	254
14-May	77	(22 1)	272	(77 9)	349
21-May	37	(30 6)	84	(69 4)	121
28-May	22	(16 2)	114	(83 8)	136
6-Jun	15	(26 8)	41	(73 2)	56
15-Jun	37	(56.9)	28	(43 1)	65
19-Jun	49	(49 5)	50	(50 5)	99
29-Jun	128	(42 4)	174	(57 6)	302
10-Jul	69	(23 2)	228	(76 8)	297
16-Jul	111	(34 5)	211	(65 5)	322
23-Jul	88	(19 7)	359	(80 3)	447
1-Aug	110	(35 7)	198	(64 3)	308
6-Aug	197	(36 5)	343	(63 5)	540
13-Aug	146	(34 4)	279	(65 6)	425
18-Aug	129	(36 6)	223	(63 4)	352
12-Sep	85	(23 5)	276	(76 5)	361
19-Sep	132	(32 9)	269	(67 1)	401
27-Sep	143	(29 8)	337	(70 2)	480
3-Oct	92	(30 7)	208	(69 3)	300
18-Oct	108	(29 0)	265	(71 0)	373
Total	2235		5334		7569

Table 2 Total number of reproductive female *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003 Relative proportions of pregnant and lactating bats compared to the total *T brasiliensis* captured are in parentheses

Date	Pregnant		Lactating		Total
18-Apr	5	(2 0)			244
25-Apr	16	(8 3)			193
2-May	52	(14 7)			354
9-May	95	(37 4)			254
14-May	231	(66 2)			349
21-May	65	(53 7)			121
28-May	102	(75 0)			136
6-Jun	39	(69 6)			56
15-Jun	26	(40 0)			65
19-Jun	27	(27 3)	5	(5 1)	99
29-Jun	3	(1 0)	147	(48 7)	302
10-Jul			195	(65 7)	297
16-Jul			144	(44 7)	322
23-Jul			239	(53 5)	447
1-Aug			75	(24 4)	308
6-Aug			101	(18 7)	540
13-Aug			64	(15 1)	425
18-Aug			40	(11 4)	352
Total	661		1010		4864

Table 3 Total number of juvenile *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003 Relative proportions of males vs. females for each night is shown in parentheses Sex ratios were tested for a deviation from the expected 1:1 ratio using a G-test The null hypothesis was accepted in all tests

Date	Males		Females		Total	d f	G
16-Jul			1	(100)	1	1	1 39
23-Jul	19	(47 5)	21	(52 5)	40	1	0 10
1-Aug	90	(48 6)	95	(51 4)	185	1	0 13
6-Aug	165	(47 4)	183	(52 6)	348	1	0 93
13-Aug	122	(50 0)	122	(50 0)	244	1	0 00
18-Aug	88	(51 5)	83	(48 5)	171	1	0 15
12-Sep	22	(51 2)	21	(48 8)	43	1	0 02
Total	506		526		1032		

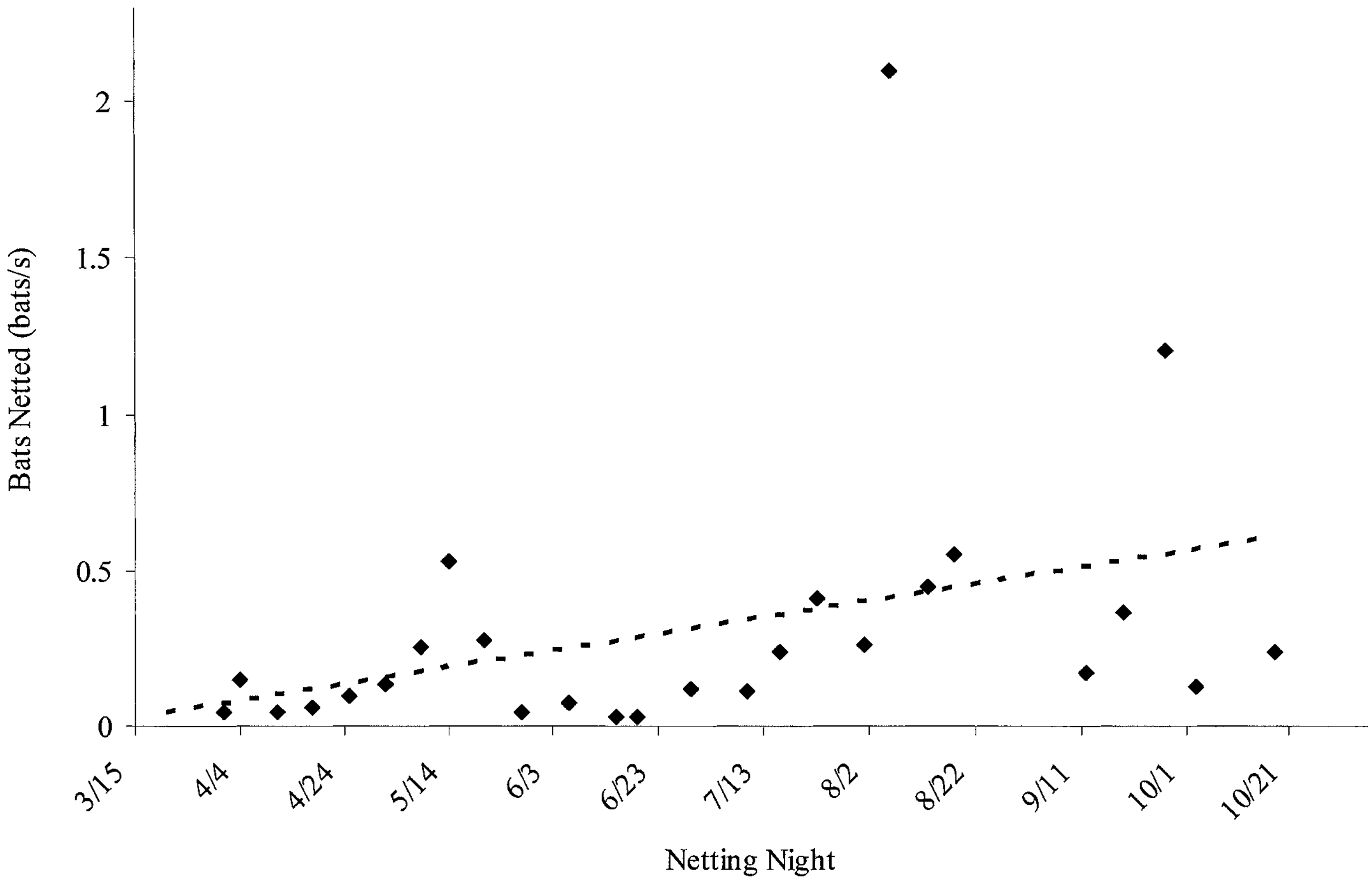

Figure 2. Annual frequency of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003

natural variations that may occur because of gender alone. The test produced a significant difference among nights ($F = 4.07, p < 0.001$) as well as gender ($F = 74.92, p < 0.001$).

The proportions of the four reproductive classes were compared to each netting night (Fig. 4). In 27 netting nights, the non-reproductive class was over 50% of the population except for 10 nights. In these 10 nights, four nights consisted of pregnant bats, two nights lactating bats, and the other four nights consisted of juveniles, which made up more than 50% of the population. The average number of bats in each reproductive class was used in ANOVA instead of the proportion of number of bats in each reproductive class. The reproductive classes were blocked to account for natural variations that may relate to the reproductive class alone. There was a significant difference among reproductive classes ($F = 15.88, p < 0.001$); however, there were no differences among netting nights ($F = 0.52, p = 0.95$).

