NATURAL HISTORY OF Neotoma micropus

IN SOUTH TEXAS

by

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A THESIS

IN

BIOLOGY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The southern plains Woodrat (*Neotoma micropus*) is a large, sigmodontine rodent that ranges from Southeastern Colorado and Southwestern Kansas through Western Texas into Northern Mexico (Wilson and Reeder, 1993; Hall, 1981) (Figure 1). It is found in the western two-thirds of Texas, and is characteristic of the brushlands in the semi-arid region between the timberlands and the arid deserts to the west (Davis and Schmidly, 1994).

Woodrats generally are thought to be solitary and territorial animals with intraspecific interactions occurring during times of mating. Defense of home ranges between competing males and between males and females occurs on a regular basis. Home ranges of woodrats most likely depend on density (population) of woodrats and availability of food (Conditt and Ribble, 1997).

Woodrats construct middens (nests) consisting of sticks and other debris that are made into a pile above ground. It is common to find discarded trash, aluminum cans, spent ammunition casings, and even livestock dung on or within a midden, giving woodrats the name "packrat." Underneath a midden (if soil composition permits), often an elaborate tunnel system is constructed. In this system, woodrats store food and nest material, and escape predation. In areas where soil does not permit the excavation of tunnels, crevices in rocks, decaying timber, and even nests built within the canopy of trees provide sufficient housing for woodrats. Virtually all woodrat nests, whether in a tree or on the ground, will have the characteristic mound of sticks over the opening of the nest.

Several studies have been conducted on the systematics and phylogenetics of woodrats (Edwards and Bradley, 2002), however, relatively few studies have examined the natural history of woodrats (Conditt and Ribble, 1997; Henke and Smith, 2000; Finley, 1958). Examination of a wide array of biological parameters such as density, population, sex ratio, number of young, number of animals per midden, and sex distribution within a given area is essential to gaining an accurate understanding of the natural history of this species and how it interacts within its own niche as well as to how it interacts with other mammalian and lower vertebrate species.

Two previous studies (Conditt and Ribble, 1997; Henke and Smith, 2000) examined the natural history of *N. micropus* in Texas. Henke and Smith used uniquely numbered aluminum foil balls placed in a circular grid pattern to estimate the home range of *N. micropus*. The foil balls were placed in a web formation around a midden with a total of 320 balls surrounding each midden for a 24-day period. Middens were then excavated and the foil balls were recovered from each midden. This study concluded that the maximum range of woodrats was 862.5 m^2. Males exhibited a greater mean and maximum travel distance and larger estimated home range size than female woodrats. In the study by Conditt and Ribble (1997), in which radio telemetry was used to determine the home range and density of *N. micropus*, home ranges for males were established to be 1692 m^2 and 188 m^2 for females and densities ranged from 2.0 woodrats per hectare in October to 5.5 per hectare in February.

The objective of this study is to examine the natural history (density, distance between middens, population dynamics, sex ratio, number of young, number of animals per midden, and sex distribution) of *N. micropus* within its habitat located within the boundaries of the Chaparral Wildlife Management Area. These variables will be examined per site, per season, and per year.

The Chaparral Wildlife Management Area (CWMA) consists of 15,500 acres (6,500 ha) and is located in southern Texas approximately 160 kilometers south of San Antonio, between Catarina and Artesia Wells, Texas on Highway 133. The CWMA occurs within both Dimmit and La Salle Counties with the county border approximately bisecting the property in half. The Chaparral Wildlife Management Area (28° 20' N, 99° 25' W) is located in the Rio Grande Plains of south Texas (Ruthven and Synatzske, 2002). Typical soils are classified as Duval Fine Sandy Loam (DYB) and Dilley Fine Sandy Loam (DFC) (Soil Survey of Dimmit and Zavala Counties, Texas, 1985). Average annual precipitation is 54.71 centimeters with most precipitation occurring between the months of April and September (Soil Survey of Dimmit and Zavala Counties, Texas, 1985). Vegetation is typical for acacia and mesquite grasslands, and include woody species such as mesquite (*Prosopis glandulosa*) and granjeno (*Celtis pallida*) to herbaceous species such as Lehmann lovegrass (*Eragrostis lehmanniana*), fringed singnalgrass (*Brachiaria cilliatissima*), and hairy grama (*Bouteloua hirsuta*) (McLendon, 1991; Ruthven and Synatzske, 2002) with a wide array of cactus species (*Opuntia sp.*).

According to Davis and Schmidly (1994), of the 97 genera and 101 species of mammals occurring in Texas, 54 mammalian species occur principally in the Rio Grande

Plains with 30 species occurring within the boundaries of the CWMA. This particular area of Texas is inhabited by a diverse array of mammalian species. Although the more recognized species of white-tailed deer (*Odocoileus virginianus*) and collared peccary (*Tayassu tajacu*) are abundant and most readily viewed, the small mammal fauna of this area is greater in abundance and diversity.

Because of its favorable soil compositions and the availability of food and cover, the CWMA provides ideal habitat for sustaining large populations of *N. micropus*. The northern half of the CWMA can be described as improved pasture; the southern half represents relatively undisturbed habitat. Rotations of cattle grazing occur throughout the year and on several different pastures. Management of the deer herd is achieved through a series of drawing hunts conducted through Texas Parks and Wildlife along with hunts for peccary. Fire is used throughout the property to control brush and provide both the livestock and the wild game with ideal habitat for food resources and cover.

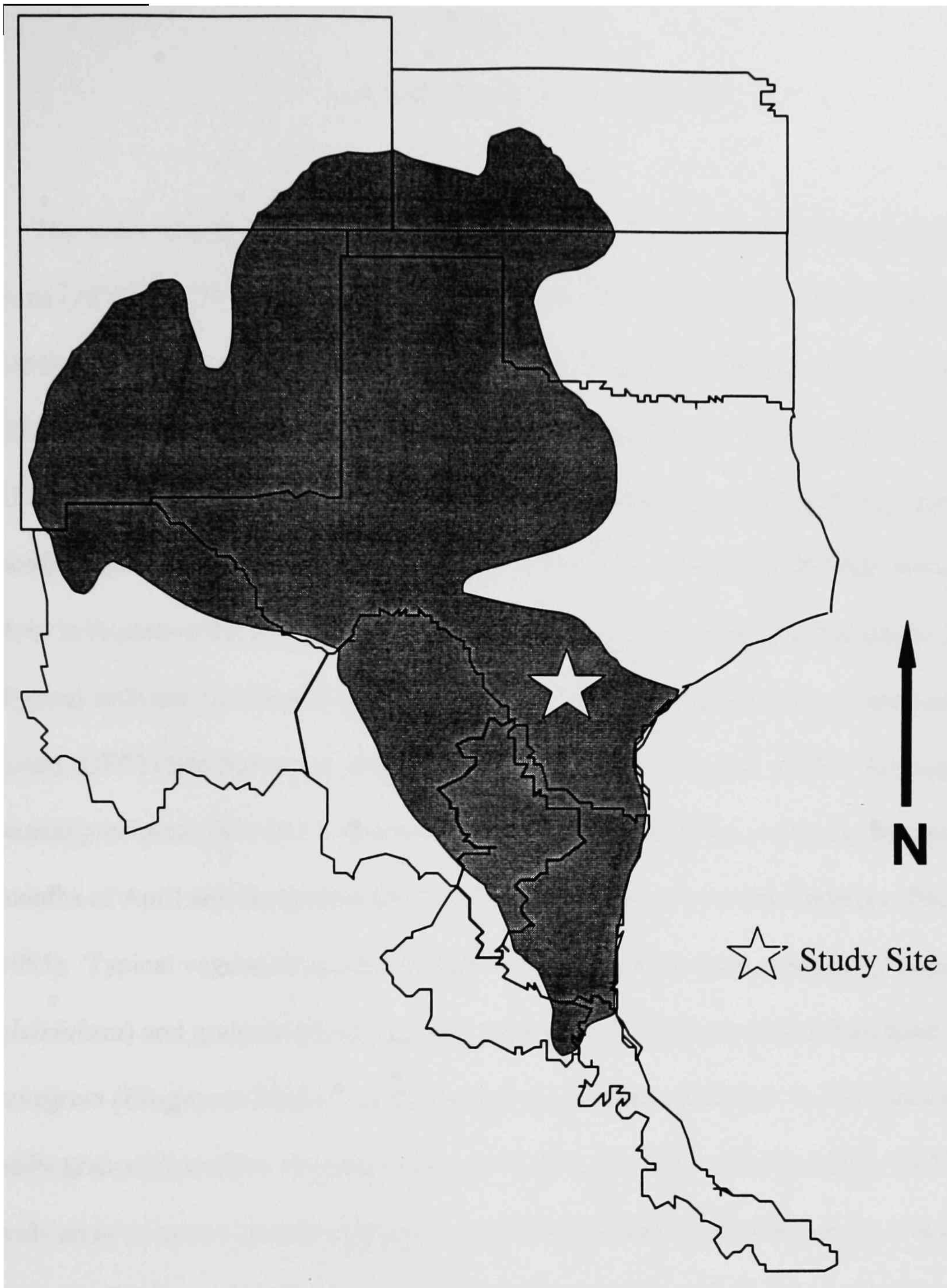

Figure 1. Map showing the home range of *Neotoma micropus* throughout the United States and Mexico.

