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**COMPARISON of the GEOGRAPHIC VARIATION in TWO SPECIES of GROUND SQUIRRELS (*Spermophilus*)**

A Thesis

by

KARAN MARIE WATTS

Presented
in partial fulfillment of the
requirements for the degree of

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18 Oct. 1993 Approved

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## ABSTRACT

Comparison of the Geographic Variation in Two Species of Ground Squirrels (Spermophilus)

Karen Marie Watts, B.S. Texas A&M University

Standard external measurement data was recorded from study skins at four Texas institutions. These collections also provided the specimen skulls from which twelve standard cranial measurements were made with digital calipers to the nearest 0.01 mm. This study included 111 Mexican ground squirrels (Spermophilus mexicanus) and 76 spotted ground squirrels (Spermophilus spilosoma). Most specimens had been collected in Texas and Mexico. Fifteen spotted ground squirrels had also been captured in four other states. An adaptation of the USDA Plant Hardiness Zone Map was used to subdivide the study area, so that geographic variation could be determined.

Comparison of mean and standard deviation for males and females of both species revealed some sexual dimorphism. Female spotted ground squirrels appear to be consistently larger than the males in body size, while the opposite appears to be true for Mexican ground squirrels.

Patterns of geographic variation differed for these two species. Climatic gradients were found for both species, although, for certain characteristics, an unexplained size increase occurs before the start of the gradual cline for the spotted ground squirrel. This study concludes that factors besides temperature are influencing geographic variation in these species. Future studies on the life histories and sexual dimorphism of these ground squirrels are needed.

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# INTRODUCTION

## Mexican Ground Squirrel

Spermophilus mexicanus (Erxleben, 1777), Order Rodentia, Family Sciuridae, Genus Spermophilus (formerly Citellus), Subgenus Ictidomys (includes S. tridecemlineatus, S. perotensis, S.spilosoma).

Two subspecies are recognized: (Howell, 1938) S. m. mexicanus (Erxleben, 1777: 428), type locality restricted to Toluca, Mexico, by Mearns (1896:1), and S. m. parvidens Mearns, 1896:1, type locality Ft. Clark, Kinney Co., Texas. In general, the Mexican ground squirrel ranges from southeastern New Mexico through southwest-central Texas to central Mexico. Some overlap with S. tridecemlineatus occurs in a region of southeastern New Mexico and northwestern Texas. Interfertile hybrids between these two species have been found in association with S. mexicanus populations (Cothran et al, 1977); both species have a diploid number of 34 chromosomes.

This small to medium-sized ground squirrel (domestic rat size) has nine rows of squarish white or light buff spots down its back. Upperparts are brown and underparts are whitish or pinkish buff. The somewhat bushy tail, comprising less than half the squirrel's total length, is flattened with a cylindrical base, and has buff tipped hairs. The ears are short and rounded. There are 8 to 10

mammae. The skull is average size in comparison with others in Ictidomys and lightly built. The postorbital constriction is narrow as for others in the subgenus. The baculum is morphologically similar to that of S. tridecemlineatus but distinct from that of S. spilosoma (Bryant, 1945 in Mammalian Species, Young and Jones, 1982). Males tend to be larger than females. The dental formula is i1/1, c0/0, p2/1, m3/3, for a 22 tooth total. Molt in this ground squirrel, described by Goetze and Stangl in 1989, resembles the spring molt in S. spilosoma in both the direction and style of pelage replacement. Guard hairs and underfur are replaced in synchronized but separate molts beginning on the head and proceeding dorsally and caudally (Goetze and Stangl, 1991).

Spermophilus mexicanus prefers sandy or gravelly soils in brushy or grassy areas with cactus, mesquite or creosote. Burrows may be found at the base of mesquite bushes or near prickly pear cactus. Entrance holes are without a dirt mound; burrow diameter is 60 mm to 80 mm with an angle at the entrance of 30 to 50 degrees. Home burrows have two entrances. Several escape burrows are also occupied. Their home range is usually 90 m or less in diameter. Hibernation may occur in northern areas; activity continues in the south all year except for inclement weather. Although somewhat colonial, intruders

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are not tolerated in burrows. One litter of one to ten (average five) are born in May; breeding occurs from late March to early April (Davis, 1974 and Edwards, 1946 per Young and Jones, 1982). This squirrel is diurnal and usually quiet and shy. Its alarm call is a short trilling whistle or shrill whistle.

Foods vary throughout the year. Green vegetation in the spring is eaten along with cultivated grains and germinating seeds. Mesquite beans and acacia seeds are favorites. By early summer insects make up half the diet. They have also been observed to feed on roadkills. In captivity, they may kill and eat their cagemate (Davis, 1974).

## Spotted Ground Squirrel

Spermophilus spilosoma Bennett, 1833, Order Rodentia, Family Sciuridae, Genus Spermophilus (formerly Citellus), Subgenus Ictidomys (includes S. tridecemlineatus, S. perotensis, S. mexicanus).

Twelve subspecies are recognized. Of these S. s. annectens Merriam 1893:132, type locality "The Tanks," 12 miles from Point Isabel, Padre Island, Texas, and S. s. marginatus Bailey, 1902:118, type locality Alpine, Brewster Co., Texas (also S. s. major Merriam a synonym) are the ones reported in Texas. Its range extends through parts of Wyoming, Nebraska, Kansas, Oklahoma, Colorado, Utah,

Arizona, New Mexico and western Texas from the Panhandle to the Rio Grande Valley into Mexico. This range is overlapped in Texas by S. mexicanus, which is recorded in a number of the same counties in west and south Texas as S. spilosoma (Davis, 1974).

The spotted ground squirrel is smaller than the Mexican species (adult hamster size). Color varies, but may be grayish or reddish-brown on the upperparts with scattered, indistinct squarish spots of white or buff; the belly is whitish. There are two annual molts. The pelage is paler in the adult than the juvenile (Sumrell, 1949 from Streubel and Fitzgerald, 1978). The tail is slender and round, not bushy and flattened like the Mexican, and comprises about one-third the total length of the squirrel. The color is the same as the dorsal pelage, but is also tipped with black. Ears are inconspicuous. Ten mammae are present. Exact gestation is not known, but is thought to be about 28 days (Streubel and Fitzgerald, 1978). Breeding may begin as early as February and continue until mid-July in parts of its range. As a rule, five to eight young are born per litter (Asdell, 1964 from Streubel and Fitzgerald, 1978). It is uncertain whether one or two litters may be produced within a year. Nadler and Hughes (1966 from Streubel and Fitzgerald, 1978) found that S. spilosoma has 32 chromosomes compared to 34 in S. mexicanus and S.

_tridecemlineatus_.

These ground squirrels are diurnal, shy and secretive. They run with their body and tail low to the ground. Hibernation probably does not occur in the southern extremes of their range. Its call is a long, bubbling whistle or trill. Activity periods outside the burrow are in the morning and late afternoon. Burrows have more than one entrance and may be located beneath bushes or rocks. Ground squirrels sometimes renovate other burrows such as those of kangaroo rats. Spotted ground squirrels prefer sandy soil, but occasionally are found on rocky mesas. Mexican ground squirrels tend to avoid rocky areas. Grassy areas and open forests or areas with scattered brush and parks are suitable habitat for these squirrels. Green vegetation, seeds and insects especially beetles and grasshoppers are their main diet. Vegetation may include cactus pulp, mesquite beans, saltbush seeds, sandbur, sunflower and gourds.

In recent years, attention has been given to the genetic variation among members of the subgenus _Ictidomys_ as it relates to their evolution and speciation. These species are considered to be more closely related to one another than to other species within the genus _Spermophilus_ (Nadler, 1966), but less closely related than other forms of this genus are in their respective subgenera.

*Spermophilus tridecemlineatus* and *S. mexicanus* are the most closely related of the three species inhabiting the United states; *Spermophilus spilosoma* appears to be the most divergent (Bryant, 1945; Nadler and Hughes, 1966; Cothran et al., 1977). Cothran (1977) considers *S. mexicanus* and *S. tridecemlineatus* to be semispecies (i.e., having both species' and subspecies' attributes). *Spermophilus spilosoma* has been shown to be less similar to *S. mexicanus* than to *S. tridecemlineatus*. Morphologically these ground squirrels have easily discernable differences but exhibit fewer distinctions chromosomally or biochemically (Cothran, 1984). As previously mentioned, all three species have ranges within Texas with overlap in certain areas (Davis, 1974; Cothran, 1983). *Spermophilus mexicanus* and *S. spilosoma* share range in western Texas from south Texas through the northern extreme of *S. mexicanus*' range. The ranges of both *S. spilosoma* and *S. tridecemlineatus* extend farther north than that of *S. mexicanus*, but all three share possible range in an area of western Texas. *Spermophilus mexicanus* and *S. tridecemlineatus* do have overlapping range there, and possibly along the middle Texas coast. Given the recent genetic work and interest in the evolution of these species, an analysis of existing morphological information may prove valuable in understanding the process of speciation within *Ictidomys*.

## MATERIALS AND METHODS

Skins and skulls of two ground squirrel species, *Spermophilus mexicanus* and *Spermophilus splilosoma* were examined at four institutions. Cranial and non-cranial data were collected from a combined total of 187 specimens at the following institutions: University of Texas at Austin (Natural History Collection), Texas Tech University (Natural Science Research Lab and TTU Center, Junction--skins only), Texas A&I University, and Incarnate Word College. Unfortunately, because of the situation created by flood damage to its collection, no specimens from Texas A&M University were available for inclusion in this study as originally intended.

Seventy-six *Spermophilus spilosoma* and 111 *Spermophilus mexicanus* skulls and/or skins comprise the total specimens examined. *Spermophilus mexicanus* was represented by a single subspecies, *parvidens*, while *Spermophilus spilosoma* included four subspecies, *marginatus* (*major*), *annectens*, *canescens*, and *spilosoma*. The possibility of small sample size necessitated inclusion of specimens with missing data.

### Measurements

Non-cranial information recorded for both species include: total length, tail length, hindfoot length, ear

length, weight and reproductive information. All lengths are expressed in millimeters. Almost three-quarters of the specimens lacked weights and even fewer had any observations on reproduction, so these will not be considered further. Several specimens, usually females, lacked all of the above, but cranial measurements were taken. Otherwise, the ear length was the measurement most often unrecorded. Lengths from obviously short or damaged tails and other questionable measurements were collected, but not used in the analysis. Body lengths were calculated from the total and tail lengths, and used as an indicator of size rather than the total especially when the tail was unusually short. Total lengths accompanied by shortened tail lengths were not used.

Twelve standard cranial measurements were taken in millimeters from the right side with digital calipers: skull length, zygomatic breadth, nasal length, rostral length, cranial breadth, interorbital breadth, postorbital breadth, upper diastema length, maxillary toothrow length, bullar length, bullar breadth, and mandible length.

Skull length represents the greatest length from the anterior portion of the nasals to the posterior aspect of the skull along the dorsal half of the occipital. Zygomatic breadth was taken as the greatest distance between the outer margins of the arches generally along the

squamosal's zygomatic process. Some slight, individual asymmetry was noticed between the right and left sides.

Nasal and rostral lengths employed specifically designated points on the skull. Nasal length was the distance between the anteriormost and posteriormost points along the nasal bones' midline suture. Rostral length was taken from the medial, anteriormost point on the nasals to a point at a suture line just anterior to the zygomatic arch. These two points provided the most consistent measurements anteriorly and posteriorly for the rostrum, although it gives an angled measure rather than the least distance for rostral length.

Cranial breadth was measured across the braincase at a point just dorsal and posterior to the posterior end of the zygomatic arch. This was not necessarily the greatest distance. That position appeared to vary with individual cranial shape and size.

Interorbital breadth was measured at a specific point rather than as the least distance across the frontal bone. A foramen along the frontal bone edge at the anterior of the orbit was used as a morphometric guide. The interorbital measure was taken immediately posterior to this to avoid any inconsistency in the measurement caused by size and shape changes in that part of the skull. Individual variation, that caused the least interorbital

distance location to shift, was observed. The postorbital measurement was made immediately posterior to the postorbital processes of the frontal bone in the postorbital constriction, and could be considered to be the least distance across the frontal bone.

The upper diastema length was measured from the right maxillary incisor's alveolus at its posterior margin to the first cheek tooth's anterior margin. Maxillary toothrow length was taken from the anterior alveolar edge of the first maxillary tooth on the right side to the last tooth's posterior edge.

Bullar length and breadth were taken across the widest and longest axis of the right bulla. Bullar length excluded the paroccipital process at the bulla's posterior. This process sometimes interfered with the measurement, but other times gave more than adequate space for the calipers to measure the bulla. Individuals showed definite variation in bullar size and shape.

Finally, mandibular length was taken from the posterior point on the mandibular condyle to the ventral alveolus of the right incisor. Although most measurements were made on the right side for consistency, one jaw length was taken from the left, when the right half was broken.

## Geographic Locations

Typically, specimen populations range from a single individual in a specific location to 14 within an area of several kilometers. The maximum number for a species in a general area was 21 spotted ground squirrels collected at different locations on Mustang Island near Port Aransas. Eighteen Mexican ground squirrels had also been collected within the city and vicinity of Kingsville. Collections yielded mostly specimens from Texas, but included specimens from surrounding states and Mexico. Spermophilus mexicanus specimens were collected in these Texas counties: Bee 3, Brewster 1, Fisher 2, Terrell 14, Travis 4, Crockett 1, Dawson 5, Howard 1, Kerr 3, Medina 1, Williamson 1, La Salle 1, Live Oak 3, Hidalgo 5, Dickens 1, Upton 6, Sutton 2, Kinney 1, Crane 1, Kimble 6, Scurry 1, Kleberg 20, Jim Wells 2, Cameron 4, Zapata 4, Gillespie 1, and Frio 1. Additionally, others were collected in Coahuila, Mexico 15.

Spermophilus spilosoma specimens were collected in Arizona: Cochise Co., Portal 6; New Mexico: Dona Ana Co., Las Cruces 5 and Bernadillo Co., Albuquerque 1; Colorado: Prowers Co., Lamar 2; Oklahoma: Jackson Co., Blur 1; Texas counties: Childress 1, Kleberg 2, Kenedy 2, Jim Hogg 2, Nueces 10, Hutchinson 3, Presidio 7, Dawson 2, San Patricio 12, Martin 1, Lubbock 3, Winkler 3, Brewster 1, Cochran 2, Reeves 1, Bailey 1, Oldham 3, Ector 1, and Culbertson 1.