The annual variation in weight was compared with the netting night (Fig. 5). The trend was slightly negative but there was virtually no correlation in weight and the netting night ($r^2 = 0.005$). When the genders were separated this did not change the strength in the correlation between netting night and weight (Fig. 6). For both genders the regression was explained by a linear regression model statement. The data were serially correlated (Female: $x^2 = 156.816, p < 0.0001$, Male: $x^2 = 50.802, p < 0.0001$). I blocked by gender in the ANOVA to account for natural variation caused by gender alone. There was a significant gender effect ($F = 7.80, p = 0.010$); however, there was no difference in nights ($F = 1.23, p = 0.30$).

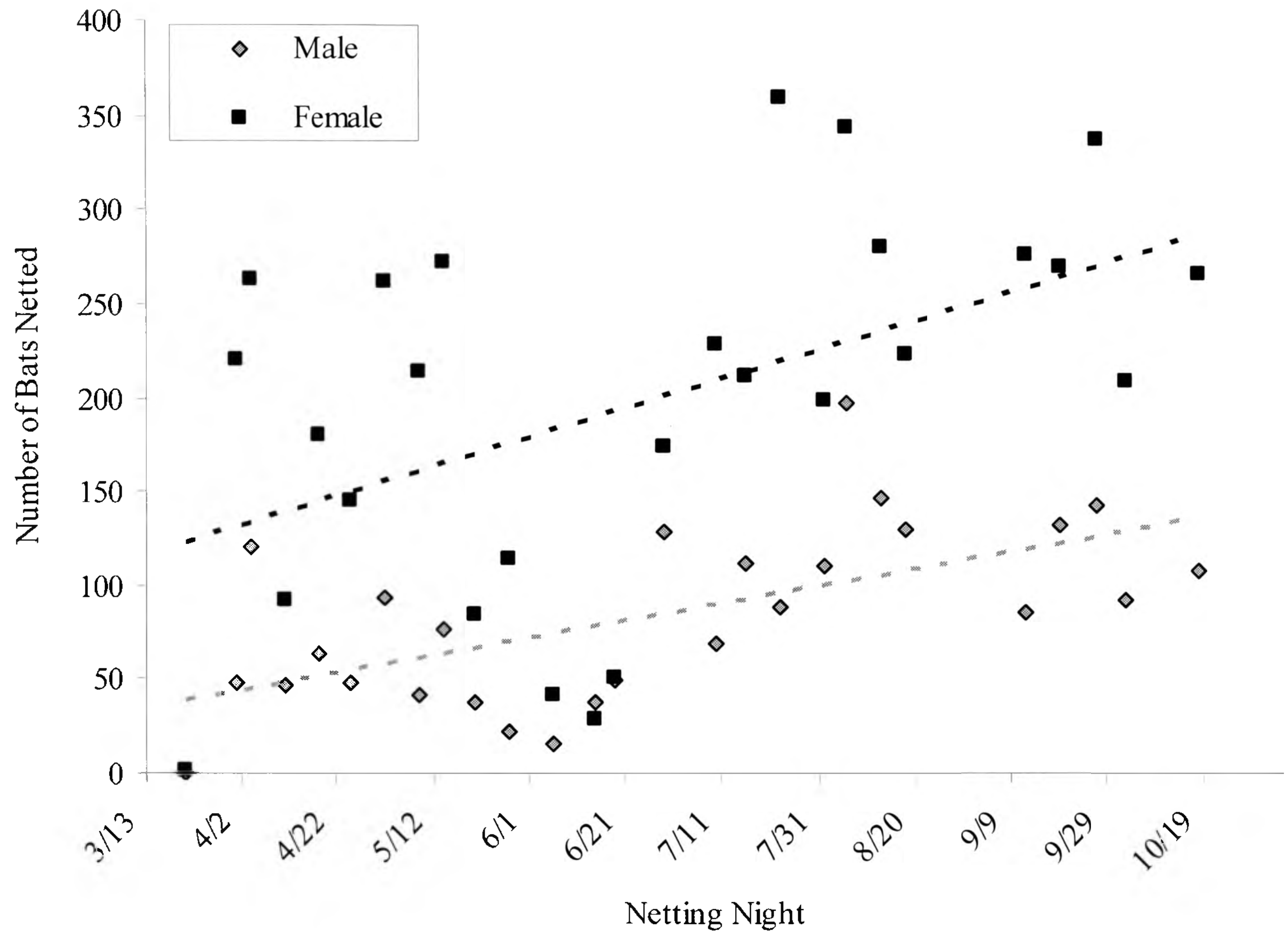

Figure 3. Annual number of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Males and females were treated as a blocking factor.