CHAPTER II

MATERIALS AND METHODS

The study sites for this project were located on the Chaparral Wildlife Management Area (28° 20' N, 99° 25' W). The Chaparral Wildlife Management Area (CWMA) consists of 15,500 acres (6,500 ha) and is located in south Texas approximately 160 kilometers south of San Antonio, between Catarina and Artesia Wells, Texas on Highway 133. The CWMA occurs within both Dimmit and La Salle Counties with the county border approximately bisecting the property in half. The Chaparral Wildlife Management Area is located in the Rio Grande Plains of south Texas (Ruthven and Synatzske, 2002). Typical soils are classified as Duval Fine Sandy Loam (DYB) and Dilley Fine Sandy Loam (DFC) (Soil Survey of Dimmit and Zavala Counties, Texas, 1985). Average annual precipitation is 54.71 centimeters with most precipitation occurring between the months of April and September (Soil Survey of Dimmit and Zavala Counties, Texas, 1985). Typical vegetative species include woody species such as mesquite (*Prosopis glandulosa*) and granjeno (*Celtis pallida*) to herbaceous species such as Lehmann lovegrass (*Eragrostis lehmanniana*), fringed singnalgrass (*Brachiaria cilliatissima*), and hairy grama (*Bouteloua hirsuta*) (McLendon, 1991; Ruthven and Synatzske, 2002) with a wide array of cactus species (*Opuntia sp.*). The dominant vegetative species coupled with climatic factors results in the classification as a semi-arid acacia-grassland or mesquite-grassland.

The design for this study involves a direct capture of woodrats by excavation of their middens on eight different sites (grids). Sites will be excavated four times per year (January, March, June, and October) over a two-year period in order to gather data for each season to be used for comparison between years. The locations of the grids (Figure 2) were selected using a predetermined protocol to provide uniformity between the grids. The grids for this study are 25 meters in diameter (0.2 ha). Grid sites for this study will not be closer than 500 meters from any other site. Once a site is selected, a center point will be determined and four people will walk, one in each cardinal direction (North, South, East, and West) for 25 paces (25 meters). The number of middens visible from the center point to the end of the 25 meter transect will be counted. If the total number of middens observed is greater than ten, the site is suitable for excavation. If the total number of middens is less than ten, then adjustments to the center point of the grid will be made in order to fulfill the requirements of the protocol. When and if the protocol cannot be met for an area, then a new site will be explored.

Once a site has been chosen and determined to be suitable for excavation, every midden at that site will be excavated, regardless of appearance. Because of the potential for an extensive tunnel system within each midden, every tunnel must be excavated to its termination point to insure that all rats have been captured from the midden or to determine the midden is truly uninhabited. Each site will be excavated within a single trip to prevent seasonal differences within a grid site and to insure the integrity of the protocol. Universal Transverse Mercater (UTM) coordinates will be recorded for each midden excavated regardless of the middens contents. These coordinates will later be used to map out each grid site in order to establish and overview of each area for the purpose of determining ratios, distances, populations, and distributions within each midden site.

Once an individual (*N. micropus*) has been captured from a midden, that individuals sex, age, and locality (midden number and UTM coordinate) are recorded in the field to be later used in the compiling of data. During the excavation of each site, if an individual woodrat escapes, an immediate effort will be made to capture the individual even if it leaves the boundaries of the site. If the individual retreats to another midden (whether it be in or out of the site boundaries), the current midden will be excavated to completion while a member from the group will watch the midden to which the woodrat ran to in order to insure that the escaped rat does not flee to another area. Once the excavation of the current midden has been completed, the new midden will be excavated in order to retrieve the escaped rat, and all animals captured within the new midden will be recorded. Any other mammalian species encountered during the excavation of the middens will be captured and recorded. If any non-mammalian species (with the exception of rattlesnakes (*Crotalus atrox*) are encountered within the midden, a simple record will be made of the species. If *C. atrox* is encountered within a midden, it will be captured and turned over to the local wildlife biologists for inclusion in an ongoing pit-tag study being conducted on the CWMA. All excavating will be conducted during the daylight hours as to not interfere with the rodent's nocturnal habits. Every mammal captured will be assigned a TK number (Museum of Texas Tech University identification number). The animals will be weighed, sexed, aged, determined if they are pregnant (females only) and either sacrificed (voucher specimens deposited in the Museum at Texas Tech University) or sent to the University of Texas Medical Branch at Galveston, Texas, to be included in a study on the natural host relationships of rodent-borne arenaviruses in southern Texas. Samples of blood, urine, and oropharyngeal secretions (throat swab) will be collected from each woodrat. If sacrificed, a set of tissues (heart, kidney, liver, muscle, spleen, and lung) will be obtained and deposited in the Museum at Texas Tech University.

A chi^2 test was performed to calculate the P-values to test for significance in sex ratios between midden site one and the other seven midden sites. When testing for significance between midden distances between each site (site one vs. the other seven sites), P-values were obtained by performing an ANOVA test and a t-test was used when looking at distances between male and female middens within the same midden site.

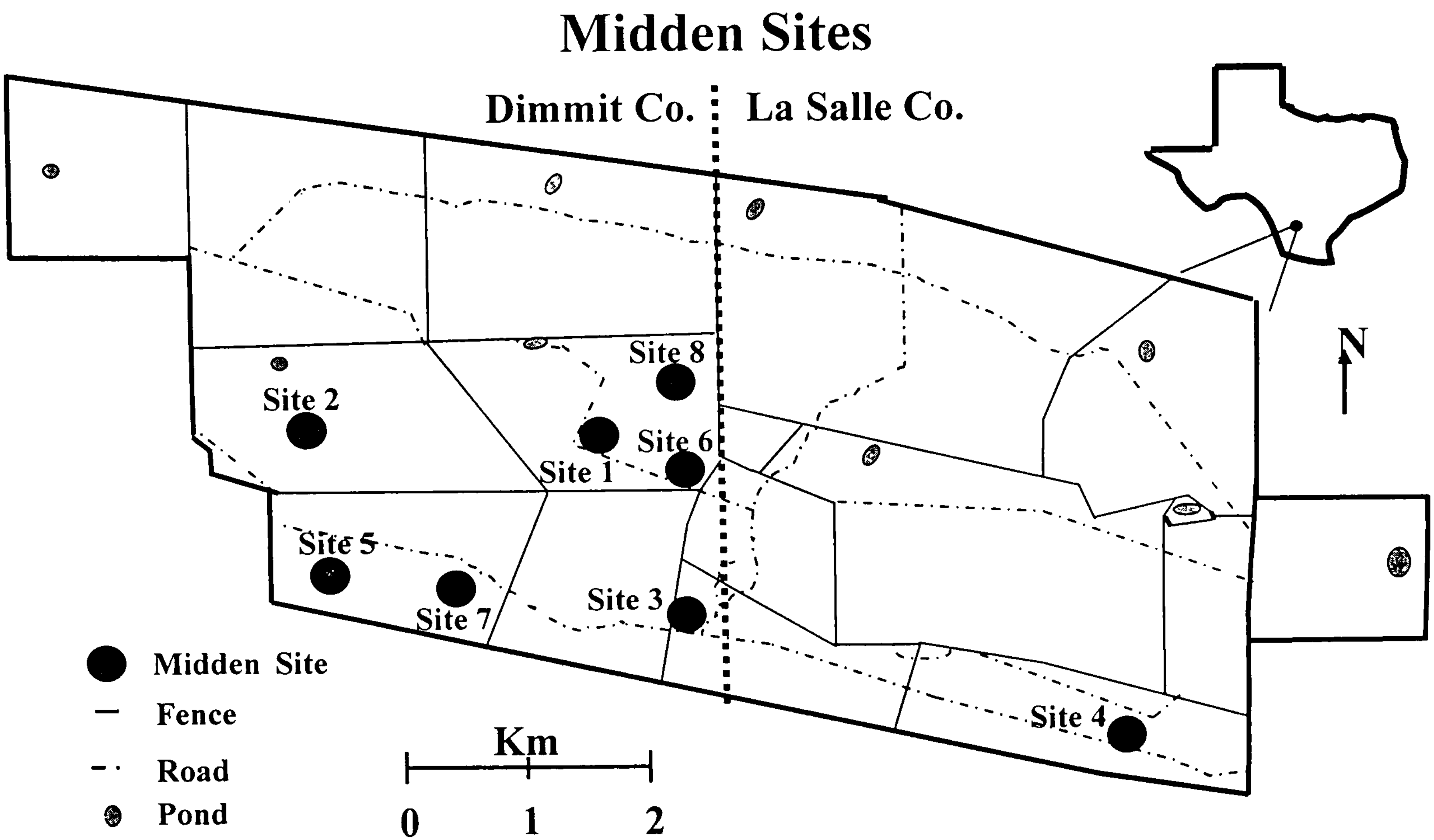

Figure 2. Map of the CWMA showing the localities of the eight midden sites.