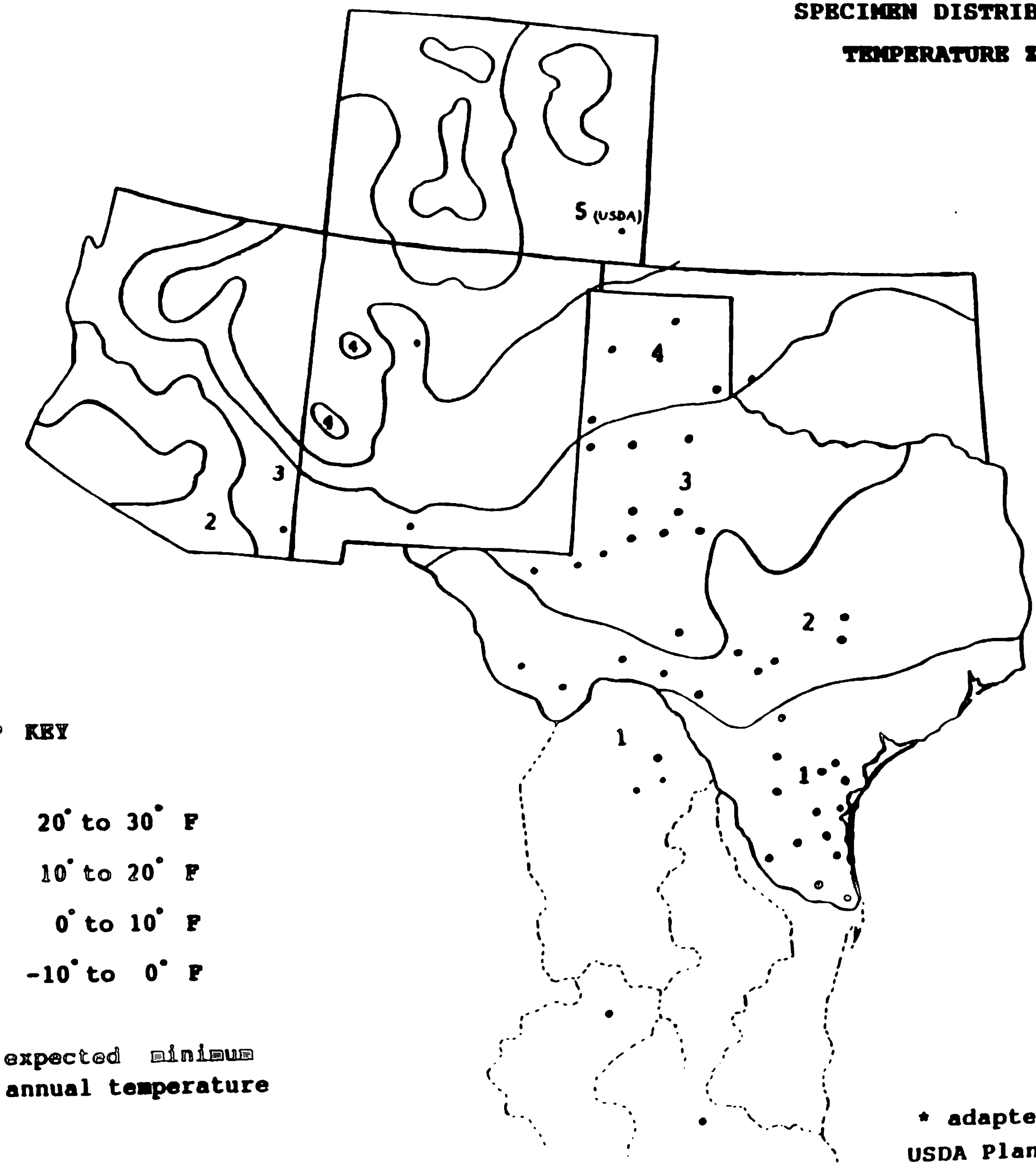
Specimens were also collected in the Mexican states Coahuila 1, San Luis Potosi 2, Zacatecas 1.

## Temperature Zones

In order to determine the extent of any geographic variation existing for the characters measured in these two ground squirrels, the United States Department of Agriculture Plant Hardiness Zone Map (1960) was used to divide the study area into four temperature zones. The minimum annual expected temperatures from the map were based on 60-year records of the U.S. Weather Bureau. For both squirrels, South Texas and the Mexican states were considered together in the warmest zone, designated here as zone 1 (USDA 9); range for the annual minimum expected temperature is 20 to 30 degrees Fahrenheit (-6.7° to -1.1° C). Counties in west-central Texas from along the Mexican border across the state fall into zone 2 (USDA 8) with a temperature range between 10 and 20 degrees F (-12.2° to -6.7° C). The remainder of western Texas with portions of north-central Texas, the southeastern corner of Arizona, and New Mexico are included in zone 3 (USDA 7) with a temperature range 0 to 10 degrees F (-17.9° to -12.2° C). The northernmost counties in Texas, the Panhandle region, and Colorado are represented only by spotted ground squirrels whose range extends farther north than the

**SPECIMEN DISTRIBUTION and**

**TEMPERATURE ZONE MAP** *




**MAP KEY**

| | |
|---|---|
| **Zone 1** | **20° to 30° F** |
| **Zone 2** | **10° to 20° F** |
| **Zone 3** | **0° to 10° F** |
| **Zone 4** | **-10° to 0° F** |

expected minimum
annual temperature

* adapted from the
USDA Plant Hardiness Zone Map

Mexican ground squirrel. The latter's range reaches its northern limit in the vicinity of the demarcation line for zone 4 (USDA 6). Colorado is actually colder than zone 4, -10 to 0 degrees F (-23.3° to -17.9° C); however, because of the limited specimens available and relative proximity to Texas-Oklahoma areas for this zone, they are placed together for convenience and sample size.

Cameron County is actually split on the USDA zone map into the warmest zone used here (20 - 30° F) and the next warmest zone, USDA 10, 30 - 40 degrees F. For the purposes here, Cameron County specimens are included in the 20 to 30° F group. Some discrepancy in zone placement exists for the Arizona specimens according to a recent version of the map for the whole country. The earlier version for the United States (used by Li, 1978), which corresponds to the more detailed one for Texas (from Sperry, 1982), places those from Arizona in the cooler group (0 - 10° F), while the later version places them in the warmer 10 - 20° F degree zone.

All specimens were categorized according to their capture sites within the corresponding zones and grouped by species for analysis. Because Mexican ground squirrels tend to be larger than spotted ground squirrels, the species had to be studied separately. The sexes of both species were also originally separated to determine if

sexual dimorphism existed. Relatively little information about this was available for the two species, but measurements in the literature for the Mexican ground squirrel indicate that those males are larger than the females. Females predominate in all groups of specimens examined here except for the largest group, composed of Mexican ground squirrels in the warmest area, in which males and females almost equaled one another in number. To increase sample size for statistical purposes the genders were grouped together by species and area.

Only specimens considered to be adults were included. Besides the interspecific size differences, the mixed nature of the collections viewed created difficulties in determining the relative age for some specimens by overall size alone. Specimens usually originated from widely separated areas across their natural ranges. Obvious juveniles were excluded. For other possible subadults or borderline cases, the size differences only became apparent once the specimens were categorized by species, sex ,and geographic-temperature areas. No single factor clearly designated a ground squirrel as an adult. Almost all had full erupted teeth. Two that lacked completely exposed molars were generally smaller in most characteristics as well, and thus, considered immature. Body size and skull length were used in conjunction with a group comparison to

judge whether or not other questionable individuals would be included or excluded. Species' measurement ranges given in Hall (1981) or other sources were not always helpful. None of the spotted ground squirrels examined had measurements that approached or fell below the lower limit for skull length stated. In the Mexican ground squirrel, individuals were encountered that fell within an acceptable range for a given character, but were still too small in others to be considered mature. When skull length and external measurements taken as a whole appeared to indicate the individual might have become larger, that specimen was excluded. This was seldom necessary. Size differences between males and females also had to be considered.

Basic statistics were calculated with a Radio Shack® graphic scientific calculator, model EC-4033. Mean, standard deviation and the high and low range values for every characteristic for each species and temperature zone were plotted for comparison. Percentages of tail and body lengths to total length and tail to body length were also calculated for each zone and species.

# RESULTS

## Geographic Variation

Neither of the two species demonstrated dramatic, consistent geographic variation. The spotted ground squirrel varied to a greater degree than the Mexican ground squirrel. Means for most characters measured in the Mexican ground squirrel fall within a narrow range showing little variation through the three zones. Ear lengths for all three areas fall within almost identical ranges with the highest range and mean in zone 2. The coolest area's mean is just slightly below that of the warmest. Mexican ground squirrel body length means vary the greatest with a gradual increase in size from the warmest to the coldest area. However, the range in size became smaller. The largest squirrel (actual size) was found in the intermediate zone, and the next largest in the warmest zone; the smallest (a male) was in zone 1 with the next smallest in zone 2.

Across all four zones for the spotted ground squirrel, over two-thirds of the measured characters had means that fell within a very narrow range, forming shallow U-curves or flattened, sideways S-curves (see Appendix II). Means in zone 4 for zygomatic breadth, ear, and total length are the greatest with the remaining zones' means closer together. Next to body length, skull length appears to

vary the most. Zone 4 means for both of these are greater than all others, but are followed by measures for the warmest zone as next largest. Nasal, rostral and mandibular lengths followed the same pattern.

### Body & Tail Percentages

Tail lengths for both species were, as expected, less than half the total length of the squirrel for all temperature zones. The spotted ground squirrel has a tail length approximately one-third its total length, while the Mexican ground squirrel has a somewhat longer tail. Correspondingly, the Mexican ground squirrel's body length is over half its total length, but less than two-thirds; the spotted ground squirrel exhibited body lengths at least equal to two-thirds the total length or greater. Equal percentages for head-body and tail to total length, and tail to head-body length occur for both species in the two coolest zones for each (2 and 3--Mexican, 3 and 4--spotted).

The spotted ground squirrel's tail percentage increases and body decreases in zone 2. The body percentage increases again in zone 1 to be the greatest for all zones; tail percentage is the lowest in this zone. Head and body show the highest value in the zone 1 range followed by that in zone 3 (means are similar for both

areas). The same pattern occurs for the tail, though the zone 2 mean is the greatest for all areas with a corresponding lowest body mean. That is, the average body length decreases from the warmest area to the next cooler one, but then rises again to about the same size and continues to increase into the coldest zone. The narrowest range for body length occurs in the coldest area. The largest average body size is found in the coldest area. The next largest is found in the warmest area.

The Mexican ground squirrel shows the smallest head-body percentage in the warmest zone with the largest percent of tail. For this area, when mean, standard deviation and the high-low range values are examined, their tail size is the largest with the widest range, and their body size is the smallest in mean with a slightly intermediate range. Generally, there is a slight decrease in tail size from warmer to cooler areas and a slight increase in body size. The narrowest range in size appears in the coldest zone for both characters.

## Hindfoot and Ear

Little variation in hindfoot or ear lengths was observed for either species. The Mexican ground squirrel's hindfoot length is similar to the ear length already mentioned by having a higher mean and upper range in the

middle temperature area, zone 2. Means and high values for the foot and ear are, respectively, 40.2, 48 and 11.2, 14.7 in mm. Hindfoot means and standard deviations for zones 2 and 3 are close with a slightly lower standard deviation in zone 3 (43.38 to 43.0 mm). The lower ranges and standard deviations for hindfoot length in zone 1 and 3 are almost equal. The upper limits in these zones are equal (45 mm each). This is also true for the spotted ground squirrel's hindfoot length in zones 1 and 4 (both 39 mm). Means for both these zones are the highest and next to highest, while the middle zones 2 and 3 are nearly equal (32.8 mm, 32.9 mm). Ear length means are nearly equal in the two warmest zones, and then, slightly lower in zone 3. However, the greatest ear mean occurs in the coldest zone (4).

## Patterns

In the spotted ground squirrel, various measurements created similar patterns when zones were compared on diagrams (see Appendix II). Bullar length and breadth patterns are exactly the same in zones 1 through 3, when their means are lined up and the diagrams are superimposed on each other. Only the means in zone 4, the coolest, differed somewhat. Bullar breadth's mean is a fraction higher than the length's, when all the rest are aligned. Means in only one of the Mexican ground squirrel's zones

could be lined up at a time. The other two means for the bullae were either slightly higher or lower.

Mean patterns for interorbital breadth and maxillary toothrow length in the spotted ground squirrel also correlate closely. When the warmest and coolest zone means are imposed on one another, the two intermediate ones are almost aligned; the interorbital means are just higher in zone 2 and lower in zone 3 than their respective maxillary toothrow figures. Zone 1 and 2 means for the Mexican ground squirrel can be nearly aligned, but the zone 3 mean for interorbital breadth (IOB) is lower (by one IOB standard deviation) than the maxillary toothrow mean.

When the upper diastema length pattern for the spotted ground squirrel is compared with that for the maxillary toothrow and interorbital breadth, only the last 2 zones (3 and 4) line up for the toothrow at the same time. Zones 1 and 2 fail to coincide with any other combination of zones. However, the interorbital's decreasing pattern from zone 1 to 2 matches that of the diastema. Likewise, the increasing patterns from 3 to 4 match for these characters. None of the patterns for these three measurements is the same for the Mexican ground squirrel. Its diastema pattern does correspond with (only a very slight difference in zones 1 and 3) that of the hindfoot length. There is also a high degree of correlation between the hindfoot and

diastema in the spotted ground squirrel. These are the only mean patterns that correspond with the same characteristics in both species.

Postorbital breadth did not appear to be similar to any other pattern for either species. Between the species some similarity could be discerned. The warmest two zones for the spotted ground squirrel and the first zone for the Mexican ground squirrel are higher in mean and range than those in the following zones. The last two zones for each species have almost identical means within their size range for the species. Postorbital breadth is somewhat wider in the spotted ground squirrel. For this squirrel, the ear length means align with those for postorbital breadth in zones 1 and 2, but not in zones 3 and 4. Cranial breadth does align with the means in zones 1, 2 and 3. In zone 4, the postorbital breadth mean is less than the cranial breadth's lower standard deviation. For the Mexican ground squirrel, cranial breadth means increase from zone 1 to 3, and postorbital breadth means decrease from 1 to 3.

Nasal and rostral lengths for the spotted ground squirrel both decrease from zone 1 to 2, and show the same difference between means when superimposed. Means for zones 3 and 4 (which increase from 3 to 4) do not correlate with each other or either 1 or 2. In the Mexican ground squirrel, these nasal and rostral means line up exactly

except for a slight difference in zone 3. The means increase from 1 to 2 then drops a tiny bit to 3.

Means for the Mexican ground squirrel's zygomatic breadth and mandible length match each other in zone 1 and 2 with a zygomatic mean in zone 3 that is about one-half a mandibular standard deviation higher than the mandible's mean in that zone. These measurements in the spotted ground squirrel have means that coincide in zones 1, 3 and 4. The zygomatic mean in zone 2 is about two-thirds a standard deviation (SD) higher than the mandibular mean (both have similar SDs).

Further relationships exist between Mexican ground squirrel mandible length, cranial breadth and skull length. The cranial and mandibular means are more or less the same for all areas. Skull length means are also similar in their patterns except that the skull mean is slightly lower in zone 1. When cranial breadth and skull mean patterns are compared, those in the warmest and coolest zones (1 and 3) match. The skull mean in zone 2 is a fraction higher than the cranial.