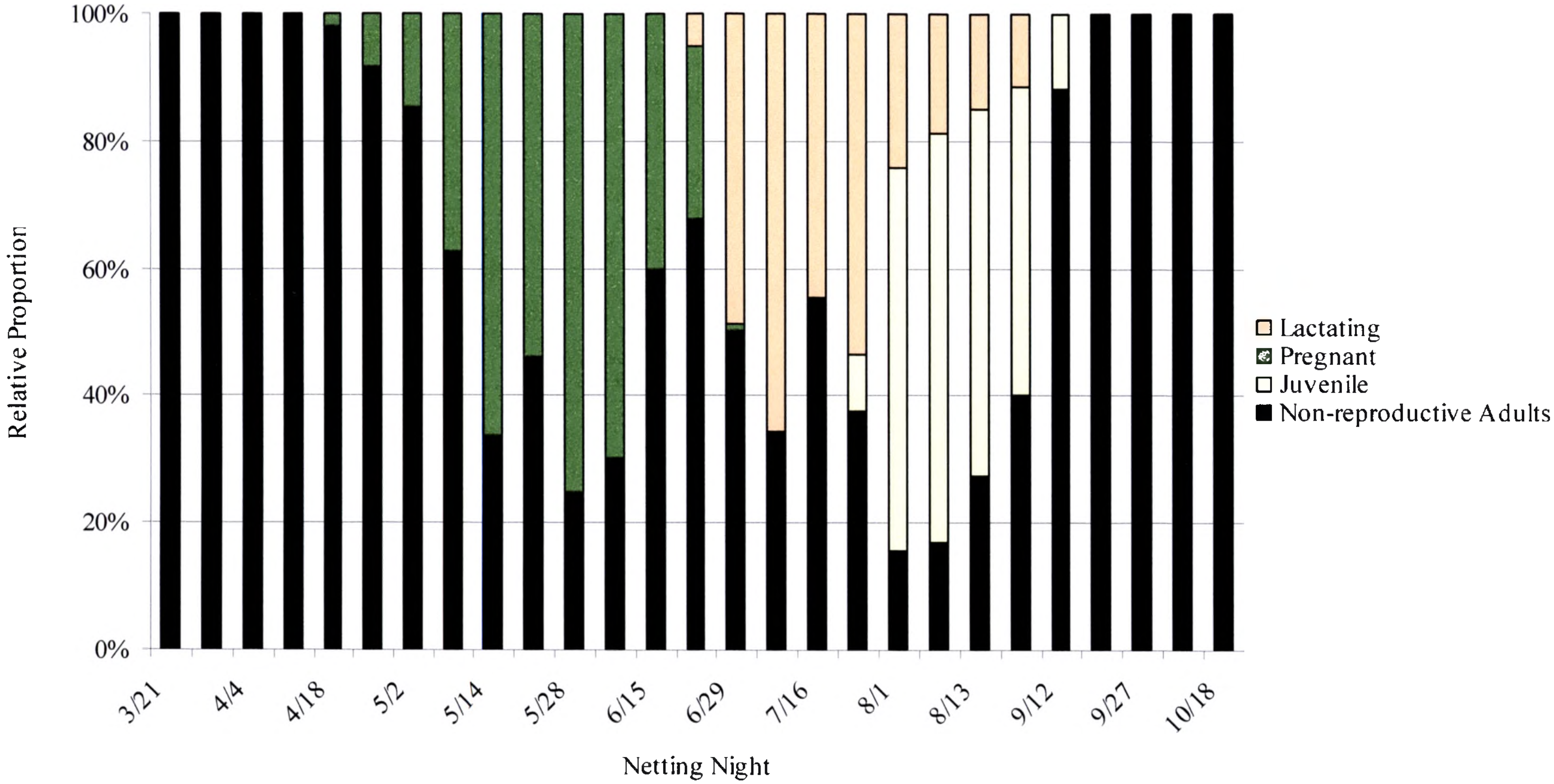

Figure 4. Annual relative proportion of *Tadarida brasiliensis* reproductive classes netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Lactating and pregnant females, juveniles, and non-reproductive adults were treated as a blocking factor.

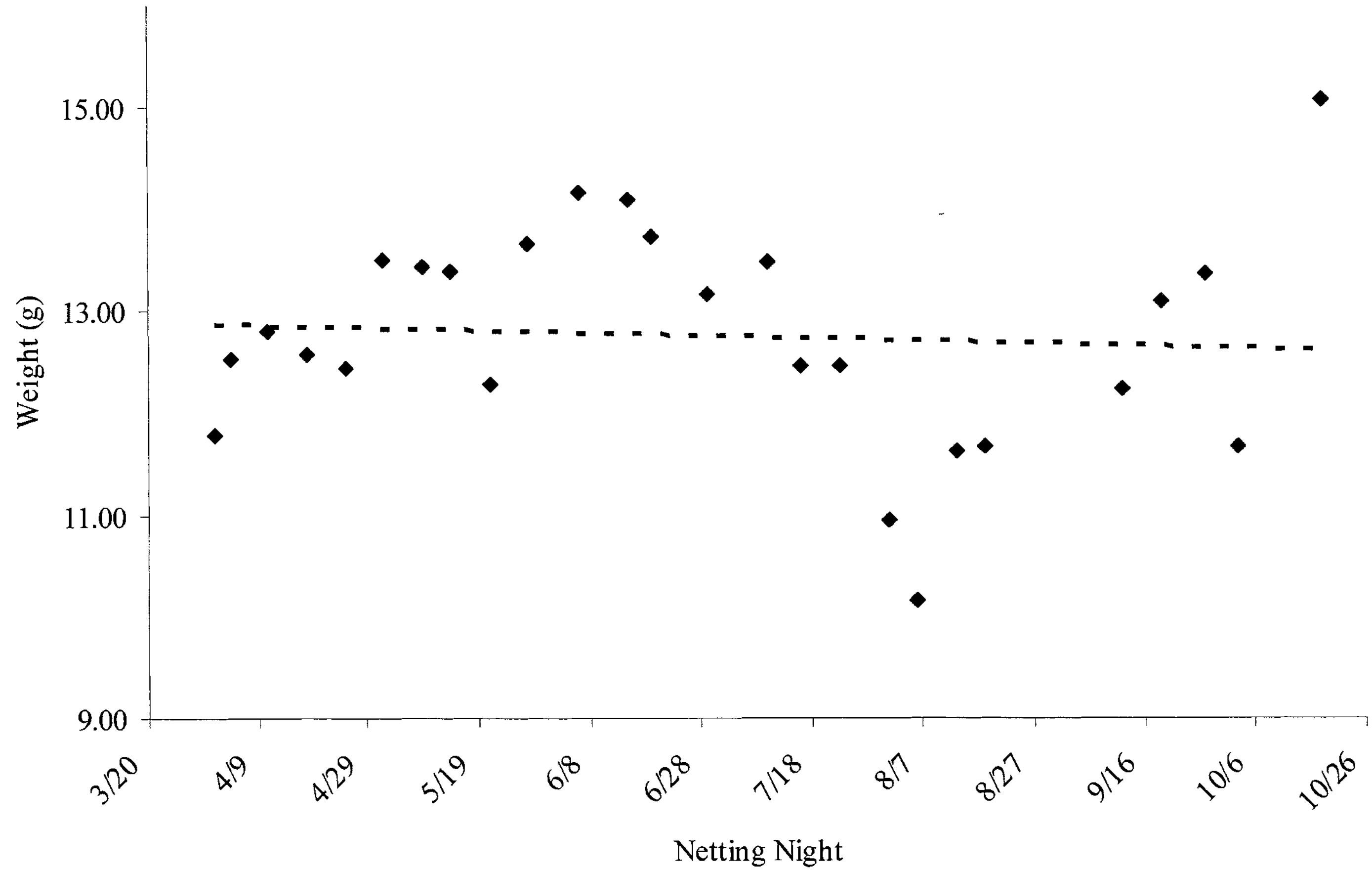

Figure 5 Annual average weights of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003.