CHAPTER III

RESULTS

In order to provide comparable data sets throughout the study, two sites were excavated each season (winter, spring, summer, and fall) over a two year period (March 2001-Januray 2003). Results are presented first across all sites and include variables between the sites and second for each of the eight sites.

All Sites. One hundred forty-eight middens were excavated and 180 individuals were captured. The number of captures by site ranged from 19 to 27 (Tables 1 and 2). The number of middens by site ranged from 11 to 23.

Age. Individuals were separated into four age classes (adult, subadult, juvenile, and pup). There were 103 adults (51 male and 52 female), representing 57.2% of the total population. Twenty-eight subadults (15.5% of the population) were captured. Twenty-eight juveniles (15.5% of the population) were captured. Twenty pups (11.1% of the population) were captured. Comparison of age classes (Table 3) revealed no significant association between age class and gender (chi^2, P>0.05) across all sites (Table 3). However, there was a statistically significant comparison of age classes (Table 4) across all eight sites resulted in a high significance (chi^2, P<0.05).

Sex. Examination of the sex (Table 1) of individuals captured during the two year study period, resulted in 91 males (50.5%) and 89 females (49.4%) captured throughout the eight sites. No significant difference (chi^2, P>0.05) was found in the number of individuals representing each sex. Examination of sex by age class resulted in 51 adult males and 52 adult females (Table 1); 28 subadults (18 males and 10 females), 28 juveniles (14 males and 14 females), and 20 pups (8 males and 12 females). A chi^2 test showed no significance difference (P>0.05) in sex by age class over the eight midden sites (Table 3). Additionally, no significant differences existed (P>0.05) in males and females over the eight sites (Table 5).

Distances between middens. Calculation of distances between middens, over all the study sites, resulted in a mean of 6.58 meters (Table 6). Ranges (greatest and shortest distances) were 1.70 and 14.12 meters, respectfully (Table 6). Distances between male middens for all eight study sites was 10.75 meters (Table 7), with ranges for male middens being 7.23 and 16.40 meters (Table 7). Distances between female middens on all eight study sites was 11.05 meters (Table 7) with ranges for female middens equaling 5.16 and 19.49 meters (Table 7). A two-tailed t-test was used to test for significance between each individual midden over the eight sites (Table 8) and the average distance between middens over the eight sites (Table 6). In all cases, the P-values were greater than 0.05 signifying no significant differences. An ANOVA was used to Compare mean midden distances for male middens throughout the eight sites (Table 7) which resulted in significant differences between the middens sites. A two-tailed t-test was used to look for specific differences between the male middens (Table 10). When using the t-test, significance was found when comparing site I to site II (P=0.001), site I to site III (P=0.004), site I to site VI (P=0.0008), site I to site VII (P=0.004), and site I to site VIII (P=0.001). Comparison of site II to the other sites revealed significant differences in site II to site IV (P=0.03), and site II to site V (P=0.03). Site III was significantly different in comparison to site IV (P=0.01), site V (P=0.03), and site VII (0.007). Site IV was significantly different from site VI (P=0.007), site VII (P=0.002), and site VIII (P=0.008). Site V was significantly different (Table 10) from site VI (P=0.01), site VII (P=0.006), and site VIII (P=0.01). Female midden distances were found not to significantly different throughout the midden sites (Table 7). When using a t-test to look for significance between female middens, midden site I differed from midden site two (P=0.04). Site II was significantly different (Table 11) from site VIII (P=0.01), and site VII was significantly different from site VIII (P=0.04). Comparison of male midden distances (Table 12) to female midden distances within each site was significant only at site VIII (P=0.003).

Middens/site. The average number of middens per site was 18.37 across the eight sites. Distances of each midden across all eight sites (Table 8) and the average distance between middens per site over all eight sites (Table 9) was tested for significance using a t-test. No significant differences were identified between midden distances (P>0.05). The average number of males per hectare was 56.87 and the average number of females was 55.62 woodrats per hectare. The average number of middens per hectare was 92.50 with the average number of woodrats per hectare being 112.50.

Occupancy per midden. When calculating multiple occupancy, (how many individuals of each age class and sex live in the same midden), adult females and their young were found together on 28 (18.9%) different occasions. Adult females and adult males were found in the same midden 13 (8.7%) times. The highest number of *Neotoma* found in one midden was six. The number of middens with greater than five individuals was 5. The number of middens found to be unoccupied was 42 (28.3%).

Site I. Site I (Fig. 3) was excavated in March 2001. Eleven middens were excavated from this site and 27 woodrats were captured (Table 2). This site had the second highest number of woodrats captured and the fewest number of age classes represented. Nine adults (4 male and 5 female) and 18 juveniles (10 male and 8 female) were captured (Table 13). Statistical tests performed on the data for this site resulted in no significant differences (chi^2 test, $P>0.05$) in either midden distances (Tables 8 and 9), sex ratios (Tables 4 and 5), or distribution of sexes and age classes (Tables 3 and 4).

Site II. Site II (Fig. 4) was excavated in June 2001. Seventeen middens were excavated from this site (Table 2) and 25 individuals of *N. micropus* were captured from the middens. Thirteen adults (6 males and 7 females), eleven subadults (6 males and 5 females), and one male juvenile was captured (Table 13). No significance (chi^2 test, $P>0.05$) was found between midden site II (midden distances, sex ratios, and ages per site) and the other seven midden sites.

Site III. Middens in site III (Fig. 5) were excavated in October 2001. Eighteen middens were examined in site III (Table 2) with 23 individuals of *N. micropus* captured. Thirteen adults (7 males and 6 females), four subadults (1 male and 3 females), and six juveniles (2 males and 4 females) were captured (Table 13). Comparison of distances between middens for site III and site VII resulted in a P-value of 0.06 (Table 8). Although this value is the closest to showing significance between any of the sites, it does not represent significance. No significant difference in age or sex class (Tables 4 and 5) was found within this site.

Site IV. Excavated in January 2002 (Fig. 6), this site represented the first season of the second year of data collection on the CWMA. Twenty-one middens were excavated (Table 2) and 20 woodrats were captured from this site. Fourteen adult woodrats (6 males and 8 females), three subadults (2 males and 1 female), two juvenile females, and one male pup were captured (Table 13). No significant differences were found ($P>0.05$) when comparing age and sex ratios (Tables 4 and 5) and midden distribution (Tables 8 and 9) with the other seven sites.

Site V. Figure 7 shows the map of midden site V. This site was excavated in March of 2002. Twenty woodrat middens were excavated from this site (Table 2) with 27 individuals captured. Of the 27 woodrats captured from this site, 13 adults (6 males and 7 females), one subadult male, and 13 pups (4 males and 9 females) made up the sex and age classes (Table 13). No significant differences were identified regarding sex ratios (Table 5) and age class (Table 4) ($P>0.05$) between midden site V and the other seven sites. In addition, no significant differences were obtained when comparing the distances between middens ($P>0.05$) between site V and the other seven sites was found (Tables 8 and 9).

Site VI. Midden site VI (Fig. 8) was excavated in June of 2002. Twenty individuals were captured out of the 21 middens excavated (Table 2). Thirteen adults (6 males and 7 females), three subadults (2 males and 1 female), and four pups (2 males and 2 females) were captured from this site (Table 13). Sex ratios between this site and the other seven sites were found to be nonsignificant (Table 5). Using a t-test, calculation of the distances between middens in this site and comparing them to the distance in the other seven middens sites produced no significant difference (Tables 8 and 9). P-values ($P>0.05$) obtained by performing a chi^2 test showed no significant difference between sites when comparing sex and age class (Tables 4 and 5).

Site VII. Site VII (Fig. 9) along with site VIII produced the fewest number of individuals during the study. Sixteen middens were excavated in site VII (Table 2) and 19 woodrats were captured. Twelve adults (6 males and 6 females), four subadult males, one juvenile female, and two pups (1 male and 1 female) were captured (Table 13). No significant difference was found ($P>0.05$) when testing the sex ratios (Table 5). Midden distances between this site and the other sites, was tested using a t-test, again no significant difference was obtained ($P>0.05$) between the sites (Tables 8 and 9). When comparing the midden distances between this site and site III using a t-test, P-values equaled 0.06 (Table 8). Although this does not signify significance, it is the closest to being significant among all the sites.

Site VIII. Site VIII (Fig. 10) was the last midden site excavated for the study. This site was excavated in January of 2003. This site, along with site VII, produced the fewest number of individuals. Site VIII also had the most middens (23) out of all the midden sites (Table 2). Nineteen individuals were captured from midden site VIII. Sixteen adults (10 males and 6 females), two subadult males, and one juvenile male were captured from this site (Table 13). A chi^2 test was conducted to test for significant differences between the sex ratios and age classes between the midden sites (Tables 4 and

5). The results concluded that there was no significance ($P>0.05$). When testing for significance between midden distances between each site, there was no significant differences ($P>0.05$) between the eight midden sites (Tables 8 and 9).

Table 1. Number of males and females within each age class.

	Adults	Subadult	Juvenile	Pup	Total
Males	51	18	14	8	91
Females	52	10	14	12	89
Total	103	28	28	20	180

Table 2. Numbers of middens per site and number of males and females in each site.