## Sexual Dimorphism

### Mexican Ground Squirrel

As previously mentioned, the sexes of both species were compared for each area before being considered

together. Mexican ground squirrel females are consistently smaller (means and ranges) than the males in body length for all three areas. The only exception is a smaller male in zone 1 (143 mm) compared to the smallest female (154 mm). The smallest female in the next, cooler zone (2) is 155 mm long. However, on the whole, the females' tail lengths are slightly greater in mean and/or range than the males. The exceptions were the lower range for males in zone 3 (smallest male, 109 mm compared to smallest female, 105 mm) and the male mean in zone 1 (male 124.6 mm to female 123.4 mm).

Total length means and ranges for zones 1 and 3 show the males to be larger than the females, but zone 2 females had a slightly higher mean (by 3.3 mm) as well as the largest size (344.5 mm compared to 335 mm for the largest male). The lowest combined length for this area was 270 mm, a female; the smallest male measured 275 mm.

Hindfoot lengths followed the above pattern with females just slightly below male sizes in means (39.5 to 40.1 mm in zone 3; 38.5 to 39.4 mm in zone 1) except for zone 2 where they exceeded the males (40.5 to 39.8 mm). The smallest female in zone 2 has a 37 mm foot length compared to the male's 34.6 mm foot. The largest female there measures 48 mm compared to 43.3 mm for the largest male.

On the other hand, ear length has a wider range and higher mean for females in zone 3 (6-14.5 mm and 10.9 mm compared to 7-12 mm and 9.9 mm). In zones 1 and 2, females have lower means (10.9 mm to male 11.6 mm in zone 2; 9.7 mm to male 10.4 mm in zone 1). The range for females in zone 2 is also broader than that for the males (6-14.7 mm to 9.8-14.5 mm). In zone 1, the female range falls within the male range (6-12.9 mm, 5-14 mm).

Mexican males and females in the warmest zone demonstrated little or no dimorphism in cranial characteristics. Three character means are the same for both sexes: nasal length, bullar length and breadth. The greatest difference is 0.23 mm for maxillary toothrow length. All other differences are 0.20 mm or less. Four are less than 0.10 mm. For all but cranial breadth (female greater by 0.4 mm), male figures exceeded the females'. Males are greater than females in most characters in two the cooler zones, in general, to a somewhat greater extent than observed in the warm zone. Sample sizes for males in these zones are less than the females, and, in zone 3, the male sample, which is not statistically significant, is always less than half the female sample. The greatest difference between male and female in zone 3 is 0.56 mm in skull length followed by 0.34 mm in zygomatic breadth. Males and females equaled each other in maxillary toothrow

length and bullar length. Females exceeded males by an average of 0.1 mm in mandible length. For zone 2, males are larger than females by 1.16 mm and 1.19 mm in skull length and zygomatic breadth. Postorbital breadth (0.63 mm), mandible length (0.45 mm), cranial breadth (0.36 mm) and interorbital breadth (0.32 mm) are other differences. None of the means are exactly equal for the sexes in this zone, but among the remaining figures (all less than 0.20 mm), females only slightly surpassed (by 0.04 mm) the males in nasal length. Thus, the expression of sexual dimorphism for the Mexican ground squirrel is not consistent through the designated zones. Both the characters and extent vary. Zone 1 squirrels exhibit the least amount, while zone 2 squirrels show the most. Zone 3 falls somewhere between the others. External measurements are usually more consistent in the differences between the sexes between zones, although those differences may not be great.

## Spotted Ground Squirrel

In contrast, the mean body lengths in spotted ground squirrel females are larger than those for the males. The largest squirrel in each zone is a female, but in zones 1 and 3, females are also the smallest. Tail length means are equal for the warmest zone. In the coldest zone, the females have a smaller tail mean than the males with a

broader range in size (60-85 mm female to 76-80 mm male). The intermediate zones show the smaller male--larger female trend. Hindfoot length means are smaller for females in the cooler zones, 4 and 3, but larger in the warmest, zone 1, and equal to that of males in zone 2. Ear length means are greater for females in all zones, although the difference between males and females in zones 3 and 4 is slight (0.2 mm and 0.3 mm respectively).

Means for cranial characteristics vary between zones as they do in the Mexican ground squirrel without a discernable consistency. Skull length is greater in the males in zone 3, though the other areas follow the larger female pattern. Ten of the 12 cranial characters for zone 4 have greater means for females than males with differences between the means ranging from 0.18 to 0.90 mm. Postorbital breadth and bullar breadth are essentially the same for both sexes (differences 0.01 mm and 0.02 mm). Males had the larger mean for bullar breadth. Two means in zone 3 are exactly the same for males and females--cranial breadth and postorbital breadth. Half the characters produced greater means for males than females, but the differences between them are relatively slight (usually between 0.06 mm and 0.15 mm). Males averaged 0.34 mm more in mandible length and 1.03 mm more in skull length in this zone. Only four male means are greater in zone 2

(zygomatic breadth 0.28 mm, cranial breadth 0.41 mm, interorbital breadth 0.04 mm, bullar breadth 0.45 mm), and one mean, the bullar length, is the same. Rostral length, interorbital breadth and upper diastema length all have differences of 0.04 mm or less. None of the differences between means is greater than 0.45 mm. Zone 1 shows the greatest difference for any character in any of the four zones. Males are smaller in skull length by an average 1.21 mm difference. Males are larger, however, in this zone by very slim margins (0.02 mm, 0.05 mm, 0.03 mm) in cranial breadth, bullar length and bullar breadth. Interorbital breadth is also close (0.09 mm) with females being the larger sex. Differences for other characters range from 0.36 to 0.84 mm.

## Species Comparison

As previously stated, the Mexican ground squirrel is larger than the spotted ground squirrel. When their external measurements are are compared, this size difference is readily apparent. Some overlap occurs usually between the largest spotted ground squirrel in a measurement category and the smallest Mexican squirrels, although more overlap is seen when both have a wide and similar range as in the ear measurements. Their tail lengths do not have a size in common to both squirrels.

The spotted ground squirrel's ear mean in the coldest zone falls within the Mexican ground squirrel's ear means, but the longest ear measurement for the former is found in the warmest zone and approaches or equals the longest ear length in all three of the Mexican ground squirrel's zones.

For all but three of the cranial measurements, the Mexican ground squirrel is larger than the spotted ground squirrel. In cranial breadth, the Mexican is just somewhat larger. The smallest of these is 19.05 mm compared to the largest spotted ground squirrel's 18.88 mm. Both species have their greatest mean in their coldest zone, 3 or 4. Zone 3 for the spotted ground squirrel has the smallest mean, which occurs in zone 1 (warmest) for the other species.

Postorbital breadth, bullar length and breadth are the measurements in which the spotted ground squirrel is greater than the Mexican ground squirrel. There is no size overlap in postorbital breadth; some is observed in bullar length. The exception is the spotted's smallest mean (zone 1) which falls between the two upper means in the Mexican ground squirrel. Also for bullar breadth, the two squirrels have equal means (7.53 mm) in zones 1 and 2, respectively.

## Comments on Pelage

Although not much consideration was given to pelage in this study, some observations were made regarding this for both species. No attempt to quantify or qualify pelage characteristics or correlate them by capture location was made. Less variation was seen in the Mexican ground squirrel than the spotted ground squirrel possibly related to the range size and number of subspecies involved. Pelage color has been observed to vary with variation in the substrate (Streubel and Fitzgerald, 1978; McCarley, 1956). Anderson (Streubel and Fitzgerald, 1978; Stangl and Goetze, 1991) noted a wide range in color variation for certain subspecies of the spotted ground squirrel. The Mexican ground squirrel's color varied from a rusty, deep brown to a lighter, dusty brown, while the spotted's color ranged from a pale brown to nearly black. The grayish and cinnamon brown coats often mentioned for S. spilosoma were typical. The gray pelage in S. spilosoma marginatus and S. s. canescens is said to be seasonal as well as regional in the Trans-Pecos (Stangl and Goetze ,1991). The black-brown specimens had been collected in West Texas.

Spot patterns in the Mexican ground squirrel sometimes included rows of spots that had run together into partial, crooked stripes--usually along the sides rather than over

the back. Spot indistinctness has been described for the spotted ground squirrel and was observed in the specimens examined (MacClintock, 1970; Davis, 1974). Spots ranged from clearly defined to blurred or faint ones. However, a few specimens were seen that virtually lacked spots. Others had soft-edged spots along their sides, but had no spots over their back. These specimens and the almost black-coated ones belong to the Natural History Collection in Austin.

# DISCUSSION

While some measured characters for the Mexican and spotted ground squirrels appear to vary geographically, if only slightly, others show no such tendency. Seldom is there concurrence between the species in their variation or non-variation. Correlations between certain cranial characters occur that vary through part or all of the animal's range in this study. Neither hindfoot length nor upper diastema length varies greatly through the geographic area for either squirrel, but these characters are the only ones that demonstrate a similar pattern between the characters for each species. Postorbital breadth seems to be less like any other character in its pattern for both squirrels.

Most means in both bullar length and breadth form a pattern across the spotted ground squirrel's zones, but fail to do so for the Mexican ground squirrel. Likewise, interorbital breadth and maxillary toothrow length do not follow a pattern for this animal as they do for the spotted ground squirrel. The opposite is true for the nasal and rostral values. These vary the same for the Mexican ground squirrel across all three zones, but not for the spotted ground squirrel. Zygomatic breadth and mandible length showed some correlation for both species except that a

different zone for each species did not follow the same pattern. Additional study regarding these cranial characters and others not included in this work may clarify the extent of geographic variation and the differences between these related species.

Overall, the Mexican ground squirrel demonstrates less significant variation between the designated zones particularly for cranial characteristics. For other external measurements, this squirrel follows a consistency between zones that the spotted ground squirrel often lacks. A cline is more readily apparent in the Mexican's head-body length than in the spotted ground squirrel's. This cline is slight, but agrees with Bergmann's Rule that body size increases from warmer to cooler areas (Mayr, 1970). The size range is also narrowest for both species in the coldest area. The largest and smallest individual ground squirrels are found in other zones. However, the spotted ground squirrel does not completely follow the above rule. Its mean body length is the longest in the coldest zone, but the next longest occurs in the warmest zone. Zones 2 through 4 do form an increasing cline in agreement with Bergmann. Some other factor besides temperature must be at work for this difference to appear. Mayr's (1970) statement about burrowing mammals being an exception to Bergmann's Rule does not explain why one of these

semifossorial species appears to follow the rule, while the other only partially does so.

These species share some overlapping range, but competition between them has not been studied. Although kangaroo rats (Dipodomys) have nocturnal lifestyles, they are burrowing rodents and inhabit some of the same arid areas as these ground squirrels. Various studies on variation in kangaroo rats have shown size differences with relevance to this study. Baumgardner and Kennedy (1993) could not consistently predict size trends on the basis of abiotic variables. They concluded that size variation is probably due to multiple factors (physiologic, ecologic and phylogenetic), which environmental factors could not completely demonstrate. A size increase correlated with increasing latitude and decreasing temperature consistent with Bergmann was found for D. ordii. However, D. simulans showed a size increase with increasing temperature and decreasing latitude. Both males and females followed these trends in the above species. Kennedy and Schnell (1978), while studying geographic variation in D. ordii, failed to find a continuous gradient in their measurements, though in smaller regions single character gradients appeared.

Kenagy (1973) studied activity patterns and energetics in two species of kangaroo rats and one pocket mouse. Interspecific size differences were related to the amount

of surface activity and foraging success during seasonal changes. Colder temperatures had relatively greater effects on the smaller species. Food availability appeared to be more important than temperature or photoperiod in surface activity in the pocket mouse. Food as a factor as well as competition with sympatric species are also discussed by Kennedy and Schnell (1978). Kennedy et al (1979) suggested the amount of habitat suitable for D. ordii in one part of their range might explain the small body size in that area. The kinds of preferred foods may vary between species in addition to seasonal availability. Spermophilus mexicanus and S. spilosoma do have some different preferences in diet and habitat. If food availability is a factor, perhaps an investigation into their diets across this shared range with an accompanying comparison could reveal the cause for the disparity between them in following Bergmann's Rule.

In accordance with Allen's Rule (Mayr, 1970), the Mexican ground squirrel's tail length decreases slightly from the warmer to colder areas. This squirrel's ear length means do not agree because the greatest value is found in the middle zone. The coldest zone mean is just below that of the warmest zone. Ear means for the spotted ground squirrel are the lowest in zone 3 (next to coldest) and greatest in zone 4, the coldest. The two warmer zones'

means are equal and fall in between the above means. Tail length means for the spotted ground squirrel do not follow a reverse pattern to body length as do the Mexican ground squirrel means. In order, zones 2, 4, 3, and 1 have the longest to shortest mean tail lengths, which does not agree with Allen. Kennedy and Schnell (1978) state that Setzer in 1949 decribed tail lengths in Ord's kangaroo rat that conflicted with Allen. The shortest appeared in the central range subspecies and the longest in the northernmost ranging subspecies.

Adequate sample size to be statistically significant was a problem in certain areas especially for the spotted ground squirrel. As mentioned previously, the Arizona specimens could have been included in another temperature area. Originally, this was the case, and calculations were made with their inclusion in the warmer zone. That gave a better division between males and females in the sample as well as a more significant sample size. The change in zone did not drastically alter the results, although some differences were apparent. Because most of the Arizona specimens are female, the male means for the affected zones were altered to a lesser degree than the female means. Both sexes showed the same direction in the changes. Female means in zone 3 generally decreased by several millimeters (external measurements) or tenths of a

millimeter with a corresponding increase in the zone 2 means. Hindfoot and ear lengths were essentially unaffected. The expression of sexual dimorphism was relatively unaffected by this shift. Nothing more will be said about this other than the samples should be larger and include more of both sexes, especially males, since they tended to be underrepresented.

Neither species demonstrated consistent sexual dimorphism in either the same cranial characters or the same geographical areas. Because of small samples for certain groups and questionable validity of results from their use, a thorough discussion of dimorphism is not possible. However, an obvious size difference in external measurements in both species warrants further study of sexual dimorphism. As expected, female Mexican ground squirrels were found to be generally smaller than the males in body size. The exception to this was the tail length, which appeared to be somewhat longer for the females. This did not prevent the males from exceeding the females in overall length. The individual largest or smallest specimen could be either sex, and the size range for any area could also be broader or narrower in either one.
Best's (1978) data concerning sexual dimorphism in kangaroo rats from Baja California show males to be larger in both total length and tail length. Females have a larger mean

in body length. In general, for the characters exhibiting sexual dimorphism, the male kangaroo rats are significantly larger.

Unexpectedly, the female spotted ground squirrels tend to be larger than the males in mean body lengths. Except for the coldest zone, tail length means for the females are also longer or equal to those of the males. Other external measurements seem to follow this trend. Cranial characteristics vary from zone to zone as they do in the other species. Obviously, with the sexual differences any future studies should consider whether or not the dimorphism will affect the results and separate data from the sexes for analysis accordingly. Other unrelated species such as the kangaroo rat have been observed to have larger males than females (Best, 1983; Kennedy and Schnell,1978). Schmidly (1971) found that sexual dimorphism in populations of Dipodomys ordii in western Texas varied geographically. Females were larger than males in two northern populations, while males in southern populations were larger than the females. The literature for other less closely related ground squirrels usually indicates that males are the larger sex, if dimorphism is mentioned at all. More investigation needs to be done to determine the true extent of sexual dimorphism in these two species.