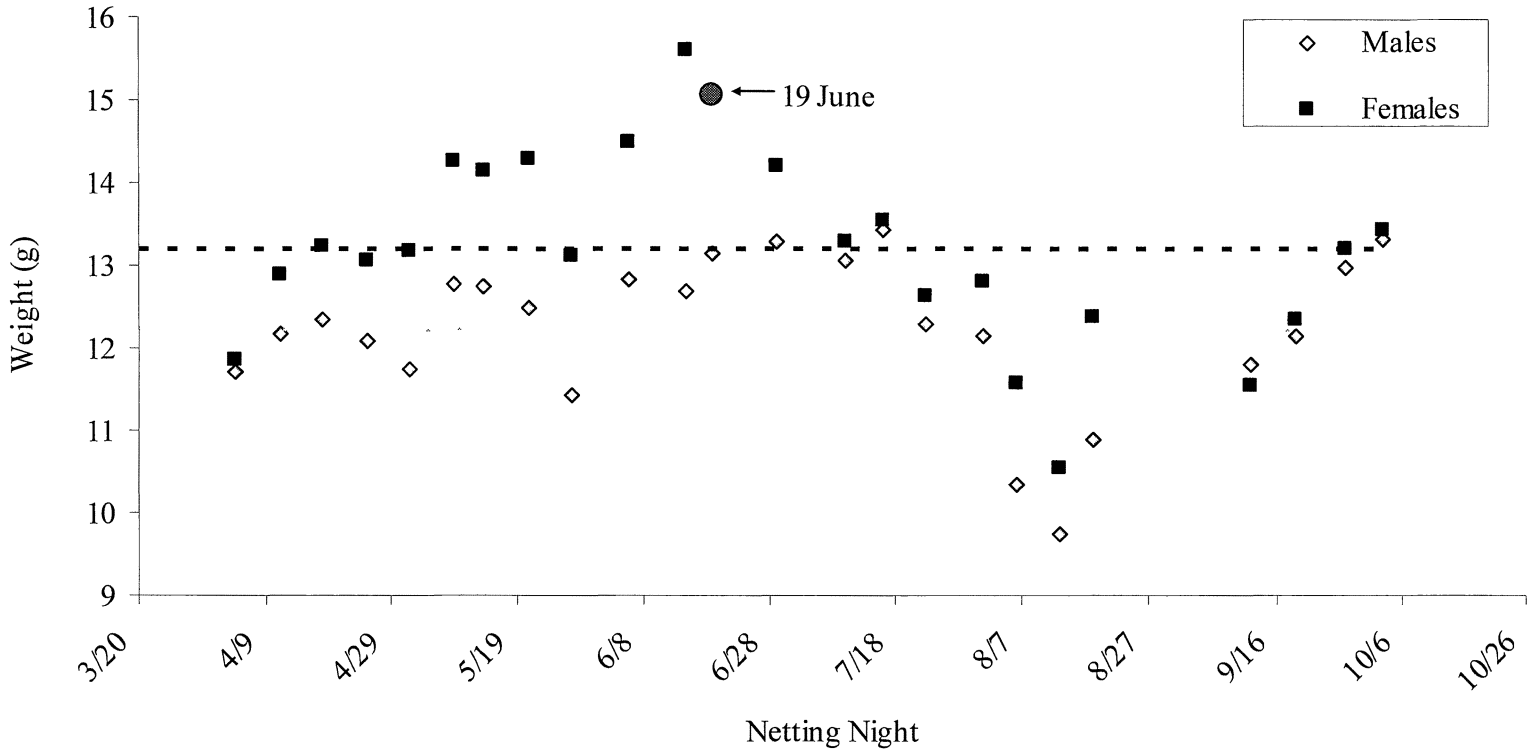

Figure 6. Annual average weights of male and female *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Males and females were treated as a blocking factor Lactating bats were first captured on 19 June

Ratios of non-reproductive bats vs. reproductive and juvenile bats were examined using regression analysis. The data were explained by a linear regression model statement using a serial correlation ($x^2 = 7.418$, $p = 0.007$).

Analyses in the netting time class category showed the frequency of bats (bats/s) had no significant trend over the netting time class (Fig. 7). There was a slight negative slope to the trendline. A substantial peak occurred at emergence and an even larger peak at their return. The regression analysis showed no correlation between frequency in the number of bats and the netting time class ($r^2 = 0.0072$). For females, the relationship was explained by a linear regression model using a simple correlation ($x^2 = 0.719$, $p = 0.397$). For males, the relationship was explained by a linear regression model using a serial correlation ($x^2 = 12.916$, $p = 0.0003$).

Comparisons of the average number of bats for each gender in the temporal category with the netting time class showed that both had negative trends with very low correlations (Fig. 8). For females, the r^2 was 0.09 and males 0.07. Most of the gender variation in the average number of bats could not be explained by the regression statements. I ran an ANOVA blocking gender to account for natural variations based on gender alone. There was no significant difference among netting time classes ($F = 4.17$, $p = 1.29$), however there was a significant difference in gender ($F = 68.95$, $p < 0.001$).

The proportions of the four reproductive classes were compared to each netting time class (Fig. 9). In 12 netting time classes, the non-reproductive class was over 50% of the population except for one class. For this time class (2000 h), the majority of bats were lactating females with pregnant females and juveniles following in percentage

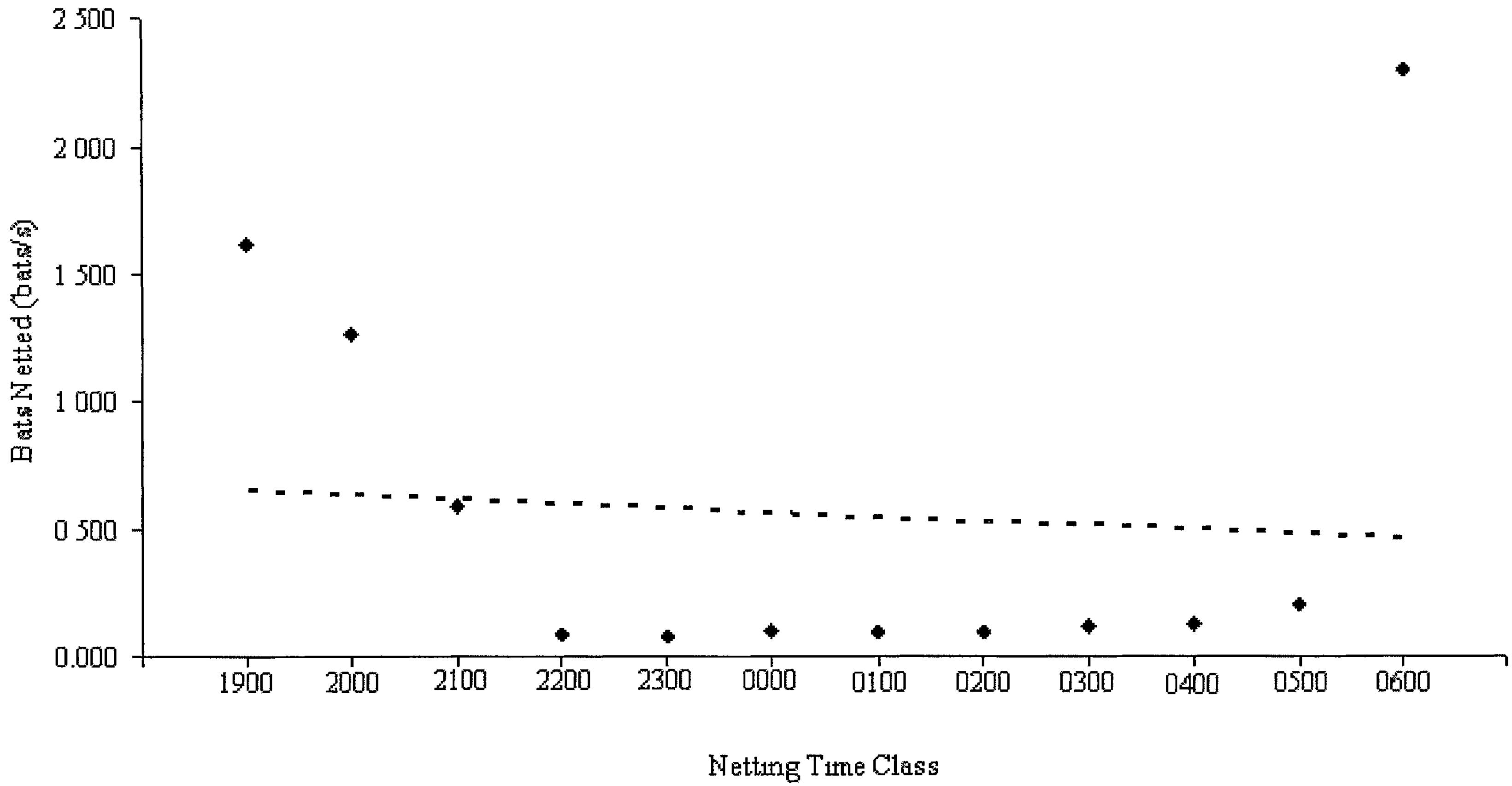

Figure 7. Temporal frequency of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003