Site	Middens	Males	Females
I	11	14	13
II	17	13	12
III	18	10	13
IV	21	9	11
V	20	11	16
VI	21	10	10
VII	16	11	8
VIII	23	13	6
Total	148	91	89

Table 3. Comparison of males and females by age class. Expected values (in parentheses) and proportions used for testing significance. A Chi2 test was used to obtain P-values (P=0.87).

	Sex			
Age	Males	Females	Total	Proportions
Adult	51 (52.0)	52 (50.9)	103	0.57
Subadult	18 (14.1)	10 (13.8)	28	0.16
Juvenile	14 (14.1)	14 (13.8)	28	0.16
Pup	8 (10.1)	12 (9.9)	20	0.11
Totals	91	89		
Proportions	0.51	0.49		

Table 4. Comparison of each age class across each of the eight midden sites. Expected Values (in parentheses) and proportions used for testing significance. A Chi^2 test was used to obtain P-values ($P=2.26X10^{-13}$).

Site	Age				Total	Proportion
	Adult	Subadult	Juvenile	Pup		
I	10 (15.4)	0 (4.2)	17 (4.2)	0 (3.0)	27	0.15
II	13 (14.2)	11 (3.9)	1 (3.9)	0 (2.8)	25	0.13
III	13 (13.1)	4 (3.5)	6 (3.5)	0 (2.5)	23	0.12
IV	14 (11.4)	3 (3.1)	2 (3.1)	1 (2.2)	20	0.11
V	13 (15.4)	1 (4.2)	0 (4.2)	13 (3.0)	27	0.15
VI	13 (11.4)	3 (3.1)	0 (3.1)	4 (2.2)	20	0.11
VII	12 (10.8)	4 (2.9)	1 (2.9)	2 (2.1)	19	0.11
VIII	16 (10.8)	2 (2.9)	1 (2.9)	0 (2.1)	19	0.11
Total	103	28	28	20		
Proportion	0.57	0.15	0.15	0.11		

Table 5. Comparison of males and females over all eight midden sites. Expected values (in parentheses) and proportions used for testing significance. A Chi^2 test was used to obtain a P-value (P=0.99).

Sites	Sex		Total	Proportions
	Males	Females		
I	14 (13.6)	13 (13.3)	27	0.15
II	13 (12.4)	12 (12.3)	25	0.14
III	10 (11.5)	13 (11.3)	23	0.13
IV	9 (10.1)	11 (9.9)	20	0.11
V	11 (13.6)	16 (13.3)	27	0.20
VI	10 (10.1)	10 (9.9)	20	0.11
VII	11 (9.5)	8 (9.3)	19	0.11
VIII	13 (9.5)	6 (9.3)	19	0.11
Total	91	89		
Proportions	0.51	0.50		

Table 6. Average distance (meters) between middens for all eight sites.

Sites	Mean	Greatest Distance	Shortest Distance
I	7.99	15.62	2.24
II	6.27	14.42	0.00
III	7.30	14.31	2.00
IV	7.56	17.02	1.41
V	6.08	12.08	2.82
VI	5.83	12.04	1.00
VII	5.54	10.00	3.16
VIII	6.06	17.46	1.00
All Grids	6.58	14.12	1.70

Table 7. Mean distances between middens occupied by adult male or adult female woodrats, by site.

Site	Male		Female	
	Number of middens	Mean distance (range)	Number of middens	Mean distance (range)
I	4	19.5 (16.8-24.1)	5	14.2 (9.8-20.5)
II	7	7.9 (1.4-15.5)	7	8.2 (5.0-15.6)
III	6	8.8 (7.2-11.0)	7	11.4 (2.0-23.2)
IV	5	14.0 (10.6-17.2)	9	12.9 (5.0-17.1)
V	7	14.7 (12.5-11.1)	7	9.9 (2.8-16.4)
VI	7	7.3 (5.0-7.2)	6	7.7 (3.0-28.2)
VII	8	5.8 (4.2-7.2)	6	9.3 (3.6-13.6)
VIII	11	7.9 (3.6-13.9)	6	14.8 (11.0-19.7)
P-value		<0.05		0.30

Table 8. T-test showing P-values for distances between each individual midden distance across the eight midden sites.

Site	II	III	IV	V	VI	VII	VIII
I	0.29	0.65	0.8	0.21	0.16	0.11	0.22
II		0.37	0.33	0.86	0.68	0.47	0.85
III			0.83	0.21	0.13	0.06	0.23
IV				0.21	0.15	0.08	0.22
V					0.77	0.5	0.98
VI						0.7	0.81
VII							0.55

Table 9. T-test showing P-values for midden distances (using averages for each midden site) between each midden site.

Site	II	III	IV	V	VI	VII	VIII
I	0.88	0.42	0.77	0.73	0.8	0.92	0.7
II		0.55	1	1	0.73	0.42	0.36
III			0.53	0.42	0.5	1	0.69
IV				0.29	0.73	0.64	0.41
V					0.5	0.55	0.4
VI						0.4	0.29
VII							0.07

Table 10. Midden distances between male middens (calculated by a t-test) across all eight study sites.

Sites	II	III	IV	V	VI	VII	VIII
I	0.001	0.004	0.052	0.10	0.0008	0.004	0.001
II		0.69	0.03	0.03	0.80	0.32	0.99
III			0.01	0.03	0.37	0.007	0.52
IV				0.83	0.007	0.002	0.008
V					0.01	0.006	0.01
VI						0.31	0.75
VII							0.10

Table 11. Distances between female middens (calculated by a t-test) showing some significance between some sites and nonsignificance between the majority of the sites.

Sites	II	III	IV	V	VI	VII	VIII
I	0.04	0.44	0.63	0.19	0.20	0.10	0.80
II		0.35	0.059	0.57	0.91	0.69	0.01
III			0.65	0.68	0.48	0.53	0.31
IV				0.31	0.29	0.16	0.39
V					0.66	0.83	0.10
VI						0.74	0.16
VII							0.04

Table 12. T-test showing P-values for distances between male and female middens within the same site.

Sites							
I	II	III	IV	V	VI	VII	VIII
0.08	0.90	0.39	0.58	0.15	0.93	0.12	0.003

Table 13. Ages and sexes for individuals captured at each midden site. Males are listed first in each age class.

Sites	I	II	III	IV	V	VI	VII	VIII	Total
Adult	4	6	7	6	6	6	6	10	51
Adult	5	7	6	8	7	7	6	6	52
Subadult	0	6	1	2	1	2	4	2	18
Subadult	0	5	3	1	0	1	0	0	10
Juvenile	10	1	2	0	0	0	0	1	14
Juvenile	8	0	4	2	0	0	1	0	14
Pup	0	0	0	1	4	2	1	0	8
Pup	0	0	0	0	9	2	1	0	12
Total	27	25	23	20	27	20	19	19	180