Neither the Mexican nor the spotted ground squirrel has been studied to the extent of other distantly related species in their genus. Studies that have been done have been localized to some degree rather than covering much of their range. Life history studies like Shockley's (1974) would be beneficial in expanding the amount of knowledge currently available on these two species and possibly help explain what I have discovered.

Kenagy (1973) observed that the kangaroo rats occupied different burrow depths in response to daily as well as seasonal temperature fluctuations. Hot summer weather caused upper tunnel temperatures to rise above 30° C, which caused the animals to avoid those areas. Most of the range inhabited by the ground squirrels I studied reach the same average maximum temperature in summer. The southern and western extremes may become hotter than the remaining range, and as such, may exert some influence on the animals living in those areas much as the cold extreme in winter does.

Adjustments in tunnel depths in response to temperature extremes has also been reported for pocket gophers. Mathisen (1976) said that this had been suggested by Kennerly in 1964. She found that populations in her northern and southern study areas had the deepest tunnels, while those in the central area with milder temperatures

dug shallower burrows. She explained the deeper tunnels as a reaction to high temperature in the south and low temperature in the north. In studying *Spermophilus mexicanus*, Shockley (1974) not only found that winter burrows were deeper and longer than summer burrows, but also that males had shallower burrows than females. He also reports that temperatures--cool or hot, precipitation, wind and cloud cover are climatic factors influencing ground squirrel activity. Similar observations have been made by other investigators. Unfortunately, not enough is known in detail about the activity patterns of the Mexican and spotted ground squirrels across their common range in Texas. Little is known with certainty regarding hibernation in apparent inactive periods. Future studies in burrow structure and utilization, home range, diet differences, food availability, interspecific competition, activity patterns, and sexual dimorphism over their general range may lead to a more complete understanding of these two ground squirrels.

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## APPENDIX I

DATA TABLES

and

PERCENTAGES TABLE

# APPENDIX I

## List of Data Tables

| Zone | Sample size | Mean | Standard deviation | Range * |
|---|---|---|---|---|
| **Table 1** | | | **BODY LENGTH** | |
| <u>Spermophilus mexicanus</u> | | | | |
| 1 | 51 | 180.5 | 161.78 - 199.22 | 143 - 221 |
| 2 | 31 | 187.9 | 171.47 - 204.33 | 155 - 241 |
| 3 | 21 | 191 | 179.96 - 202.04 | 175 - 212 |
| <u>Spermophilus spilosoma</u> | | | | |
| 1 | 29 | 161.1 | 147.58 - 174.62 | 140 - 200 |
| 2 | 9 | 155.9 | 146.16 - 165.64 | 132 - 163 |
| 3 | 20 | 160.4 | 146.95 - 173.75 | 136 - 190 |
| 4 | 12 | 169.3 | 162.02 - 176.58 | 161 - 180 |
| **Table 2** | | | **TAIL LENGTH** | |
| <u>Spermophilus mexicanus</u> | | | | |
| 1 | 50 | 124.2 | 111.19 - 137.21 | 94 - 159 |
| 2 | 28 | 122.7 | 107.72 - 137.68 | 101 - 150 |
| 3 | 20 | 122.3 | 113.17 - 131.43 | 105 - 141 |
| <u>Spermophilus spilosoma</u> | | | | |
| 1 | 29 | 68.9 | 61.22 - 76.58 | 59 - 90 |
| 2 | 8 | 77.1 | 70.56 - 83.68 | 60 - 86 |
| 3 | 20 | 71.1 | 62.26 - 79.86 | 60 - 87 |
| 4 | 12 | 75.2 | 68.61 - 81.79 | 60 - 85 |
| **Table 3** | | | **TOTAL LENGTH** | |
| <u>Spermophilus mexicanus</u> | | | | |
| 1 | 50 | 304.3 | 277.7 - 330.9 | 246 - 367 |
| 2 | 28 | 308.6 | 287.8 - 329.4 | 270 - 344.5 |
| 3 | 21 | 311.0 | 296.8 - 325.2 | 285 - 345 |
| <u>Spermophilus spilosoma</u> | | | | |
| 1 | 29 | 230 | 212 - 248 | 201 - 282 |
| 2 | 8 | 233.5 | 225.6 - 241.4 | 207 - 245 |
| 3 | 20 | 231.4 | 218 - 244.8 | 216 - 258 |
| 4 | 12 | 244.5 | 235.8 - 253.2 | 230 - 256 |

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|

Table 4 HINDFOOT LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 52 | 39 | 36.16 - 41.84 | 30 - 45 |
| 2 | 31 | 40.2 | 37.4 - 43.0 | 34.6 - 48 |
| 3 | 21 | 39.7 | 36.02 - 43.38 | 30.9 - 45 |
| *Spermophilus spilosoma* | | | | |
| 1 | 29 | 34.5 | 32.03 - 36.97 | 28 - 39 |
| 2 | 9 | 32.8 | 31 - 34.67 | 30 - 35.1 |
| 3 | 20 | 32.9 | 30.54 - 35.24 | 27 - 38 |
| 4 | 12 | 35.2 | 32.87 - 37.53 | 30 - 39 |

Table 5 EAR LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 42 | 10 | 7.9 - 12.1 | 5 - 14 |
| 2 | 31 | 11.2 | 9.2 - 13.2 | 6 - 14.7 |
| 3 | 21 | 10.6 | 8.45 - 12.75 | 6 - 14.5 |
| *Spermophilus spilosoma* | | | | |
| 1 | 29 | 8.6 | 6.24 - 10.96 | 4 - 14 |
| 2 | 9 | 8.6 | 6.68 - 10.56 | 5.4 - 11.8 |
| 3 | 20 | 8.05 | 6.33 - 9.77 | 4.5 - 11 |
| 4 | 12 | 10.4 | 8.62 - 12.18 | 6 - 12 |

Table 6 SKULL LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 46 | 43.43 | 41.71 - 45.15 | 40.07 - 46.81 |
| 2 | 25 | 43.93 | 42.37 - 45.49 | 39.70 - 46.63 |
| 3 | 19 | 43.85 | 42.41 - 45.29 | 41.15 - 46.11 |
| *Spermophilus spilosoma* | | | | |
| 1 | 27 | 40.46 | 38.97 - 41.95 | 37.54 - 42.88 |
| 2 | 9 | 38.54 | 36.83 - 40.25 | 35.45 - 41.35 |
| 3 | 21 | 39.24 | 37.41 - 41.07 | 35.28 - 43.32 |
| 4 | 12 | 41.67 | 40.74 - 42.60 | 40.56 - 43.60 |

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| **Table 7** | | ZYGOMATIC BREADTH | | |
| *Spermophilus mexicanus* | | | | |
| 1 | 46 | 25.79 | 24.40 - 27.18 | 23.46 - 28.56 |
| 2 | 25 | 25.86 | 24.51 - 27.21 | 23.16 - 28.27 |
| 3 | 17 | 26.30 | 25.18 - 27.42 | 24.35 - 28.57 |
| *Spermophilus spilosoma* | | | | |
| 1 | 27 | 23.91 | 22.92 - 24.9 | 21.81 - 25.27 |
| 2 | 9 | 23.61 | 22.85 - 24.37 | 22.69 - 24.58 |
| 3 | 21 | 23.44 | 22.36 - 24.52 | 21.40 - 25.95 |
| 4 | 11 | 24.57 | 23.89 - 25.25 | 23.73 - 26.01 |
| **Table 8** | | NASAL LENGTH | | |
| *Spermophilus mexicanus* | | | | |
| 1 | 45 | 14.52 | 13.47 - 15.57 | 11.97 - 16.30 |
| 2 | 25 | 15.19 | 14.26 - 16.12 | 13.40 - 16.93 |
| 3 | 17 | 15.20 | 14.57 - 15.83 | 13.88 - 16.55 |
| *Spermophilus spilosoma* | | | | |
| 1 | 26 | 12.82 | 11.91 - 13.73 | 10.72 - 14.77 |
| 2 | 9 | 11.84 | 10.60 - 13.08 | 9.25 - 13.31 |
| 3 | 19 | 12.32 | 11.41 - 13.23 | 11.16 - 13.93 |
| 4 | 12 | 13.57 | 12.84 - 14.30 | 12.77 - 14.87 |
| **Table 9** | | ROSTRAL LENGTH | | |
| *Spermophilus mexicanus* | | | | |
| 1 | 45 | 11.45 | 10.79 - 12.11 | 10.18 - 13.01 |
| 2 | 25 | 12.15 | 11.49 - 12.81 | 10.52 - 13.47 |
| 3 | 17 | 11.95 | 11.28 - 12.62 | 10.26 - 12.99 |
| *Spermophilus spilosoma* | | | | |
| 1 | 25 | 9.98 | 9.31 - 10.65 | 8.65 - 11.16 |
| 2 | 9 | 9.06 | 8.16 - 9.96 | 7.53 - 10.45 |
| 3 | 19 | 9.89 | 9.28 - 10.50 | 9.00 - 11.33 |
| 4 | 12 | 10.53 | 10.10 - 10.96 | 9.88 - 11.33 |

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|

Table 10 CRANIAL BREADTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| Spermophilus mexicanus | | | | |
| 1 | 45 | 19.05 | 18.56 - 19.54 | 18.15 - 20.10 |
| 2 | 25 | 19.30 | 18.71 - 19.89 | 18.12 - 20.37 |
| 3 | 17 | 19.43 | 18.77 - 20.09 | 18.49 - 20.41 |
| Spermophilus spilosoma | | | | |
| 1 | 27 | 18.54 | 18.06 - 19.02 | 17.66 - 20.14 |
| 2 | 9 | 18.64 | 18.02 - 19.26 | 17.90 - 19.67 |
| 3 | 21 | 18.42 | 17.95 - 18.89 | 17.70 - 19.42 |
| 4 | 11 | 18.88 | 18.49 - 19.27 | 18.24 - 19.55 |

Table 11 INTERORBITAL BREADTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| Spermophilus mexicanus | | | | |
| 1 | 46 | 10.13 | 9.43 - 10.83 | 8.83 - 11.53 |
| 2 | 25 | 10.07 | 9.45 - 10.69 | 9.00 - 11.15 |
| 3 | 17 | 9.72 | 9.16 - 10.28 | 8.48 - 10.62 |
| Spermophilus spilosoma | | | | |
| 1 | 26 | 9.46 | 8.90 - 10.02 | 8.52 - 10.94 |
| 2 | 9 | 9.08 | 8.41 - 9.75 | 7.90 - 10.35 |
| 3 | 21 | 8.66 | 8.14 - 9.18 | 7.87 - 9.64 |
| 4 | 12 | 9.26 | 8.54 - 9.98 | 8.34 - 10.48 |

Table 12 POSTORBITAL BREADTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| Spermophilus mexicanus | | | | |
| 1 | 46 | 13.21 | 12.52 - 13.90 | 11.56 - 14.72 |
| 2 | 25 | 12.93 | 12.22 - 13.64 | 11.87 - 15.13 |
| 3 | 16 | 12.87 | 12.29 - 13.45 | 11.72 - 13.88 |
| Spermophilus spilosoma | | | | |
| 1 | 26 | 14.04 | 13.53 - 14.55 | 13.28 - 15.31 |
| 2 | 9 | 14.13 | 13.54 - 14.72 | 13.20 - 15.37 |
| 3 | 21 | 13.87 | 13.50 - 14.24 | 12.90 - 14.45 |
| 4 | 12 | 13.79 | 13.10 - 14.48 | 12.92 - 14.97 |

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|

Table 13 UPPER DIASTEMA LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 46 | 10.89 | 10.18 - 11.60 | 9.44 - 12.22 |
| 2 | 25 | 11.13 | 10.53 - 11.73 | 10.12 - 12.70 |
| 3 | 18 | 10.89 | 10.28 - 11.50 | 9.97 - 12.02 |
| *Spermophilus spilosoma* | | | | |
| 1 | 26 | 9.18 | 8.64 - 9.72 | 8.16 - 10.30 |
| 2 | 9 | 8.91 | 8.32 - 9.50 | 7.94 - 9.78 |
| 3 | 21 | 8.97 | 8.45 - 9.49 | 8.00 - 9.76 |
| 4 | 12 | 9.47 | 9.02 - 9.92 | 8.47 - 10.21 |

Table 14 MAXILLARY TOOTHROW LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 45 | 8.43 | 7.85 - 9.01 | 7.21 - 9.51 |
| 2 | 25 | 8.26 | 7.88 - 8.64 | 7.23 - 8.94 |
| 3 | 18 | 8.61 | 8.32 - 8.90 | 7.96 - 9.17 |
| *Spermophilus spilosoma* | | | | |
| 1 | 26 | 8.24 | 7.80 - 8.68 | 7.21 - 8.96 |
| 2 | 9 | 7.70 | 7.45 - 7.95 | 7.26 - 8.03 |
| 3 | 21 | 7.55 | 7.17 - 7.93 | 6.78 - 8.44 |
| 4 | 12 | 7.95 | 7.63 - 8.27 | 7.42 - 8.42 |

Table 15 BULLAR LENGTH

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| *Spermophilus mexicanus* | | | | |
| 1 | 45 | 9.34 | 8.91 - 9.77 | 8.61 - 10.38 |
| 2 | 25 | 9.48 | 8.97 - 9.99 | 7.97 - 10.43 |
| 3 | 17 | 9.28 | 8.81 - 9.75 | 8.53 - 10.14 |
| *Spermophilus spilosoma* | | | | |
| 1 | 26 | 9.42 | 8.98 - 9.86 | 8.66 - 10.43 |
| 2 | 9 | 10.16 | 9.78 - 10.54 | 9.29 - 10.67 |
| 3 | 21 | 9.69 | 9.33 - 10.05 | 8.91 - 10.48 |
| 4 | 12 | 9.66 | 9.29 - 10.03 | 9.16 - 10.44 |

| Zone | Sample size | Mean | Standard deviation | Range |
|---|---|---|---|---|
| **Table 16** | | BULLAR BREADTH | | |
| Spermophilus mexicanus | | | | |
| 1 | 45 | 7.66 | 7.24 - 8.08 | 6.88 - 9.34 |
| 2 | 24 | 7.53 | 7.07 - 7.99 | 6.34 - 8.65 |
| 3 | 16 | 7.75 | 7.46 - 8.04 | 7.05 - 8.27 |
| Spermophilus spilosoma | | | | |
| 1 | 24 | 7.53 | 7.16 - 7.90 | 6.96 - 8.79 |
| 2 | 9 | 8.26 | 7.76 - 8.76 | 7.59 - 8.93 |
| 3 | 21 | 7.84 | 7.55 - 8.13 | 7.36 - 8.49 |
| 4 | 12 | 8.05 | 7.73 - 8.37 | 7.62 - 8.61 |
| **Table 17** | | MANDIBLE LENGTH | | |
| Spermophilus mexicanus | | | | |
| 1 | 44 | 24.34 | 23.30 - 25.38 | 22.62 - 26.54 |
| 2 | 24 | 24.50 | 23.60 - 25.40 | 22.67 - 26.12 |
| 3 | 16 | 24.46 | 23.65 - 25.27 | 23.20 - 26.27 |
| Spermophilus spilosoma | | | | |
| 1 | 26 | 21.92 | 21.27 - 22.57 | 20.28 - 23.04 |
| 2 | 9 | 21.11 | 20.32 - 21.90 | 19.80 - 21.90 |
| 3 | 21 | 21.62 | 20.39 - 22.85 | 19.96 - 24.39 |
| 4 | 12 | 22.63 | 21.93 - 23.33 | 21.74 - 24.01 |

* mean, standard deviation and range are all expressed in millimeters.