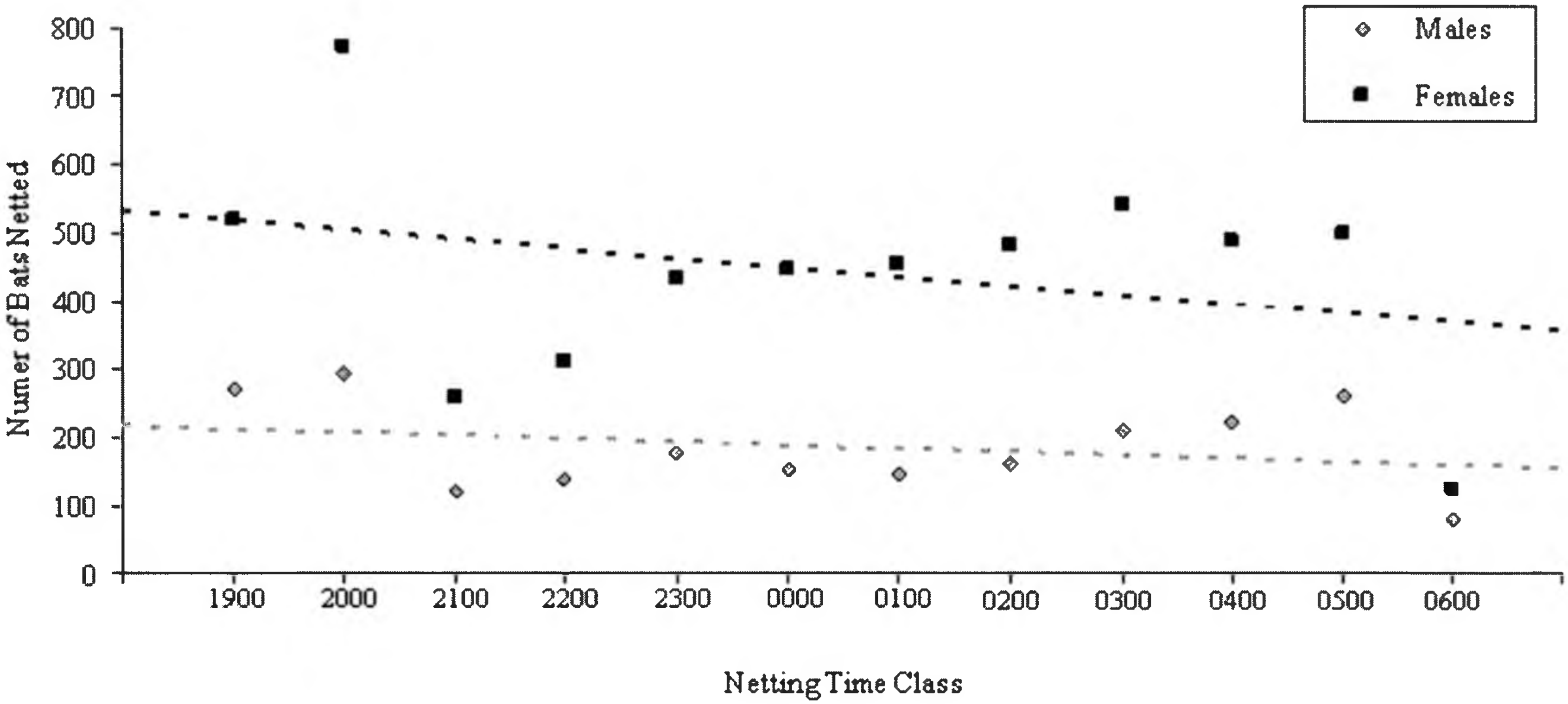

Figure 8. Temporal number of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Males and females were treated as a blocking factor.

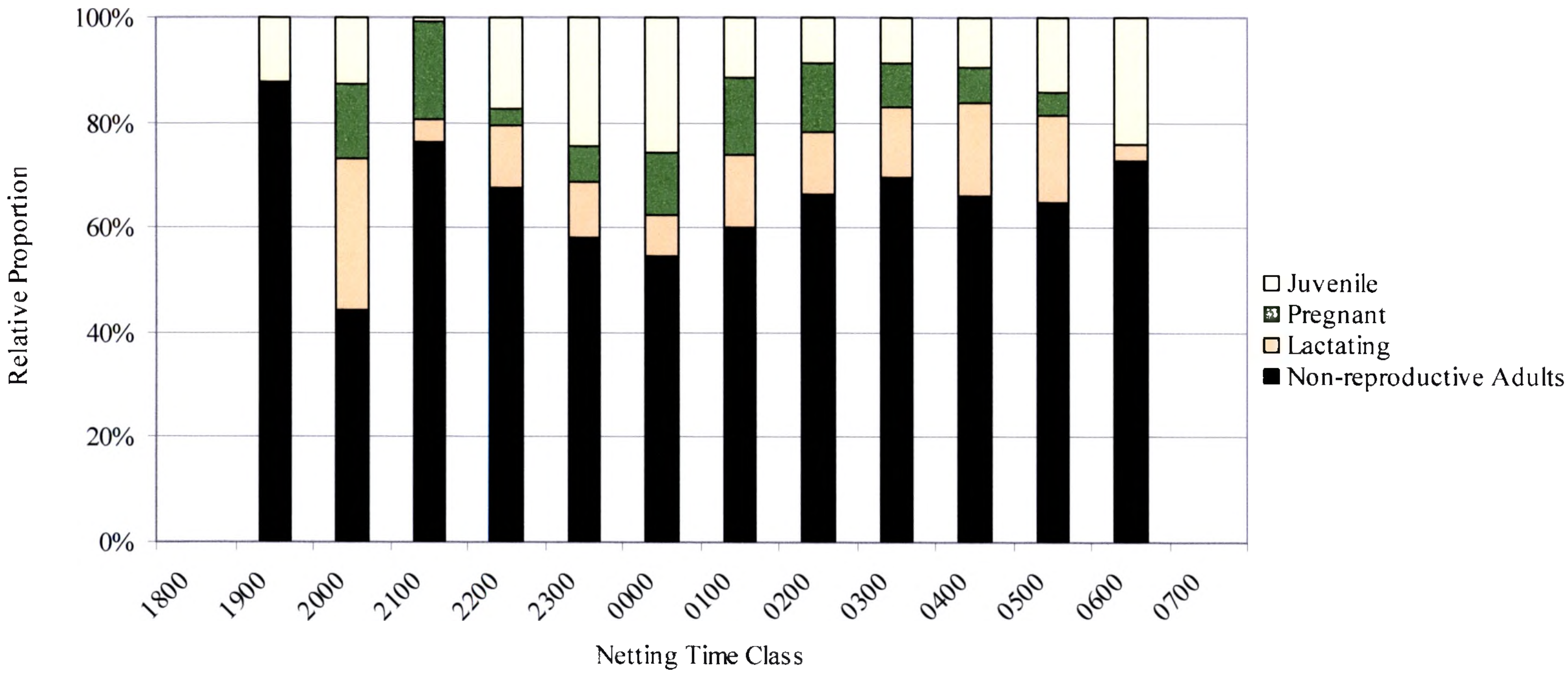

Figure 9. Temporal relative proportion of *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Lactating and pregnant females, juveniles, and non-reproductive adults are treated as a blocking factor.

(Table 4). The time class 2000 h was the time when the majority of emergences occurred during the 2003 netting season (Table 4). I ran another ANOVA using average number of bats in each class instead of the proportion of the number of bats in each reproductive class. The reproductive classes were blocked to account for natural variations that may occur based on reproductive class alone. There was a significant difference among the netting time classes ($F = 2.08, p = 0.05$) and reproductive classes ($F = 55.81, p < 0.001$).

The temporal variation in weights of both genders was compared with the netting time class (Fig. 10). There was a low correlation between weight and netting time classes. A separation by gender produced a slight positive trend for both genders over time of night. They almost paralleled with one another. The coefficient of determination showed a small correlation for both genders from the regression statement. Males had an r^2 of 0.27 and females were slightly higher ($r^2 = 0.29$). For both genders the regression was explained by a linear regression model using serial correlations (Female: $x^2 = 156.816, p < 0.0001$, Male: $x^2 = 57.538, p <0.0001$). I ran an ANOVA blocking for gender to account for natural variations related to gender alone. There was a significant difference among netting time classes ($F = 34.97, p <0.001$) as well as gender ($F = 135.68, p < 0.001$).