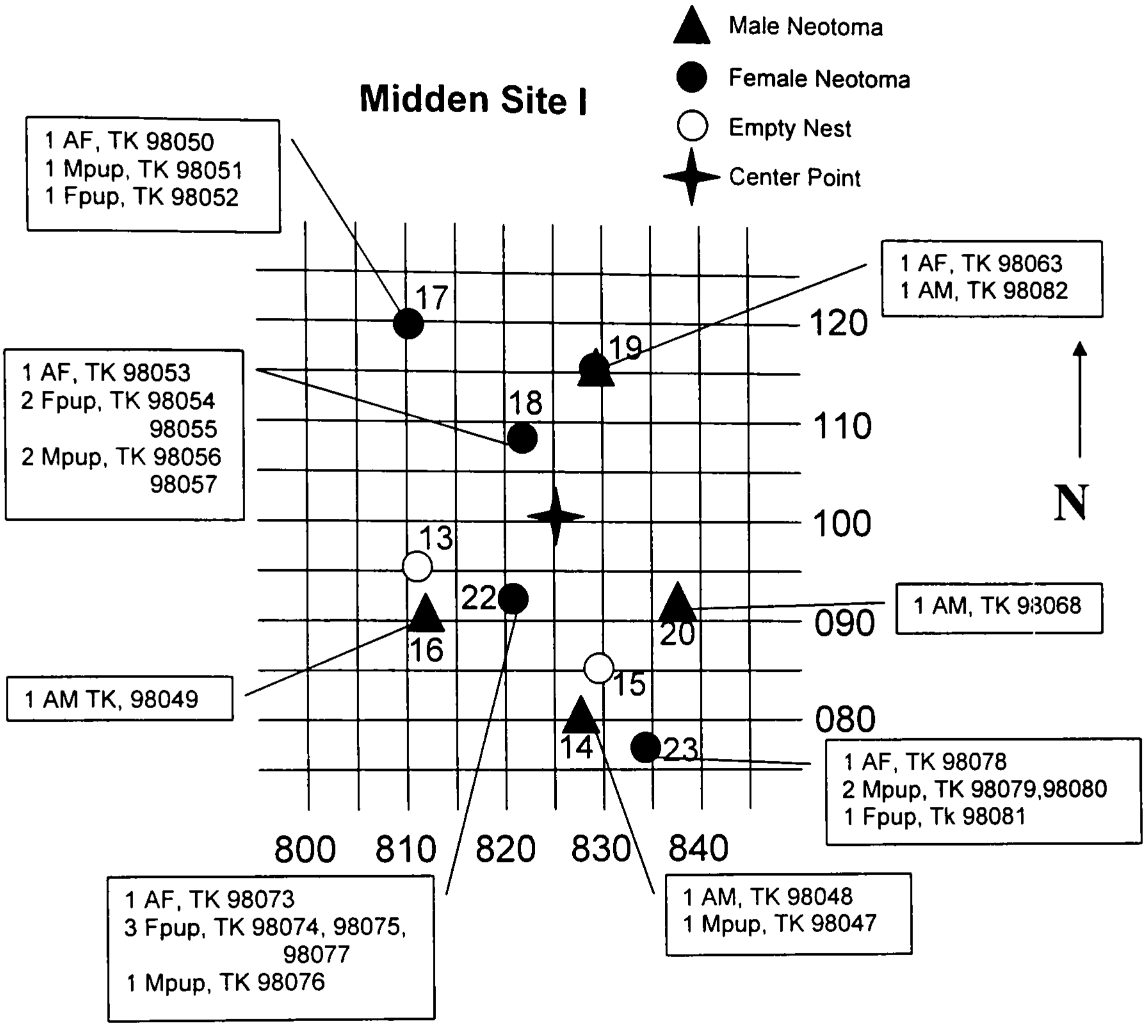

Figure 3. Map of midden site I constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age, and spatial reference.

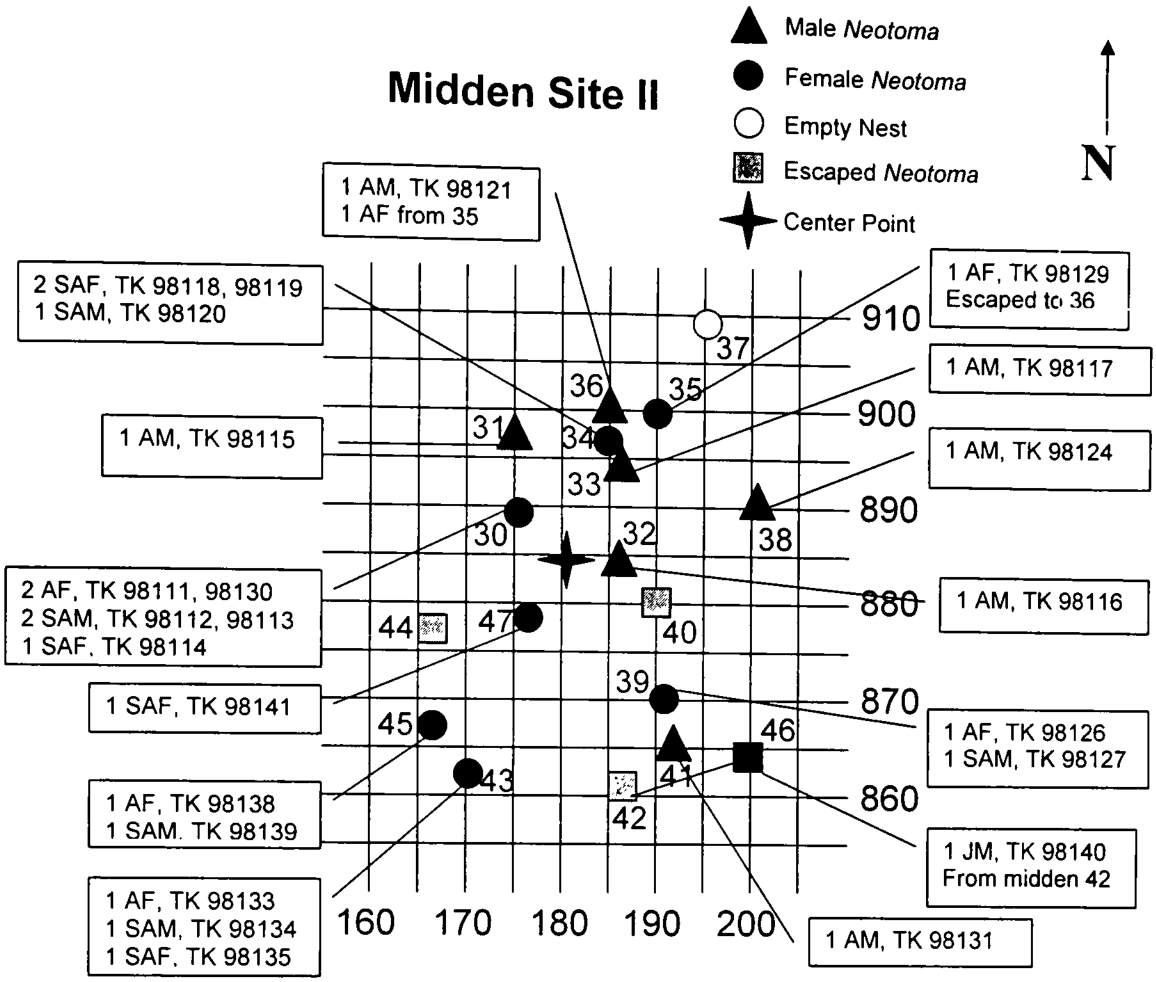

Figure 4. Map of midden site II constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age and spatial reference.

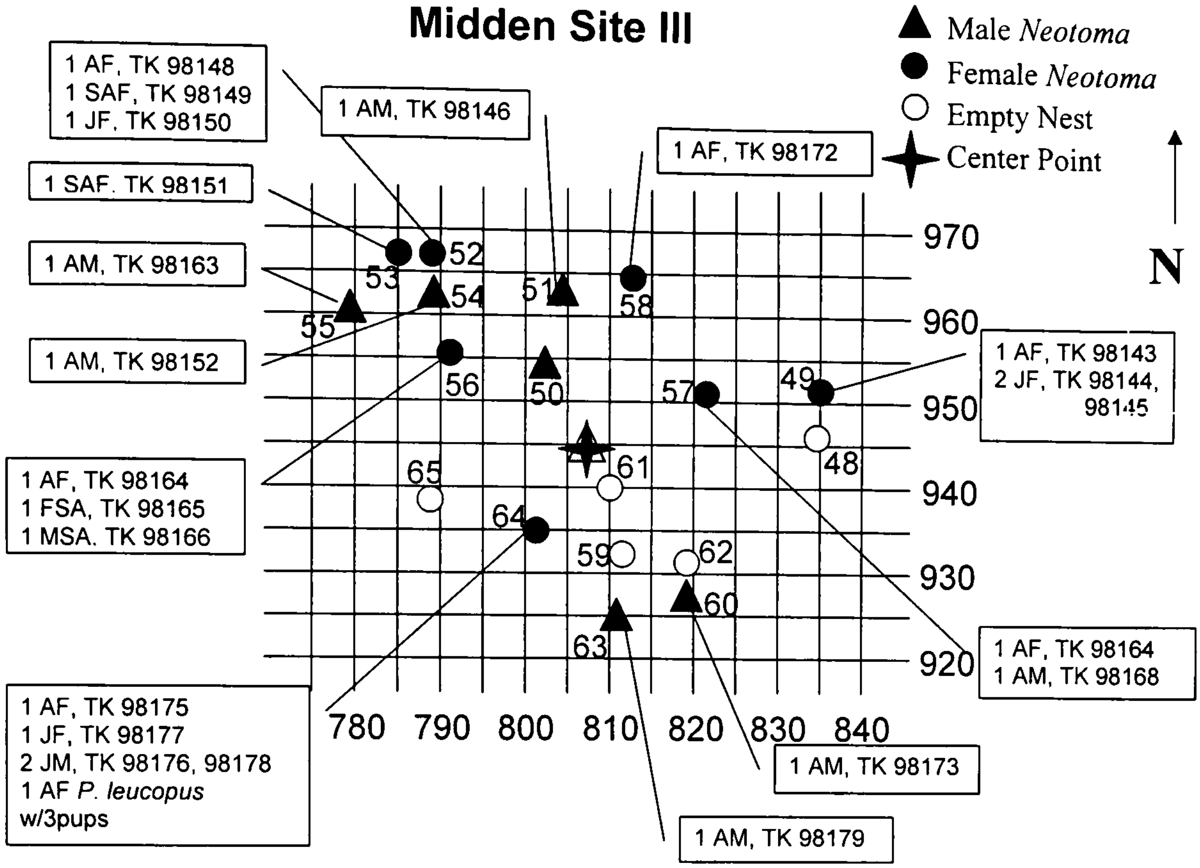

Figure 5. Map of midden site III constructed using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age, and spatial reference.