SPERMOPHILUS MEXICANUS

| | Zone 1 20° - 30° | Zone 2 10° - 20° | Zone 3 0° - 10°F |
|---|---|---|---|
| Head & Body % Total Length | 59% | 61% | 61% |
| Tail % Total Length | 41% | 39% | 39% |
| Tail % Head & Body Length | 69% | 65% | 65% |

SPERMOPHILUS SPILOSOMA

| | Zone 1 20° - 30° | Zone 2 10° - 20° | Zone 3 0° - 10° | Zone 4 -10° -0°F |
|---|---|---|---|---|
| Head & Body % Total Length | 70% | 67% | 69% | 69% |
| Tail % Total Length | 30% | 33% | 31% | 31% |
| Tail % Head & Body Length | 43% | 49% | 44% | 44% |

Table 18. Percentages of head-body and tail lengths to total lengths and tail to head-body length by species and geographic area.

## APPENDIX II

## DICE-GRAMS

Key to the diagrams:

Mean is represented by the horizontal bar.

Standard deviation is represented by the open rectangle.

Range is indicated by the vertical line (sexes of the largest and smallest individuals are included).

Sample size for each zone is given in parentheses below the diagrams.

All measurements are recorded in millimeters.

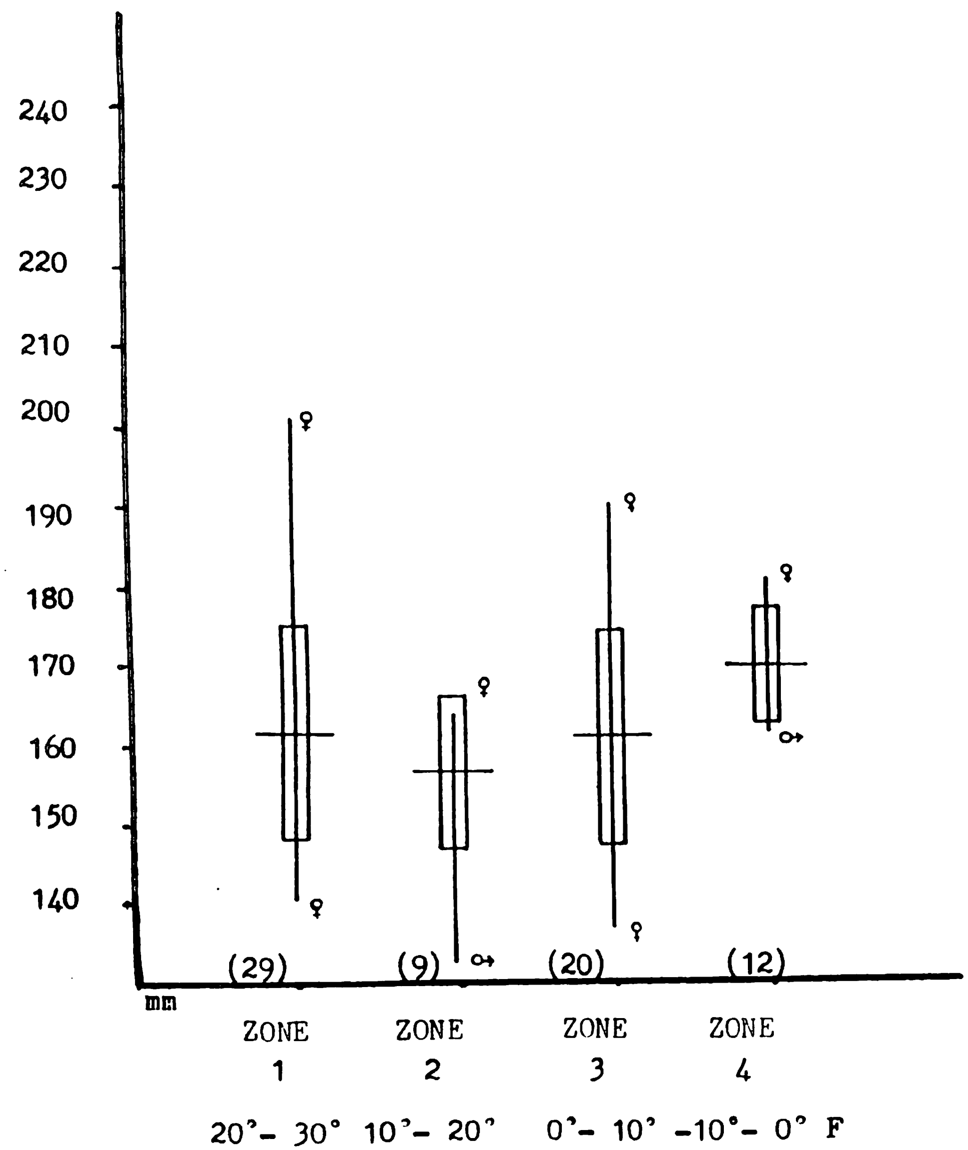
## APPENDIX II

## List of Dice-grams

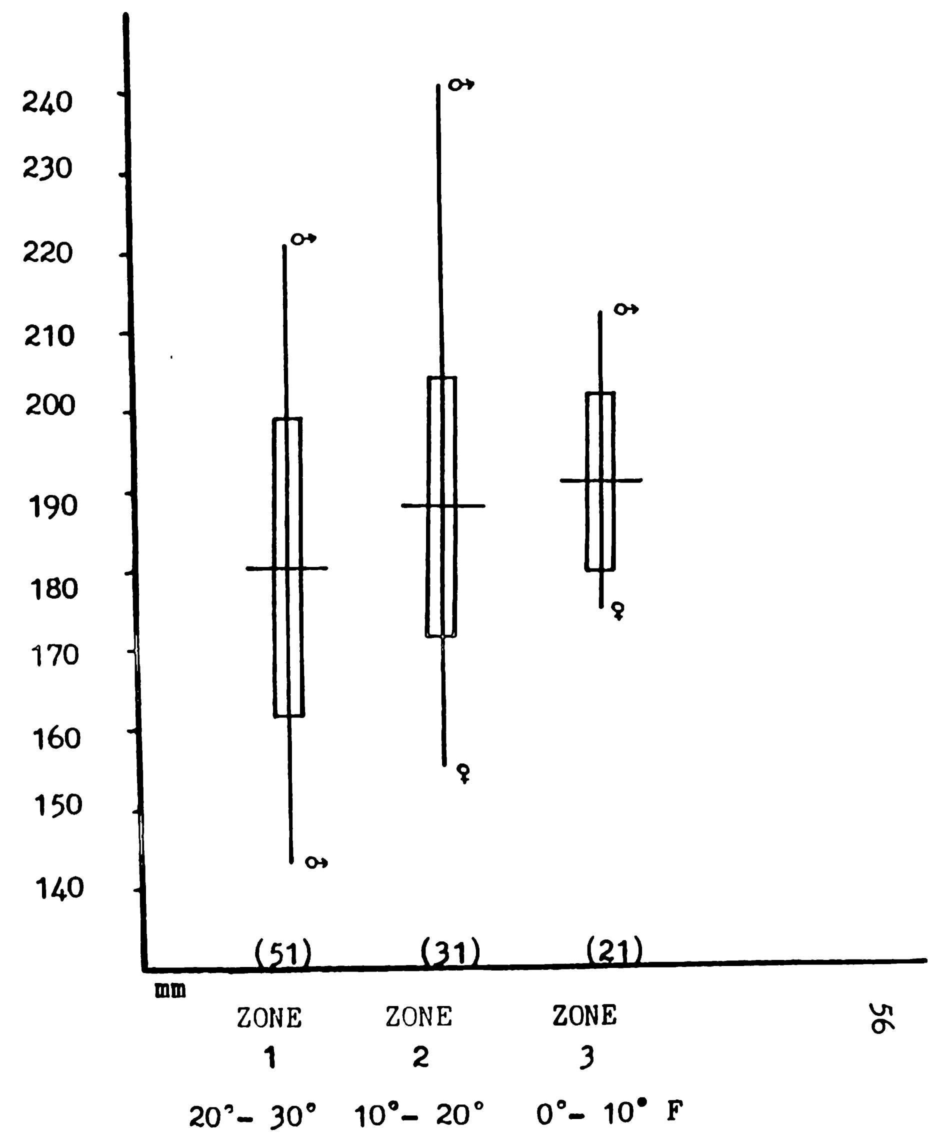
(Modified Dice-Leraas Diagrams)