Ratios of non-reproductive bats vs. reproductive and juvenile bats were examined using regression analysis. The data were explained by a simple linear regression model statement using a serial correlation ($x^2 = 10.215, p = 0.0014$).

Formal analyses were not run on the *Myotis velifer* because of the minute data set. A total of 78 cave myotis (25 males and 53 females) were netted over an eight-month

Table 4 Total number of *Tadarida brasiliensis* netted during each netting time class at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Relative proportions of non-reproductive, pregnant, lactating, and juvenile bats compared to the total *T brasiliensis* captured are shown in parentheses

Time	Non-Reproductive		Pregnant		Lactating		Juvenile		Total
1900	684	(87 4)			2	(0 3)	97	(12.4)	783
2000	465	(43.7)	153	(14 4)	310	(29.1)	136	(12.8)	1064
2100	297	(76 7)	71	(18.3)	16	(4 1)	3	(0 8)	387
2200	301	(67 5)	15	(3 4)	52	(11.7)	78	(17.5)	446
2300	358	(58.2)	40	(6 5)	66	(10.7)	151	(24.6)	615
0000	322	(54.8)	70	(11.9)	46	(7 8)	150	(25.5)	588
0100	363	(60.3)	87	(14 5)	82	(13 6)	70	(11.6)	602
0200	443	(67 2)	85	(12 9)	76	(11.5)	55	(8 3)	659
0300	516	(69 2)	64	(8.6)	101	(13 5)	65	(8 7)	746
0400	457	(65 5)	46	(6 6)	127	(18 2)	68	(9.7)	698
0500	498	(65 3)	30	(3 9)	126	(16 5)	109	(14 3)	763
0600	162	(74 3)			6	(2.8)	50	(22 9)	218
Total	4866		661		1010		1032		7569

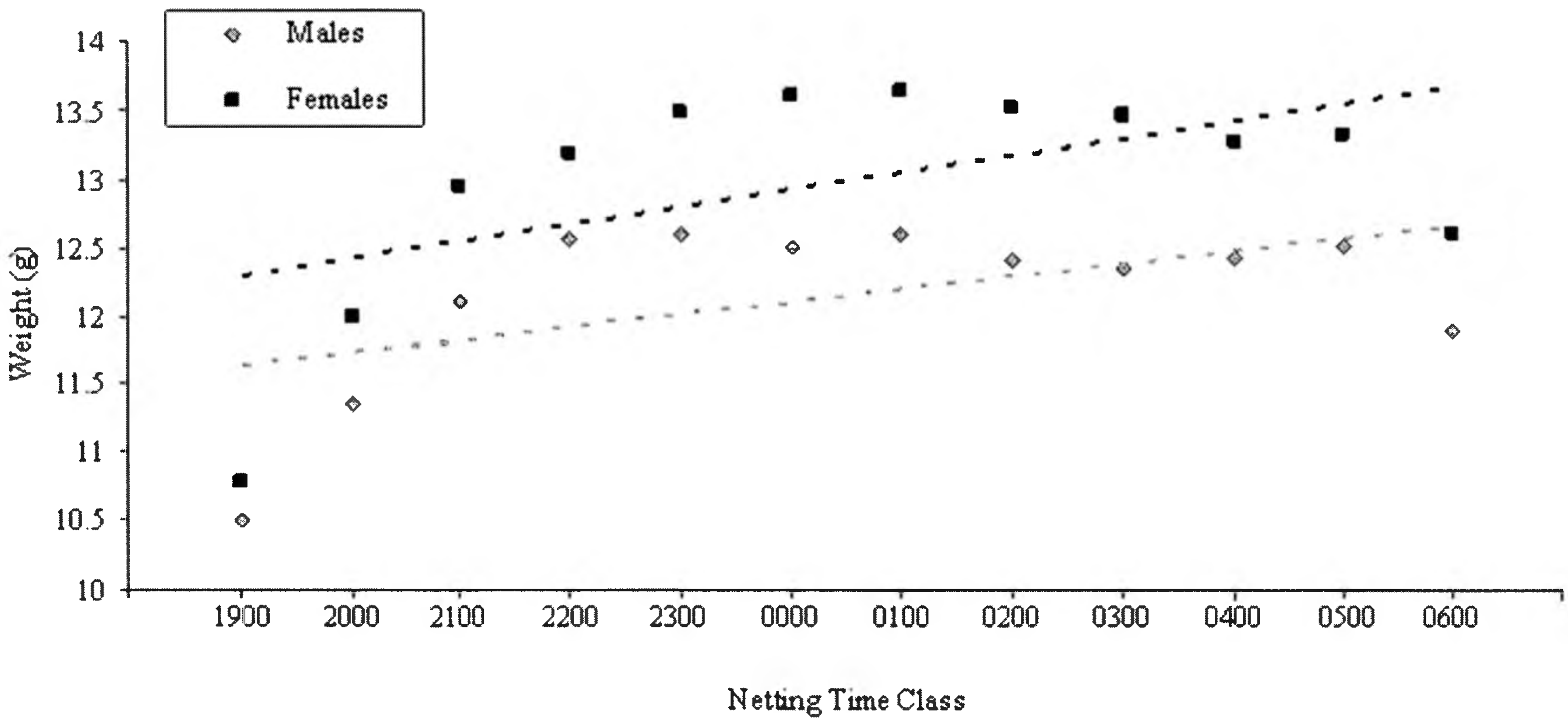

Figure 10. Temporal average weights of male and female *Tadarida brasiliensis* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Males and females were treated as a blocking factor.

netting period (Table 5). This resulted in a sex ratio of 1:2, which was similar to the *T brasiliensis* bat population. Only one cave myotis was pregnant, 9 were lactating, 8 were juveniles, and 2 males had descended testes. The rest of the bats were non-reproductive adults (Fig. 11). Volant juveniles were netted at the end of July and reproductive males were netted on 13 August. Because of the small sample size, I could not determine if this is a representative sex ratio for this species, especially at OTWMA. Further research needs to be conducted.

Temperature and relative humidity were recorded from 12 February until 15 June, 2003. Data for interior temperatures and relative humidities consisted of maximum, average, and minimum numbers (Table 6). They showed a fairly dynamic system over the year and nights.

During spring 2003, two bats with wing bands from previous research at OTWMA were observed (Tanner 1999, Hein 2001). On 31 March, a male Mexican free-tailed bat was found in San Marcos, Texas. The band number was JB01 1207. The number and color indicated this was from the 2000 recapture research under Hein's study (2001). On 18 April, a male Mexican free-tailed bat was netted at OTWMA. The band number documented was JB00385 and the band was white indicating that this bat had been banded during the 1997 recapture research under Tanner (1999).