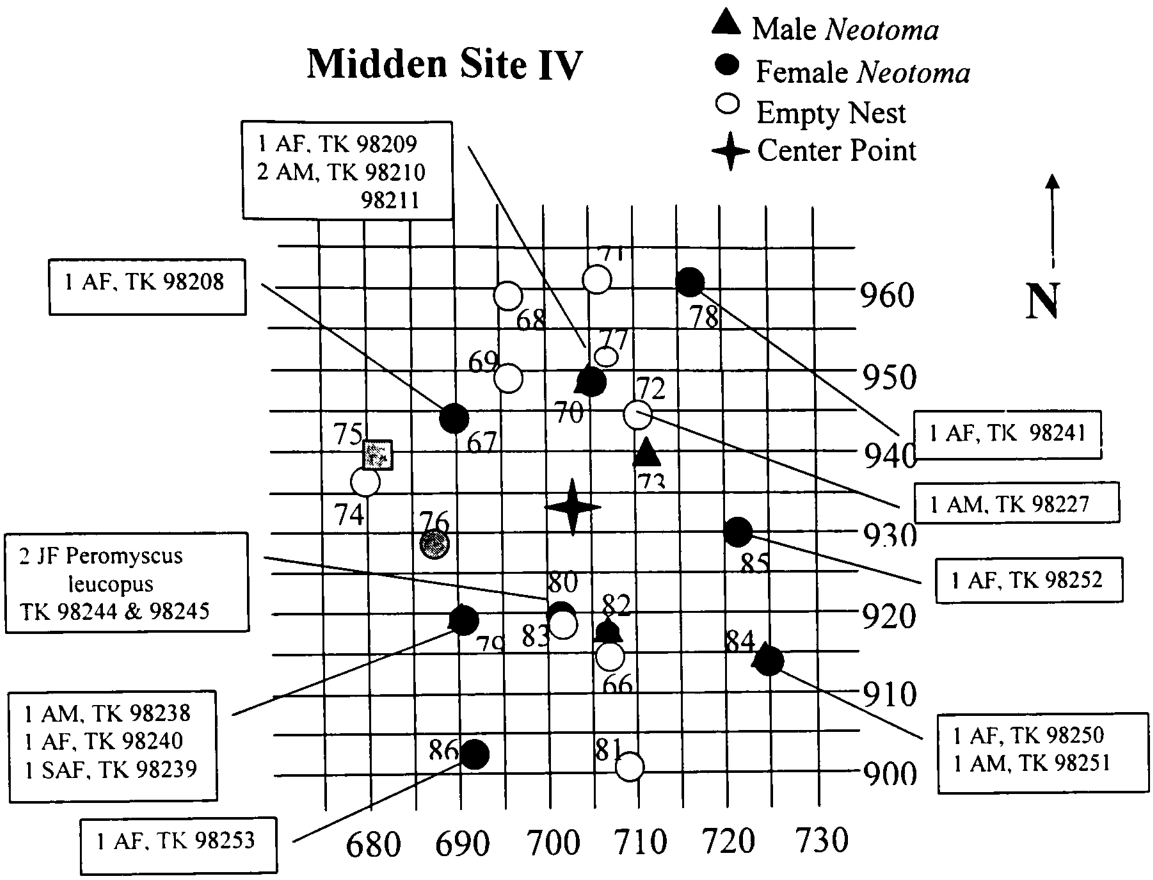

Figure 6. Map of midden site IV constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age and spatial reference.

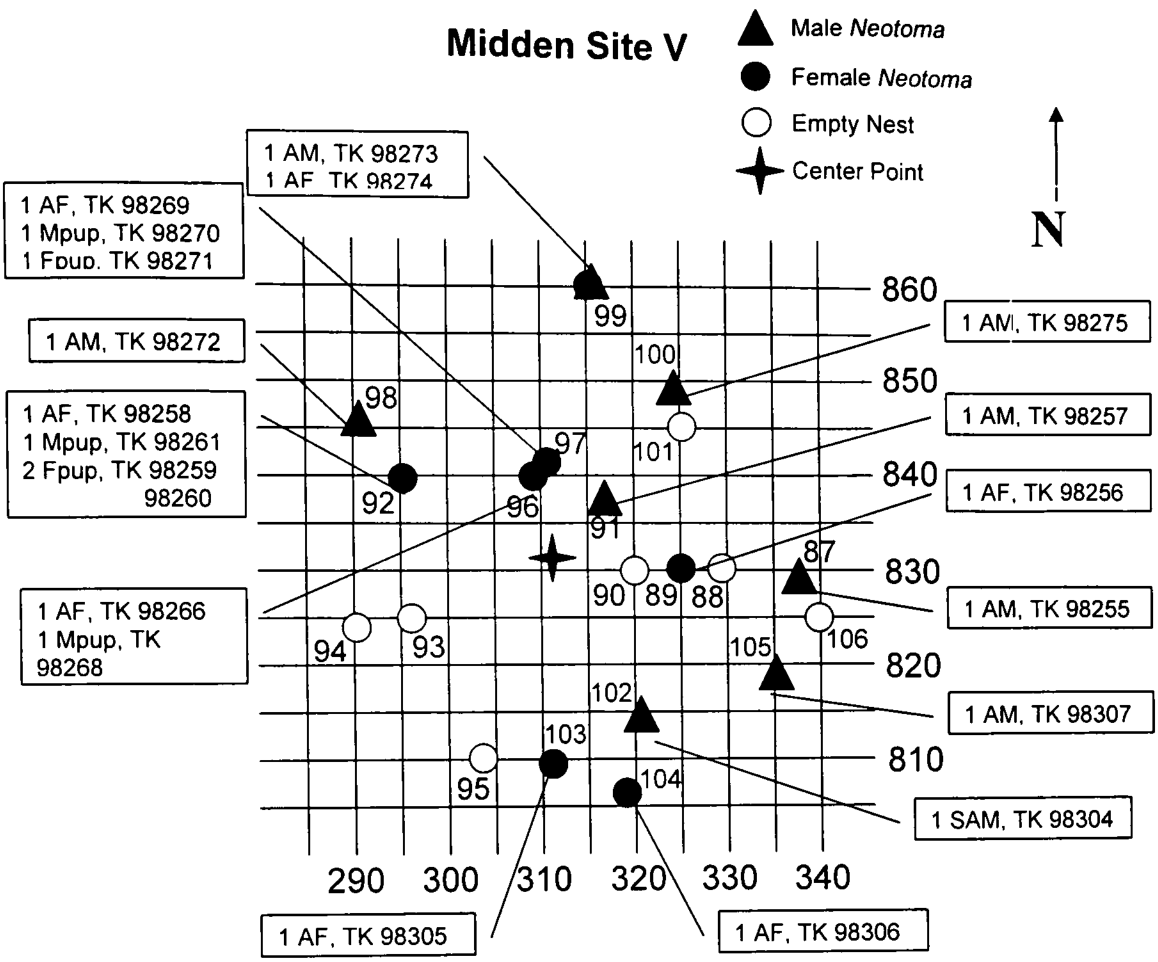

Figure 7. Map of midden site V constructed using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of N. micropus within the site, age and spatial reference.

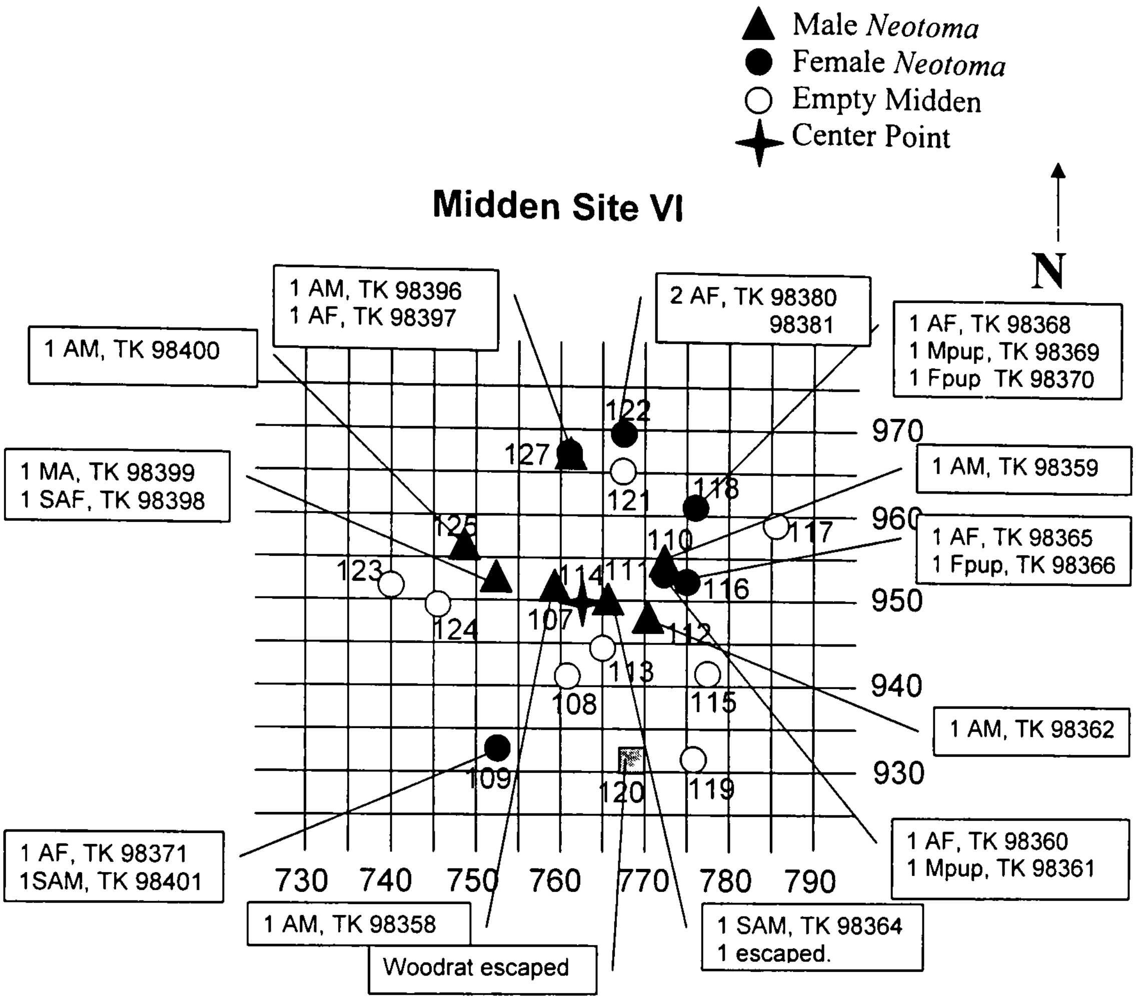

Figure 8. Map of midden site VI constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age, and spatial reference.