HEAD–BODY LENGTH

Spermophilus spilosoma

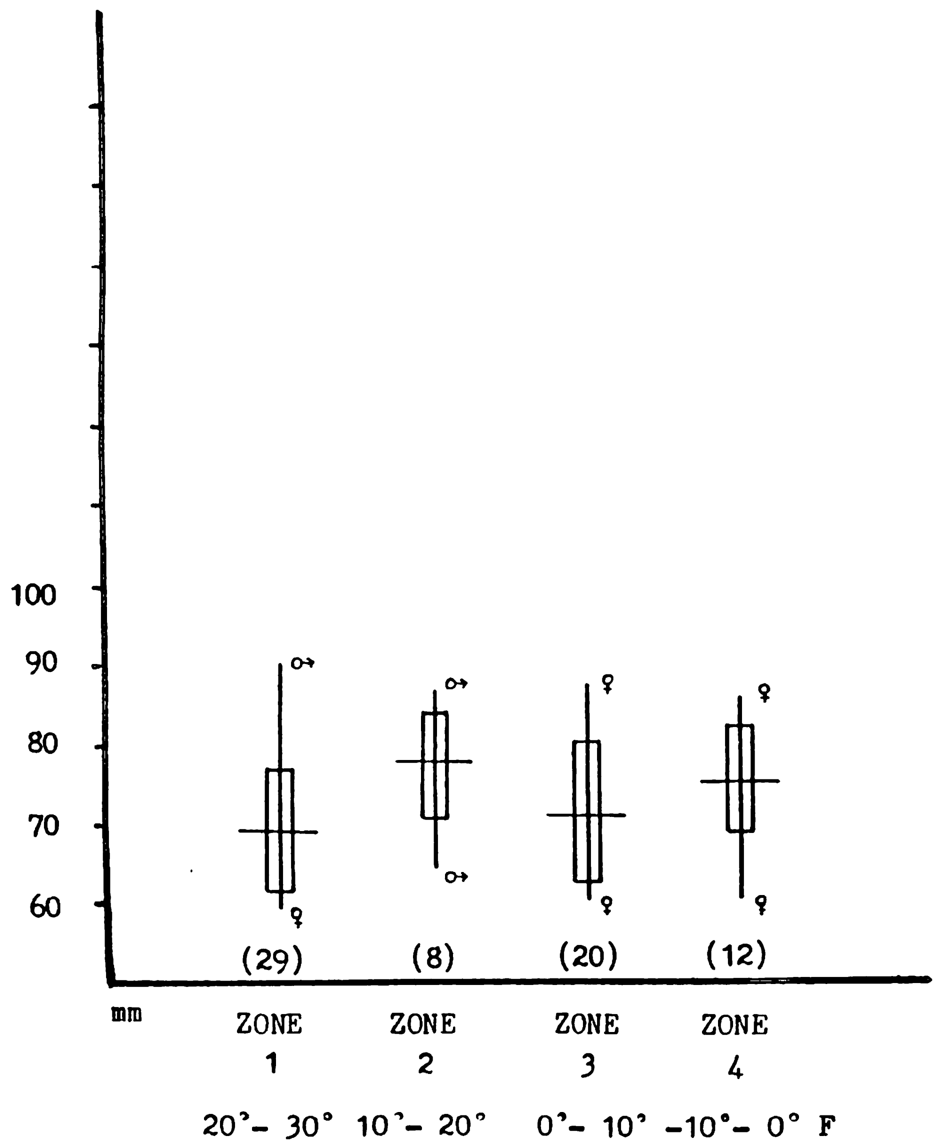



Spermophilus mexicanus

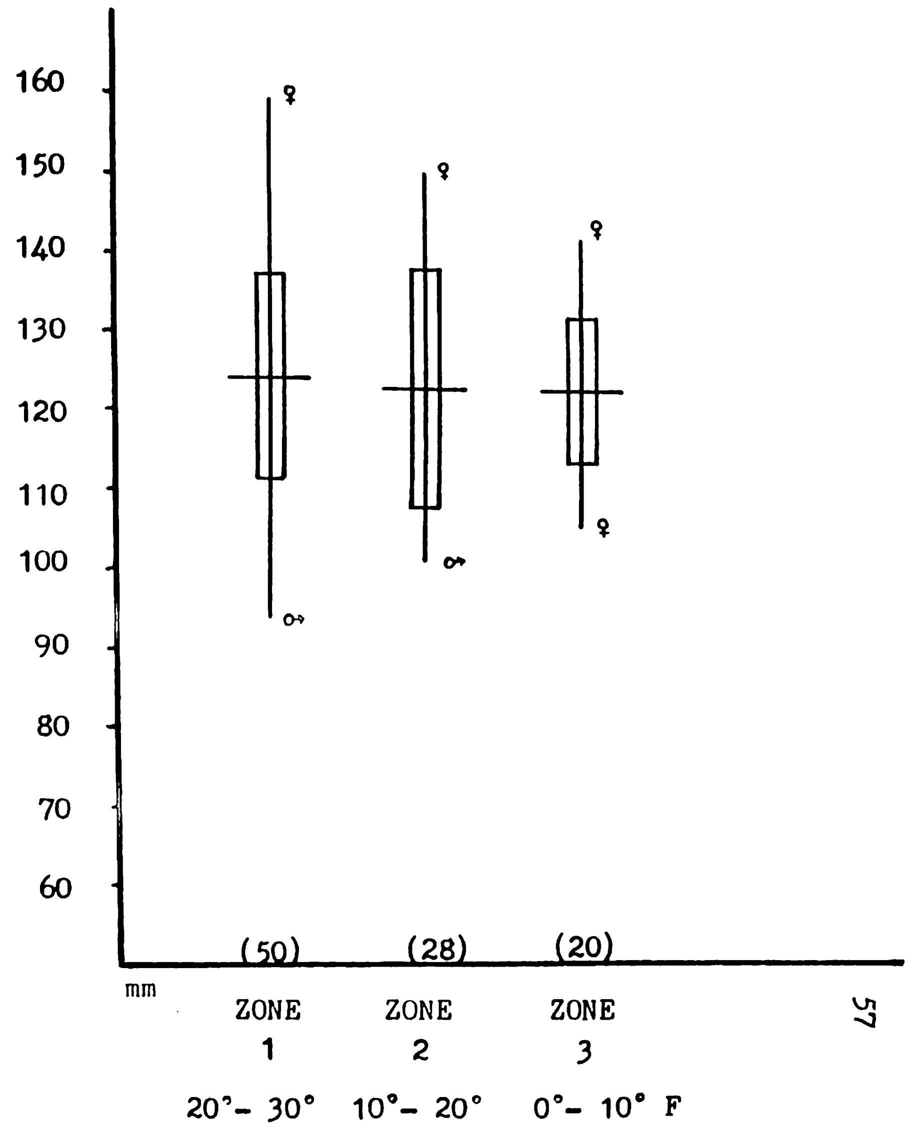


TAIL LENGTH

Spermophilus spilosoma

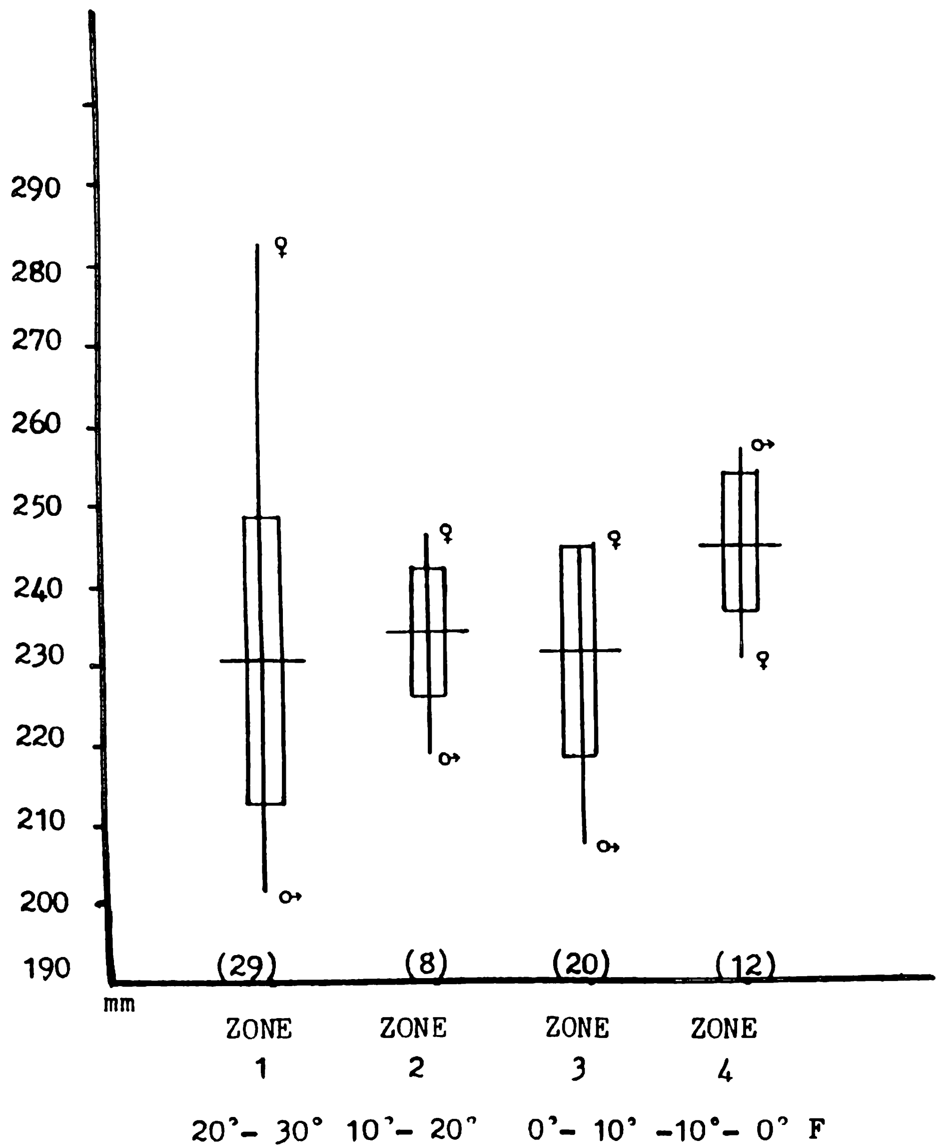



Spermophilus mexicanus

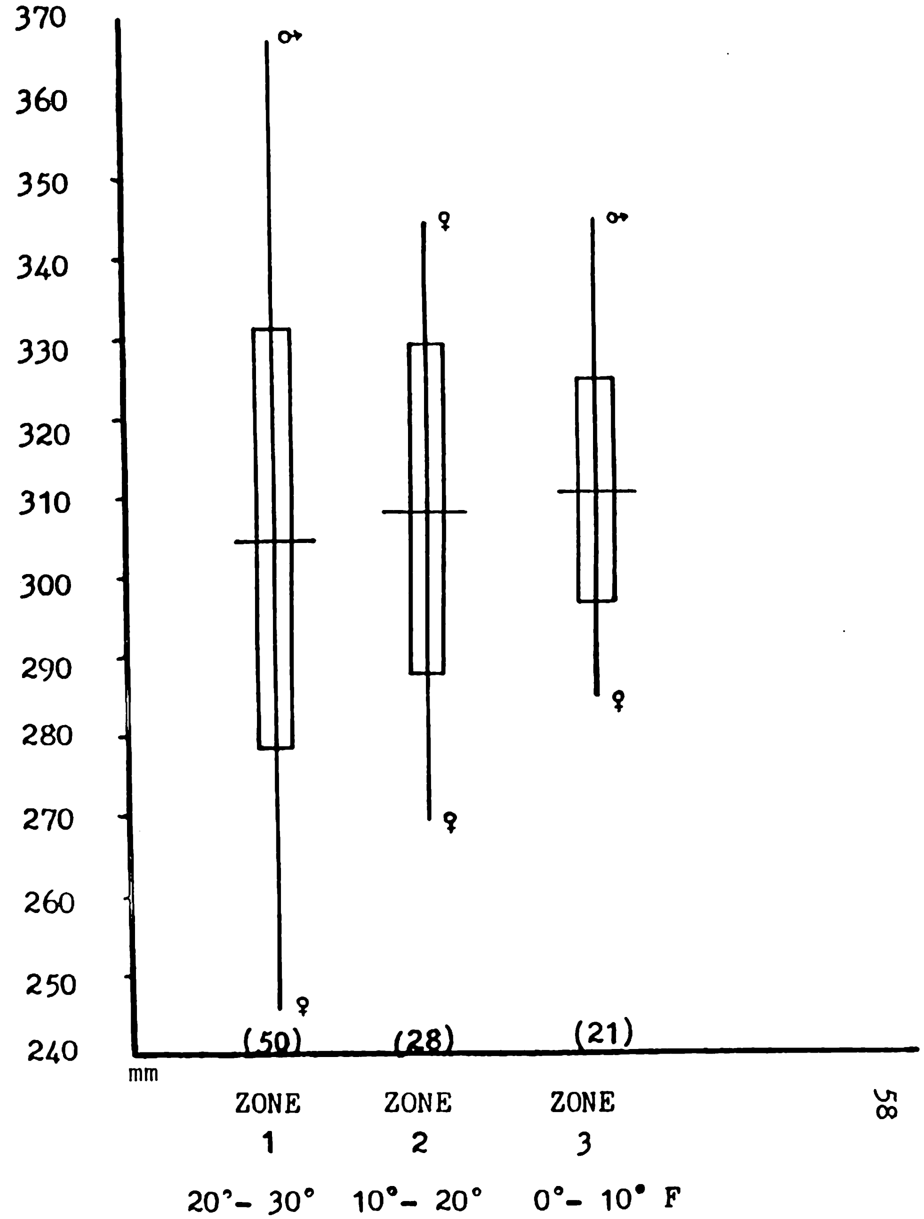


TOTAL LENGTH

Spermophilus spilosoma

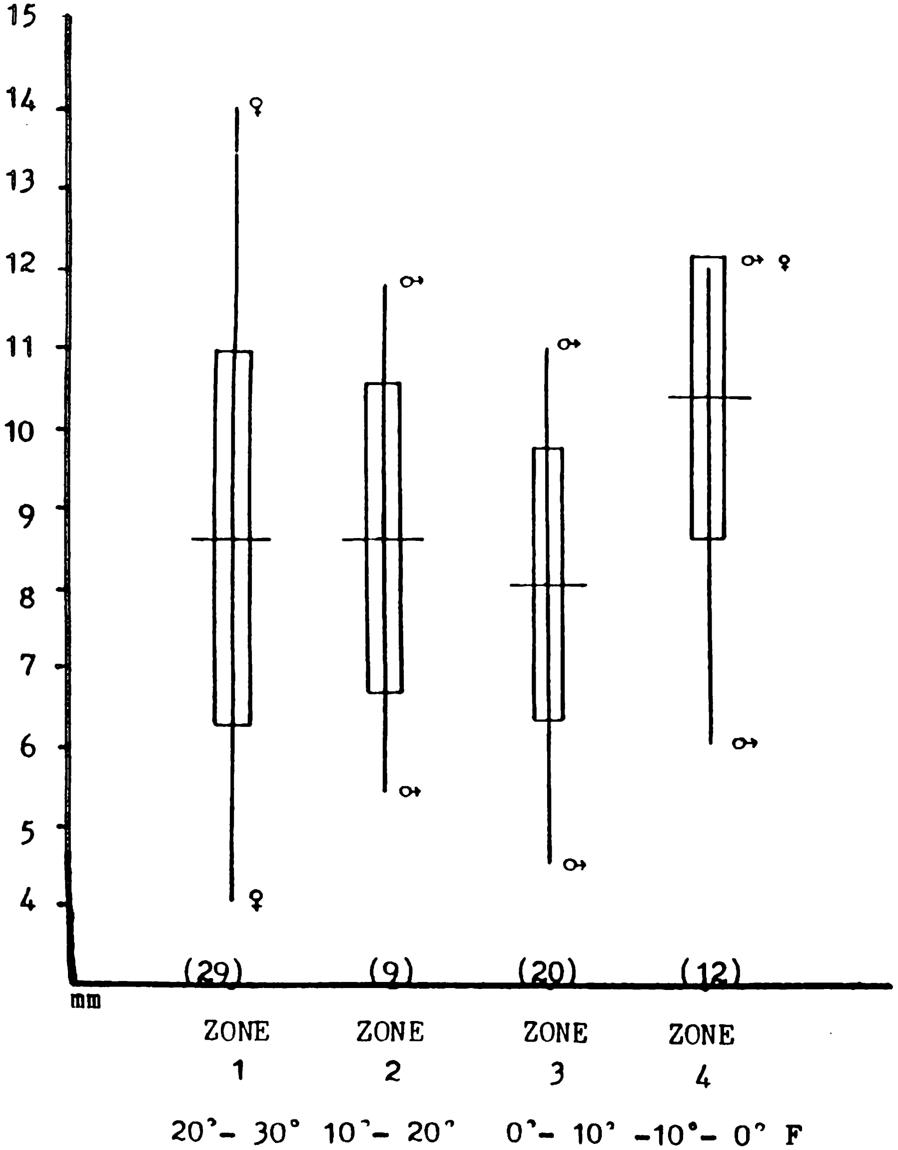