Table 5 Total number of *Myotıs velıfer* netted each nettıng nıght at Old Tunnel Wıldlıfe Management Area, Kendall County, Texas, 2003 Relatıve proportıon of males vs. females for each nıght ıs shown ın parentheses

Date	Males		Females		Total
21-Mar	1	(50 0)	1	(50 0)	2
1-Apr	3	(37 5)	5	(62 5)	8
4-Apr	2	(50 0)	2	(50 0)	4
11-Apr			3	(100)	3
18-Apr					
25-Apr			4	(100)	4
2-May					
9-May			1	(100)	1
14-May	2	(66 7)	1	(33 3)	3
21-May			9	(100)	9
28-May	1	(50 0)	1	(50.0)	2
6-Jun	2	(66 7)	1	(33 3)	3
15-Jun	1	(100)			1
19-Jun	5	(100)	5	(100)	10
29-Jun	2	(28 6)	5	(71 4)	7
10-Jul	1	(25 0)	3	(75 0)	4
16-Jul	1	(33.3)	2	(66 7)	3
23-Jul	1	(16 7)	5	(83 3)	6
1-Aug					
6-Aug					
13-Aug	2	(66 7)	1	(33 3)	3
18-Aug					
12-Sep			3	(100)	3
19-Sep	1	(50 0)	1	(50 0)	2
27-Sep					
3-Oct					
18-Oct					
Total	25		53		78

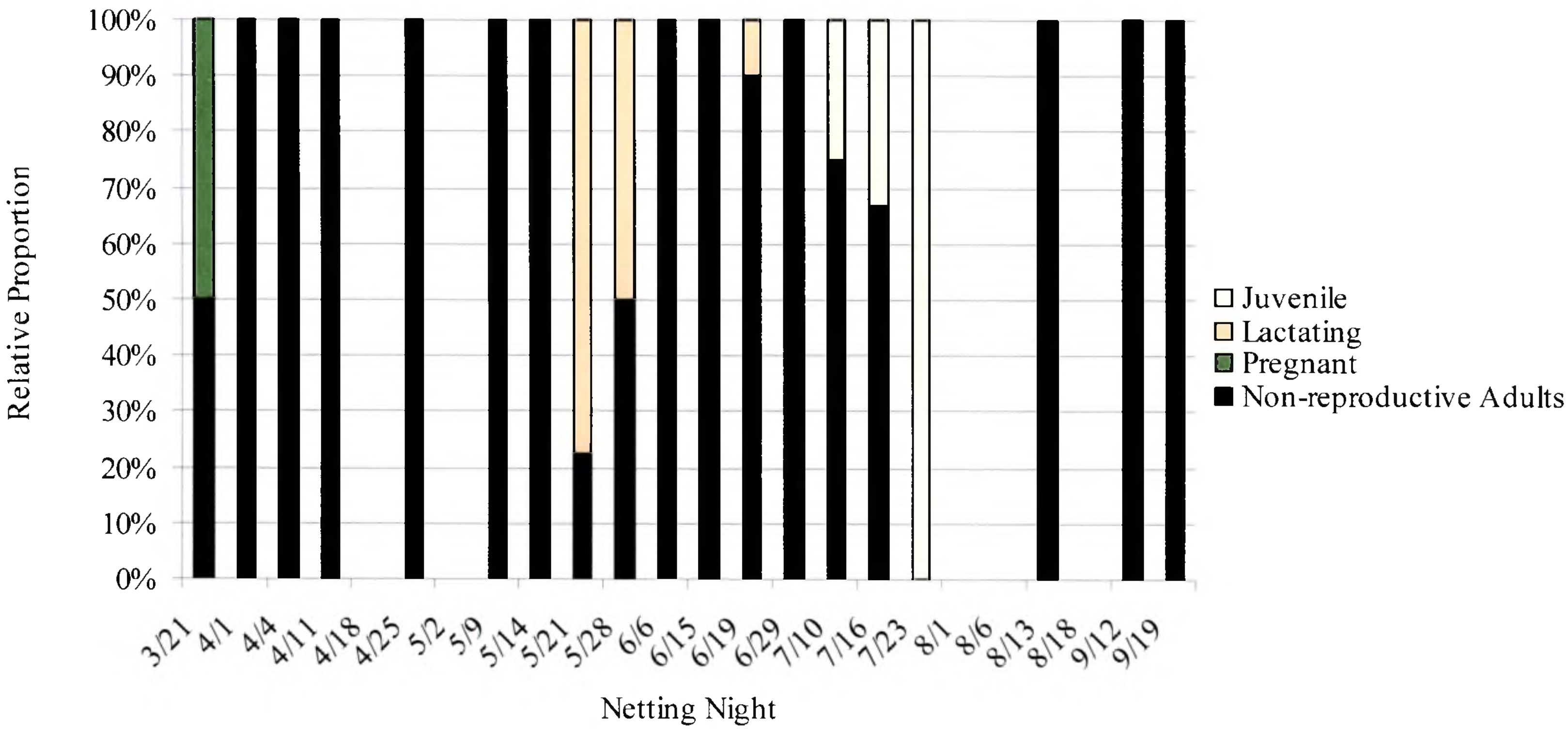

Figure 11. Annual relative proportion of *Myotis velifer* netted each netting night at Old Tunnel Wildlife Management Area, Kendall County, Texas, 2003. Lactating and pregnant females, juveniles, and non-reproductive adults were treated as a blocking factor.

Table 6 Interior envıronmental temperatures and relative humıdıty's recorded at Old Tunnel Wildlıfe Management Area, Kendall County, Texas, 2003. Recordıngs shown are from 12 February untıl 15 June, 2003 Yearly averages are also shown

Dates Recorded	Temperature (°C)			Relative Humidıty		
	min	mean	max	min	mean	max
February 12 - 22	0 29	12 60	29 50	26 20	79 59	100.60
Aprıl 25 - May 5	13 32	22 44	33 17	15 80	77 69	100 30
May 5 - 16	16.76	24 26	35 70	15 80	79 67	101 00
May 16 - June 1	14 47	23 38	34 43	17 90	67.61	100.30
June 1 - 11	15.62	22 69	30 31	45 40	80.83	100 60
June 11 - 15	16.00	23 59	30 31	56 80	87.74	101.00
Average	12 74	21 49	32.24	29.65	78 86	100 63

CHAPTER IV

DISCUSSION

During 2003, from 21 March through 18 October, trends differed slightly from the results of previous research on *Tadarida brasiliensis* conducted at OTWMA (Tanner 1999, Hein 2001). However, as a whole, the results of research conducted at OTWMA are similar to previous research at maternal caves in Texas such as Bracken, Ney, Eckert James River, and Davis Caves (Cagle 1950, Eads at al. 1957, Short 1961, Davis et al. 1962). In 2003, the Mexican free-tailed bat population had a significant female bias in the sex ratio. This trend is consistent with the normal life cycle of this migratory bat in that most adult males remain in Mexico during the parturition season of summer (Davis et al. 1962, Villa and Cockrum 1962). Females migrate to locations north of Mexico during the summer birthing season (Davis et al. 1962, Villa and Cockrum 1962). Therefore, it was expected that females would outnumber males. It was also expected that pregnant and lactating females were in smaller numbers than non-reproductive adults because the OTWMA has been recognized as a pseudomaternal colony (Bailey 1993, Wallace and Lawyer 1996, Harper 1997, Tanner 1999). This may be a result from adult female bats remaining closer to their pups during the lactation period (Henry et al. 2002).

It was evident from the small amount of data from the interior dataloggers that the temperature fluctuates throughout the day (Table 6). It is possible that interior temperatures and relative humidities are unacceptable for pup development. However, in Twente's (1956) research of the Merrihew Cave, Kansas, he found that temperatures ranged anywhere between 8°C to 28°C between April and June, 10°C to 43°C in total, and relative humidities ranged from 10% to 90%. Twente (1956) noted that Mexican free-tailed bats tolerate dynamic environments, however, the stable environment of a maternal cave allow for ideal development of the pups (Kunz and Robson 1995). At Eckert James River Bat Cave, Texas, Kunz and Robson (1995) found that prepartum maximum and minimum temperatures ranged from 25.8 to 20.8 respectively. They also found that relative humidity ranged from 60-80%. Further research on interior bat roosts is needed to determine if ideal conditions exist for Mexican free-tailed bats or if they are indeed cosmopolitan in nature.