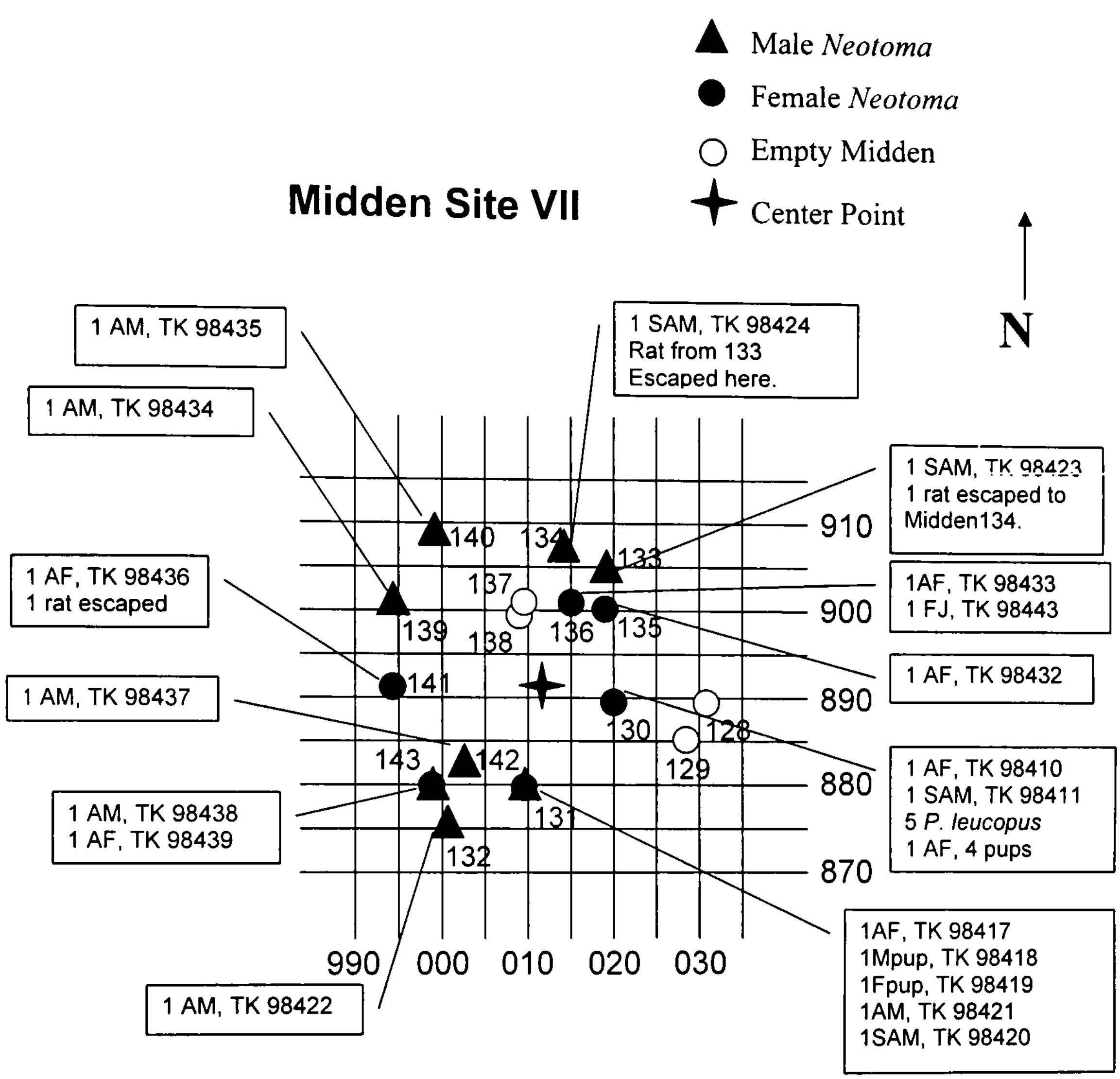

Figure 9. Map of midden site VII constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age, and spatial reference.

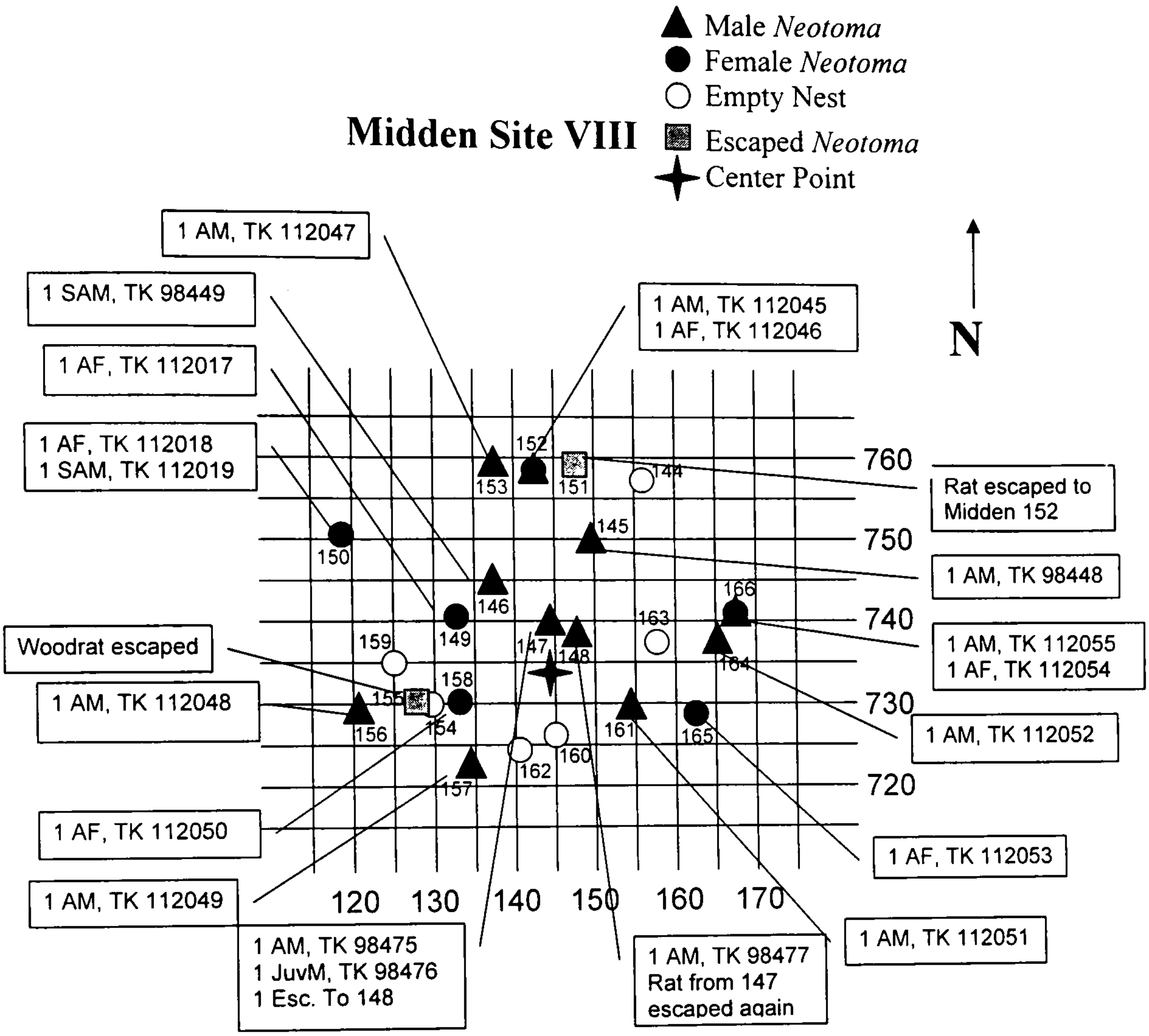

Figure 10. Map of midden site VIII constructed by using UTM coordinates collected in the field to establish an overview of the midden site that includes sex distribution, number of *N. micropus* within the site, age, and spatial reference.