Spermophilus mexicanus

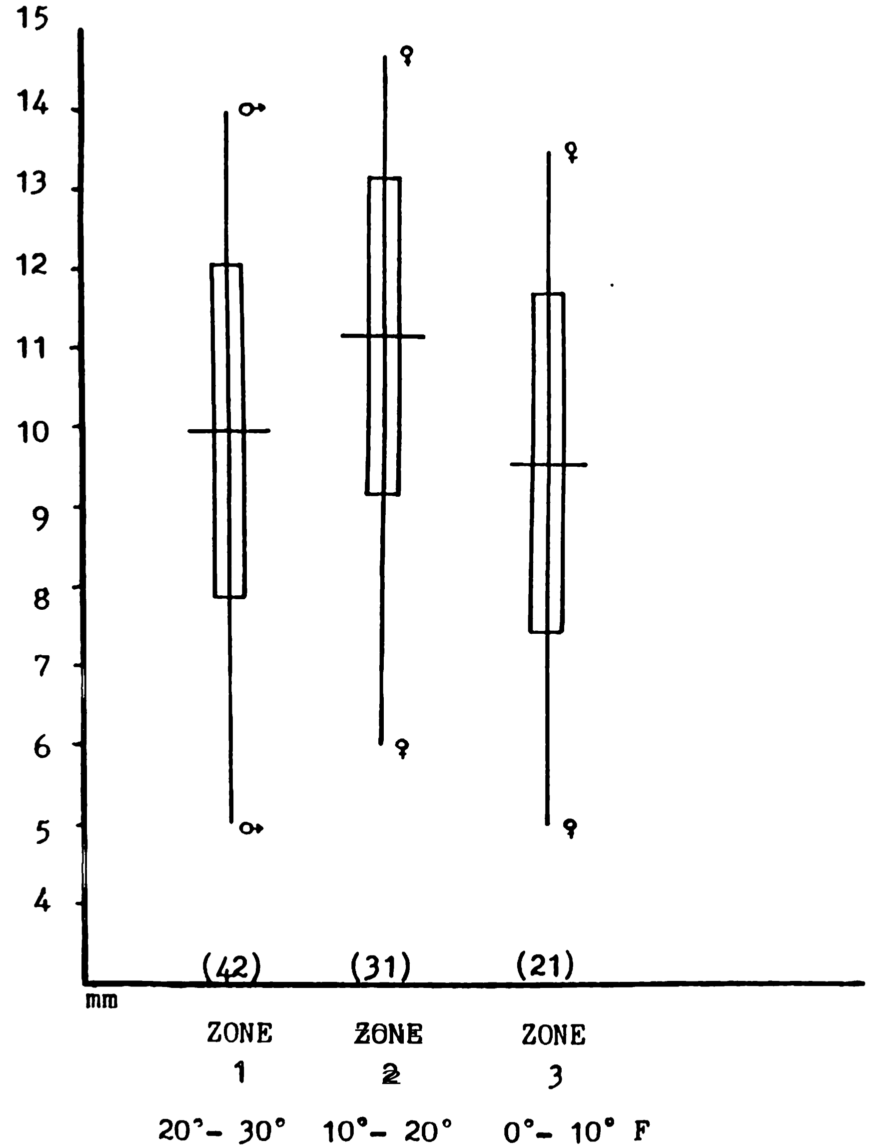


EAR LENGTH

*Spermophilus spilosoma*

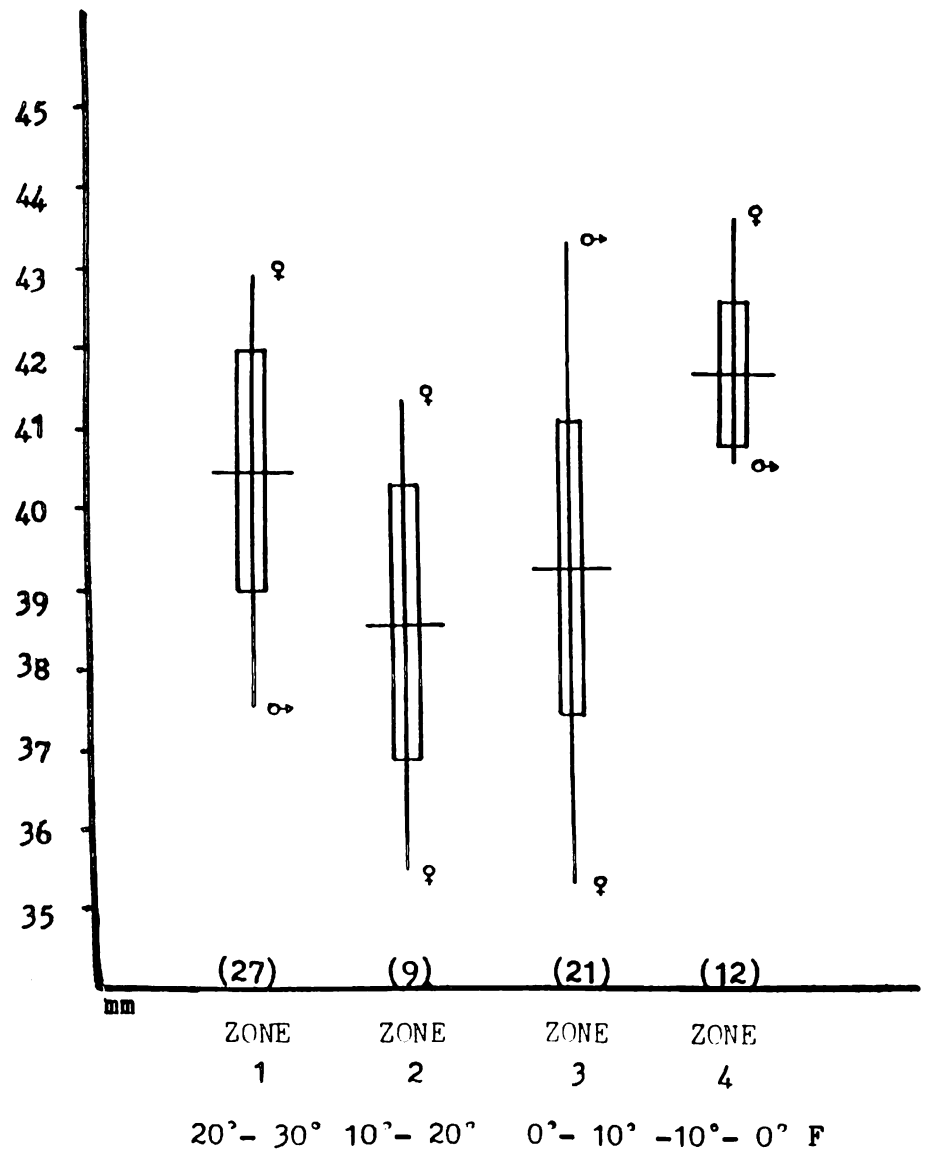



*Spermophilus mexicanus*

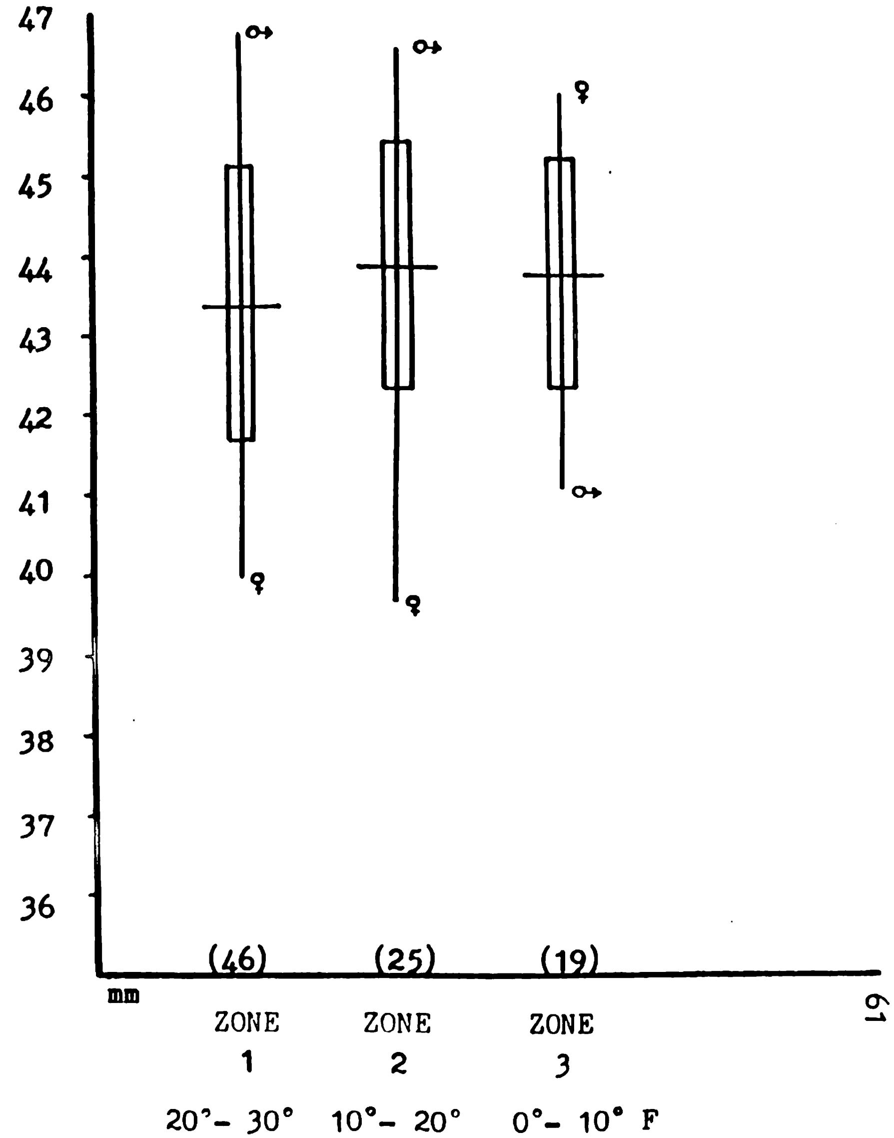


## SKULL LENGTH

Spermophilus spilosoma

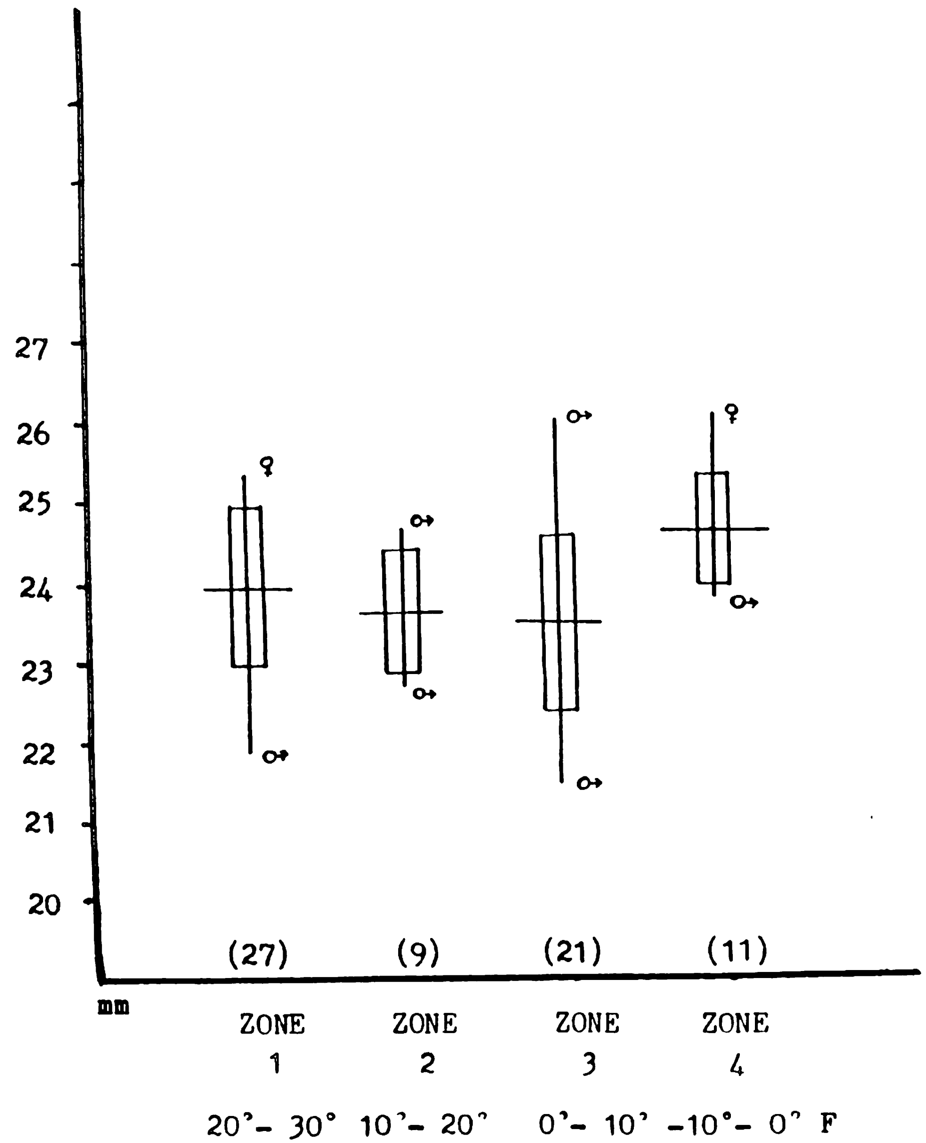



Spermophilus mexicanus

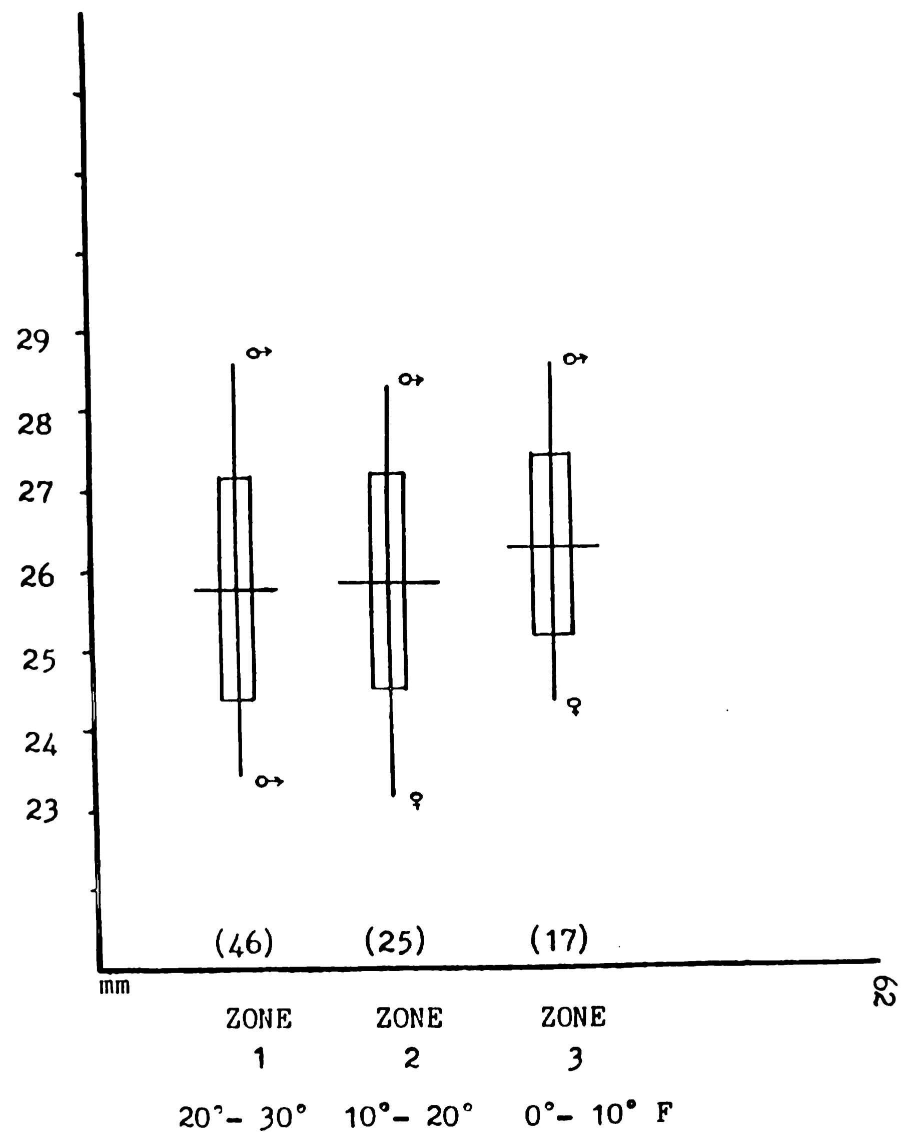


ZYGOMATIC BREADTH