The location of the bats within the tunnel indicate they had a preference for the northern entrance when roosting. The bats' preference might be related to differing internal environmental conditions, requiring more data for a positive speculation. Disturbances from visitors on the southern end of the tunnel may also be a factor, especially at the peak of the season (Bailey 1993).

A total of 1,040 bats were volant juveniles with an almost 1:1 sex ratio, and the rest of the sample population (6,607) was adults. This suggests a possible high mortality of juvenile bats using OTWMA, inappropriate growth and roost conditions for young-of-year bats at OTWMA, or possible trap shyness. This ratio was expected since previous studies have reported similar trends (Davis et al 1962, Wilkins 1989, Kunz and Robson 1995). It was assumed, and observed in previous studies, that the primary (after fertilization), secondary (after birth but before volancy), and tertiary (after volancy) sex ratios of juveniles should be close to a 1:1 ratio (Davis et al. 1962, Wilkins 1989, Kunz and Robson 1995). In previous research at OTWMA, the tertiary sex ratio of juveniles was skewed toward males (Hein 2001); however, during the 2003 netting season this was not the case.

It was typical to see an increase in male juveniles and a decrease in female juveniles in the last three or four netting time classes just before sunrise when bats returned in the morning. This was also true of adults in the population, however, their sex ratio was skewed (2.3:1) favoring the females, which is common for northern latitudes (Twente 1956, Villa and Cockrum 1962). In Twente's study at Merrihew Cave, Kansas (1956) 76% of the population in a maternal colony were females. Villa and Cockrum (1962) discovered that bats from various Arizona day roosts had a ratio of 2.5:1 favoring female bats. This suggests that pseudomaternal colonies may follow trends for maternal and day roost colonies.

The frequency of bats increased throughout the year. It is suspected that as roosts such as OTWMA have an increase in the number of bats, there will be a negative correlation in the frequency and number of bats at maternal colonies. It is very common for adult and newly volant bats to retreat from the maternal caves for a few weeks to let them "air out" possibly due to the increased heat, toxins, and parasites (Tuttle 1994). This could explain the continual increase in activity of bat populations at OTWMA throughout the year. The change in the interior environment indicates that the tunnel may air out on a regular basis and may be a retreat from the harsh conditions bats deal with at the maternal colonies. It is also known that man-made structures, specifically those not used as nursery roosts, are used as stop-over sites during fall migration (Davis and Cockrum 1963, Cockrum 1969, Fraze and Wilkins 1990). Northern populations of bats moving south during fall migration to Mexico use places such as OTWMA, which causes fluctuations in the bat population (Cockrum 1969, Fraze and Wilkins 1990). Most likely, the fluctuation in population density resulted from these bats moving to Mexico for the winter.

The relative proportion of reproductive classes follows the normal spring-fall cycle of Mexican free-tailed bats in northern latitudes. Palpation of female bats showed that pups began to develop shortly after females arrive from Mexico. It was evident that pups were born within a short time of one another because once lactating females were observed hardly any pregnant females were seen thereafter. I propose, based on my data, that the females gave birth after 15 June but before 19 June with 19 June very possibly as the night that parturition began at the associated maternal colonies. This assumption is based on no lactating females being caught on the 15 June, but on 19 June, five lactating females were netted beginning at 0200 h (Figure 6). Before that, only pregnant females were caught. It is also unknown whether females leave maternity roosts to hunt for food immediately after giving birth because of higher energy demands.

Volant juveniles were netted five weeks after the assumed night of parturition. Juveniles are nursed for about six weeks before they are able to fly (Wilkins 1989, Kunz and Robson 1995). This indicates parturition may have occurred one week earlier than 19 June. The approximate time juveniles arrived at OTWMA was 23 July, this corresponding to the same time frame as previous results at other man-made bat roosts (Svoboda and Choate 1987, Fraze and Wilkins 1990).

Variation in weight barely changed for male and female Mexican free-tailed bats during the netting season. When change in weight was classified by gender, males had a slight positive trend and females had a slightly larger negative trend. Females continually decreased in weight over the year possibly because of higher energy demands for raising pups; however, it was unclear whether this was the only factor influencing weight loss by females.

For the temporal category, there was no significant trend for the frequency of bats over the netting time classes. A peak occurred at the time of emergence and in the morning. It is possible that the bats continued to feed throughout the night because the energy gained from one night of foraging must last the next entire day. More than likely this was most important during lactation when the females continued to nurse throughout the night (Henry et al. 2002). This could be why there was a positive increase in activity (bats/s) from the middle of June until August. Once bats emerged, there was a decline in activity until about 2330 h. After a few months, this lull in activity became very predictable. It was not until about 2330 h that bats began returning to the tunnel. Their return, not a second emergence, was determined visually by watching which side of the harp net bats hit. Their distinctive flight behavior and noise of "dive-bombing" into the tunnel entrance was also noted during their return. It is unclear why they returned so predictably each night and if these bats were new to the tunnel from the previous day.

In temporal bat classes, no one class was noted more often than another throughout the night. This differed from previous research in that there was no difference in the number of juveniles caught at emergence (Tanner 1999, Hein 2001). This may be due to the difference in trapping technique in that I left the harp net in front of the tunnel well before emergence began. This method was chosen to capture bats that emerge first, hopefully reducing the bias of capture at emergence by using a set method. Two distinctions were found in activity patterns. One was the increase in reproductive bat captures during a majority of emergence times (2000 h). This was probably because of higher energetic demands. The second distinction was the time juvenile bats began flying back into the tunnel. During the 2200 h through 0000 h time classes, juveniles were netted in higher capture rates as well as in the morning netting times (0500 to 0600 h). These shorter flying times could be related to the new experience of flying and possibly because their wing joints were not fully developed for an entire night of flying. It is also possible that juveniles were arriving from nearby roosts during these times.

The temporal changes in weight were as expected. From emergence to their return, the weights of both genders increased proportionally with one another. It then leveled for most of the night as bats continued flying in and out of the cave after about 2330 h. I assume that there is a limit to the intake of food in proportion to use of energy and further research would be of use.

Myotis velifer were also found at OTWMA. This is not unusual since this species is often found in close association with *Tadarida brasiliensis* at other types of roosting sites (Twente 1955). Throughout 2003, only 78 cave myotis were netted. They had a 1:2 sex ratio with the same skewed female population as the Mexican free-tailed bats.

When comparing cave myotis reproductive classes to the Mexican free-tailed reproductive classes over netting nights, the cave bat reproductive season was about one month ahead of the Mexican free-tailed. This follows previous research at maternal roosts (Hayward 1970, Kunz 1973, Fitch et al. 1981). One pregnant female was netted on 21 March, but pregnant Mexican free-tails were not seen until 18 April. Lactating females were captured starting on 21 May, whereas, lactating Mexican free-tailed females were not caught until 19 June. Juvenile cave bats were first netted on 20 July; whereas, the first Mexican free-tailed juvenile was not netted until 23 July. Their interaction with one another at transient roosts, if any, needs further exploration.

Further studies on *Tadarida brasiliensis* and *Myotis velifer* bat populations at the Old Tunnel Wildlife Management Area should include the following: 1) long term collection of environmental parameters with the use of data loggers for different locations along the interior tunnel, 2) the collection of data on bat activity for annual and temporal seasons at the northern end of the tunnel, 3) the comparison of annual and temporal population characteristics, as well as interior environmental parameters, of the southern and northern ends of the tunnel, 4) the comparison of OTWMA data to other local maternal and transient roosts.

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VITA

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