CHAPTER IV

DISCUSSION

The excavation of 148 middens from March 2001 to January 2003 resulted in the capture of 180 individuals. Two sites were excavated per season (winter, spring, summer, and fall) over the two-year study period in order to obtain two sampling periods per season. Ninety-one males and 89 females were captured from the midden over the two year study period. Parameters compared across the eight sites were found to be statistically nonsignificant in most cases.

Age. Four age classes were recognized (adults, subadults, juveniles, and pups) in this study. Adults (103) were the most numerous age class captured ($P<0.05$). Both subadults and juveniles, were represented by 28 individuals, and pups (20) were the least numerous. Tests conducted to test the ratios of the different age classes showed no significance between the age classes across the eight midden sites and within each of the eight sites.

Sex. The overall comparison of the number of males to females across the eight midden sites resulted in no significant differences when t-tests were performed. Examination of sex ratios across the four age groups, (a chi^2 test) resulted in no significant differences ($P>0.05$) across the eight midden sites. Overall results for comparisons between the sexes across the sites and within the sites indicated an equal distribution of males and females within each site and across the midden sites.

Distance between middens. Distance between middens was the only aspect of the study to show any significance. Examination of the midden distances across the eight sites using a t-test produced no statistically detectable differences. Averages of midden distance between the sites also produced no significant differences. Evaluation of the midden distances for males to females within each midden site revealed that, midden site VIII was significantly different (P=0.003) indication that male midden distances were statistically significant. None of the other seven midden sites show any significant differences in the distance between male and female middens. Using an ANOVA resulted in statistical significance between male middens across the eight sites while at the same time showing nonsignificance between female middens across the eight sites. Using a t-test to look for specific differences between males, results showed significant differences at 16 different occasions across the eight sites. When using a t-test to compare distances between female midden, significant differences were detected on only three occasions.

Middens/site. No significance differences were found between midden densities across the eight sites. The fewest number of middens excavated was within site I (11) and the most numerous middens excavated were in site VIII (23). The average number of middens excavated was 18.37 across the eight sites.

Occupancy. Twenty-eight middens showed an occupancy of adult females with their young. It was not uncommon to find multiple generations living in the same midden at the same time. Male adults and female adults were found in 13 middens. The highest number of individuals found in one midden was six and the number of middens with greater than five individuals was five.

At the beginning of this study, several predictions were made concerning the habits of *N. micropus*. For instance, it was thought that the social mating structure would be one based on a harem-like system, with one dominant male surrounded by several reproductively active females with the male territory being guarded against other potential male suitors. The different tests conducted (chi^2, ANOVA, and t-test) using the data collected in the field resulted in conclusions that do not support a harem mating system. Additionally, the maps of each midden site revealed no visible patterns that would support any type of social structure regarding midden placement or midden selection by males or females.

Second, because of the idea that the woodrats were thought to have a harem based mating system, it was predicted that the number of females collected during the study would be more numerous than males captured. As shown, there were more males captured than females. Not only were more males captured, the number of males was greater than the number of females captured in the adult and subadult age classes. The number of juveniles captured was equal across both sexes and the only age class to show more females captured than males was pups. However, the difference in the number of males and females captured was not significant across the eight study sites. More adults than any other age class were captured from the midden sites which showed significant differences when compared to the other three age classes ($P=2.26X10^{-13}$).

Because it was thought that there would be a harem based mating system, I predicted that this would have some effect on the distances between each midden within the sites. It was thought that there would be some kind of "standard" distance between male middens and to a lesser degree, the female midden distances would differ as well. Statistical tests showed that there was some significance of midden distances between male middens across the eight sites. Female midden distances were shown to be statistically significant on three occasions across the eight sites. Within each site, however, there was shown to be no significance between the midden distances with one exception. Midden site VIII was statistically different compared to the distances of male middens to the distances of female middens. The reason for this is difficult to speculate on due to the fact that no other site during the study resulted in similar conclusions. One reason could be that there were several more males captured from this site than females.

The social structure within the midden itself was another aspect of the study that did not hold true with predictions of woodrat habits. The most surprising finings was that of adult males and adult females captured within the same midden. On 13 different occasions, males were found in the same midden as adult females. There are at least two possibilities to explain these finding. The simplest would be that the male was there solely for mating purposes. Although this may be true, all middens were excavated during the daylight hours, and *N. micropus* is a nocturnal species. Because of this, several questions arise as to the social habits of *N. micropus*. How long does courtship take place—perhaps they stay "overday." Because of the high densities of woodrat middens on the CWMA, do adult males and females cohabitate? Parameters of this study do not give significant conclusions to these questions, only more hypotheses.

Because of the direct capture of all individuals throughout all midden sites, one aspect of their natural history that we could not measure is the home range. Studies by Henke and Smith (2000) and Conditt and Ribble (1997) that studied the home ranges of *N. micropus* found that the home range of males to be 1696 m^2 and 1829.2 m^2 respectively. Female home range was found to be significantly less at 188 m2 and 258.2 m^2 (Fig. 11). Due to the large numbers of woodrats per hectare and the abundance of resources, the home ranges of woodrats on the CWMA is most likely does not have to be that large. Figure 11 is a map of the resulting home ranges concluded by the studies conducted by Henke and Smith (2000) and Conditt and Ribble (1997). When superimposed on a map of one of the midden sites, it is easy to see that the suggested home ranges of *N. micropus* would extend well beyond the boundaries of the midden sites. The number of woodrats per hectare in this study was 112.50 and the number of middens per hectare was 92.50. The number of males was 56.87 and the number of females was 55.62 per hectare. These numbers are much greater than that found in the two most recent natural history studies (Henke and Smith, 2000; Conditt and Ribble, 1997) conducted on *N. micropus*. One possible explanation for the large increase for this study is that this study was biased for high densities of woodrat middens.

This study answered several questions regarding the natural history of *N. micropus* in South Texas. Because of the habitat conditions, the survival and maintenance of the *N. micropus* population on the CWMA is ideal for sustaining large populations of woodrats.

The large amounts of food and cover resources available to the woodrats on the CWMA enable the populations to not only survive but survive in such close proximity with each other that early predictions on the habits and social structure simply do not apply in this study. One observable limiting factor keeping the *N. micropus* population from expanding is the absence of favorable habitat conditions across the entire property.

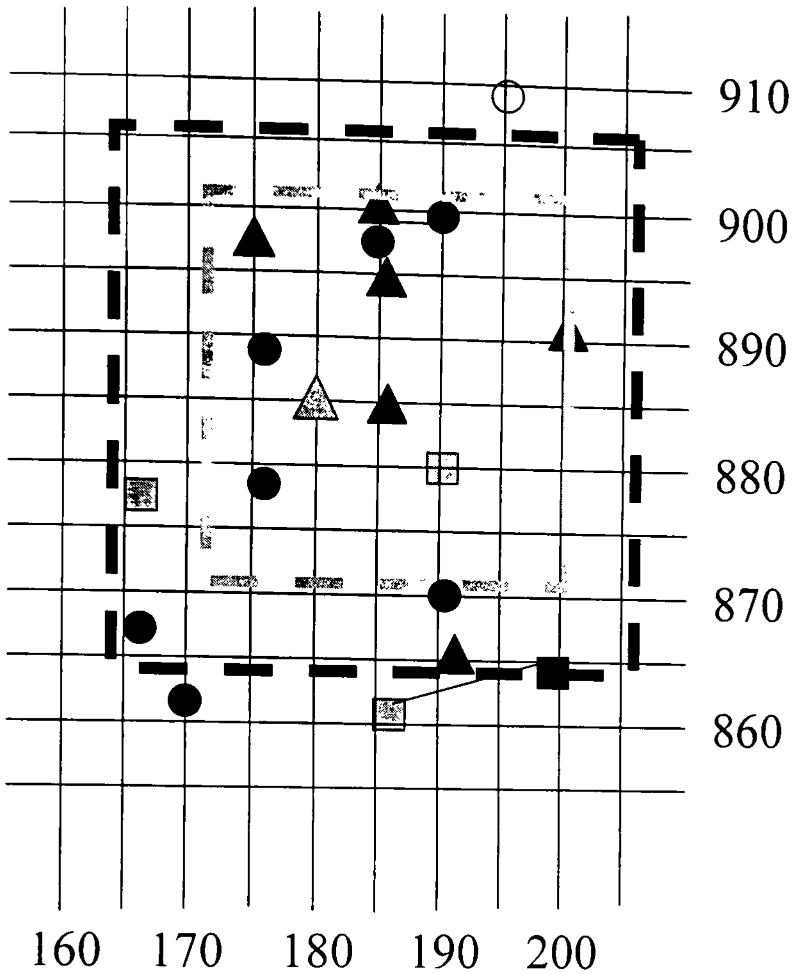

Figure 11. Home range estimate based on papers written by Condit and Ribble (2000) (black), and Henke and Smith (1997) (grey) placed over a site map.

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