Spermophilus spilosoma

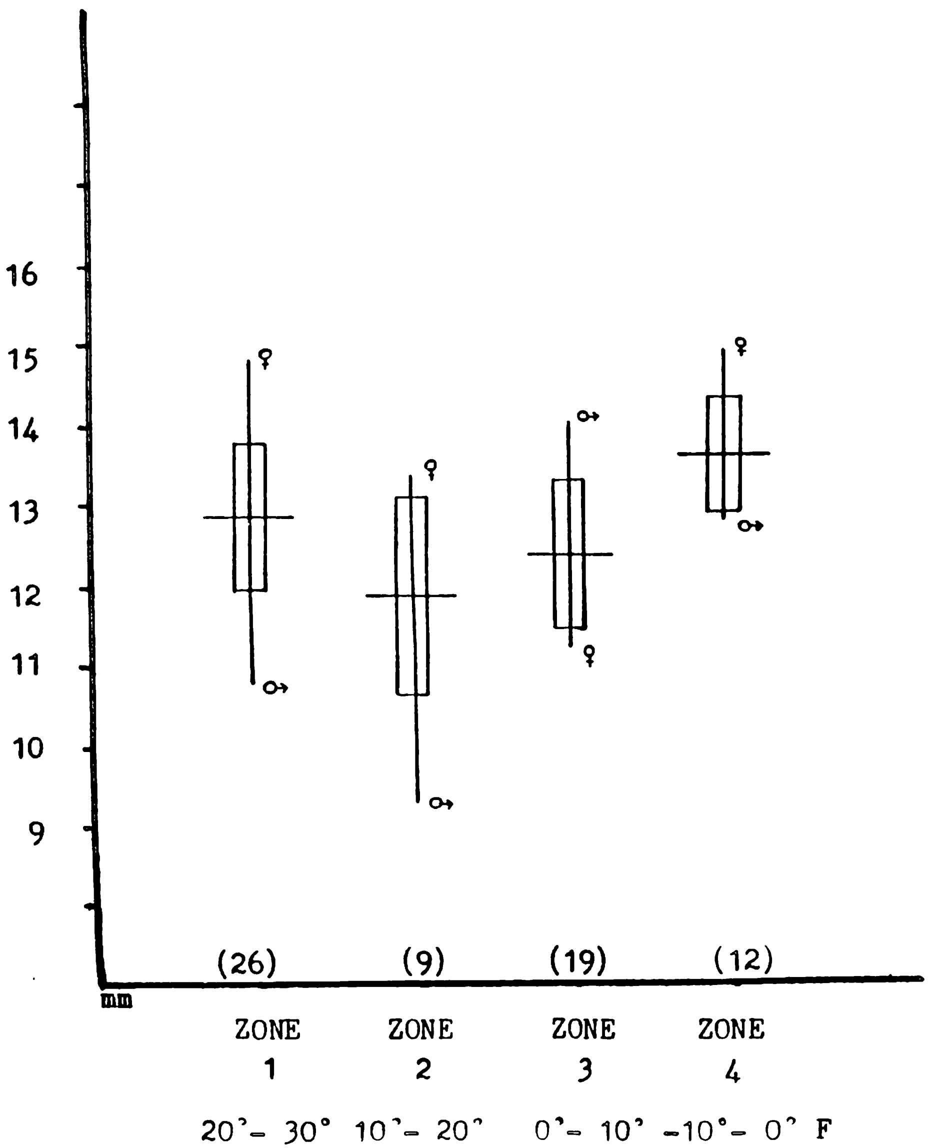



Spermophilus mexicanus

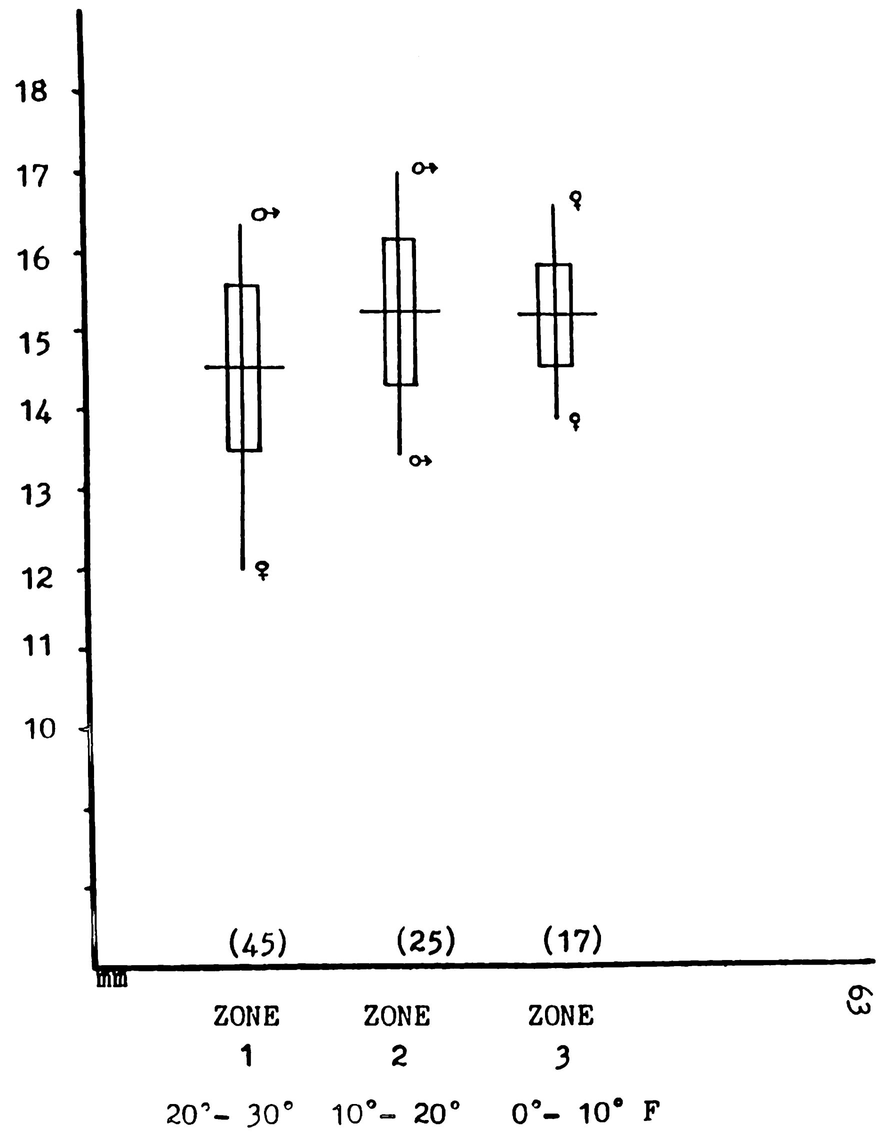


NASAL LENGTH

Spermophilus spilosoma

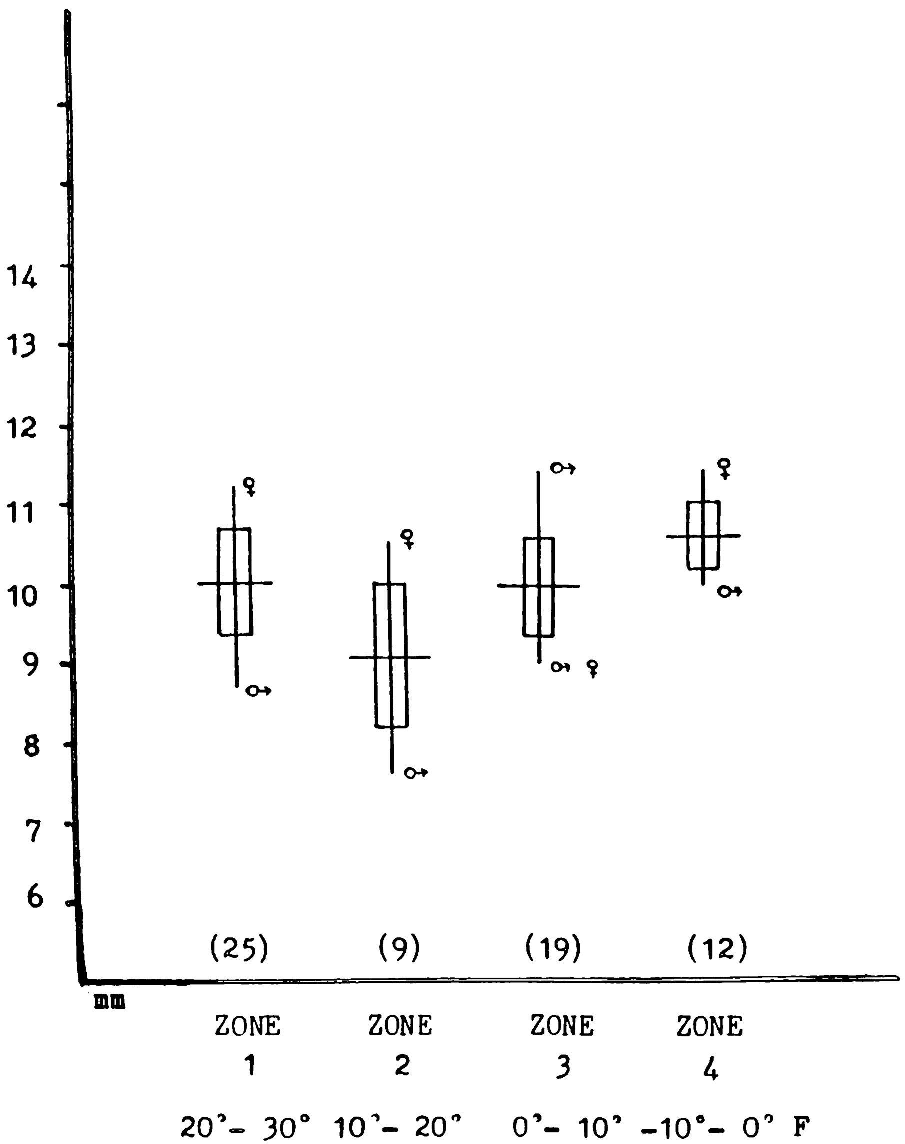



Spermophilus mexicanus

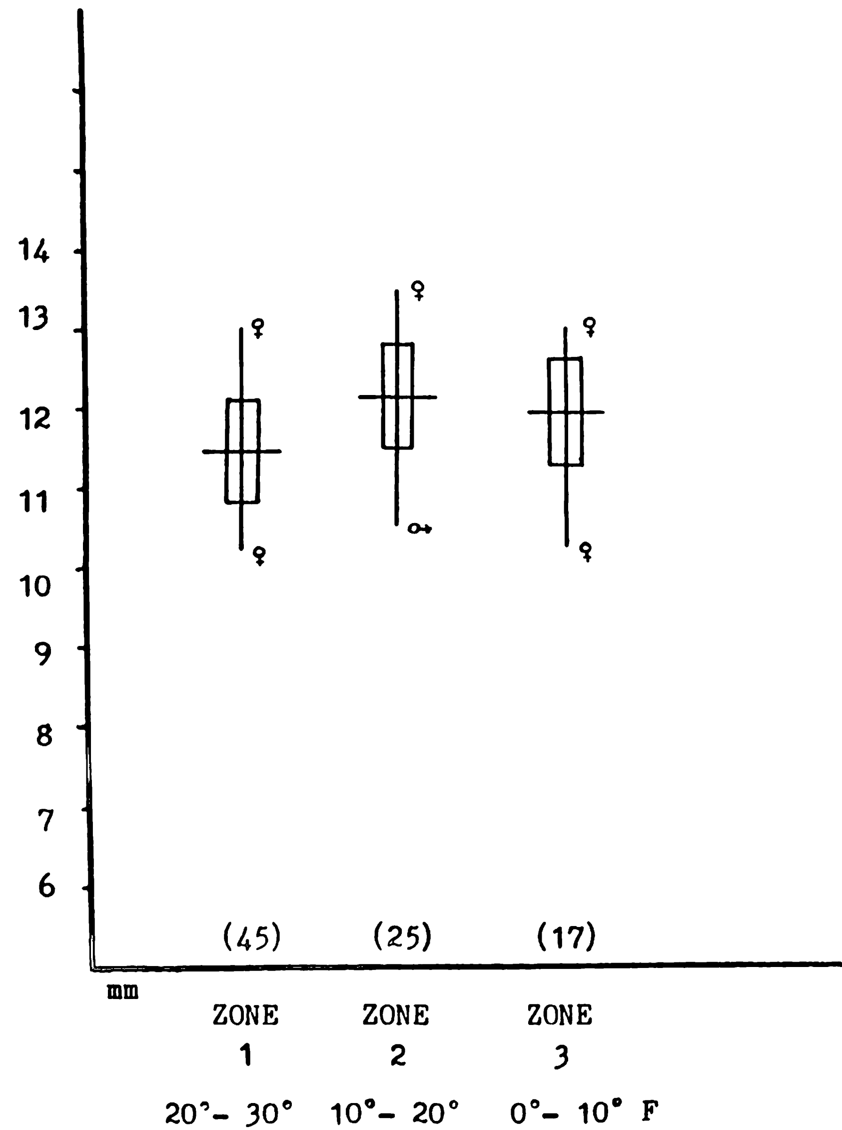


ROSTRAL LENGTH

Spermophilus spilosoma

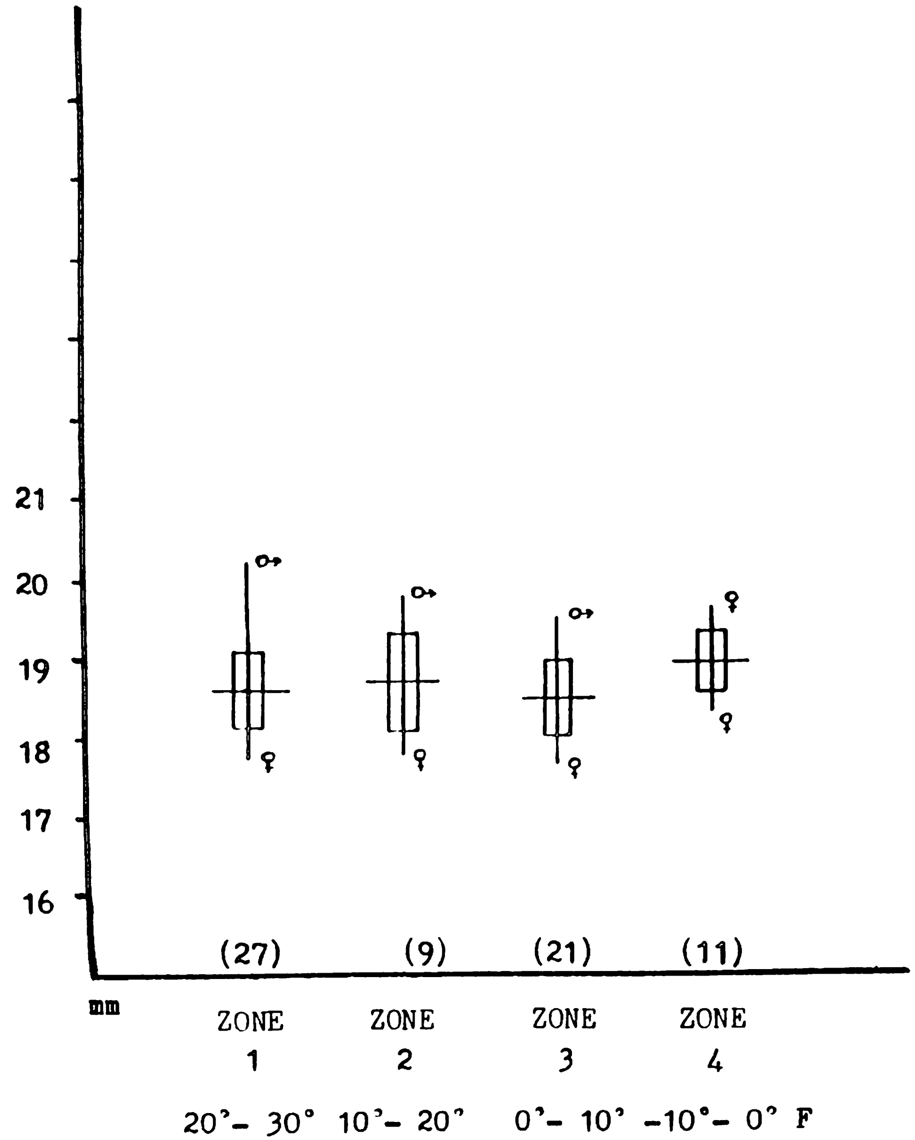



Spermophilus mexicanus

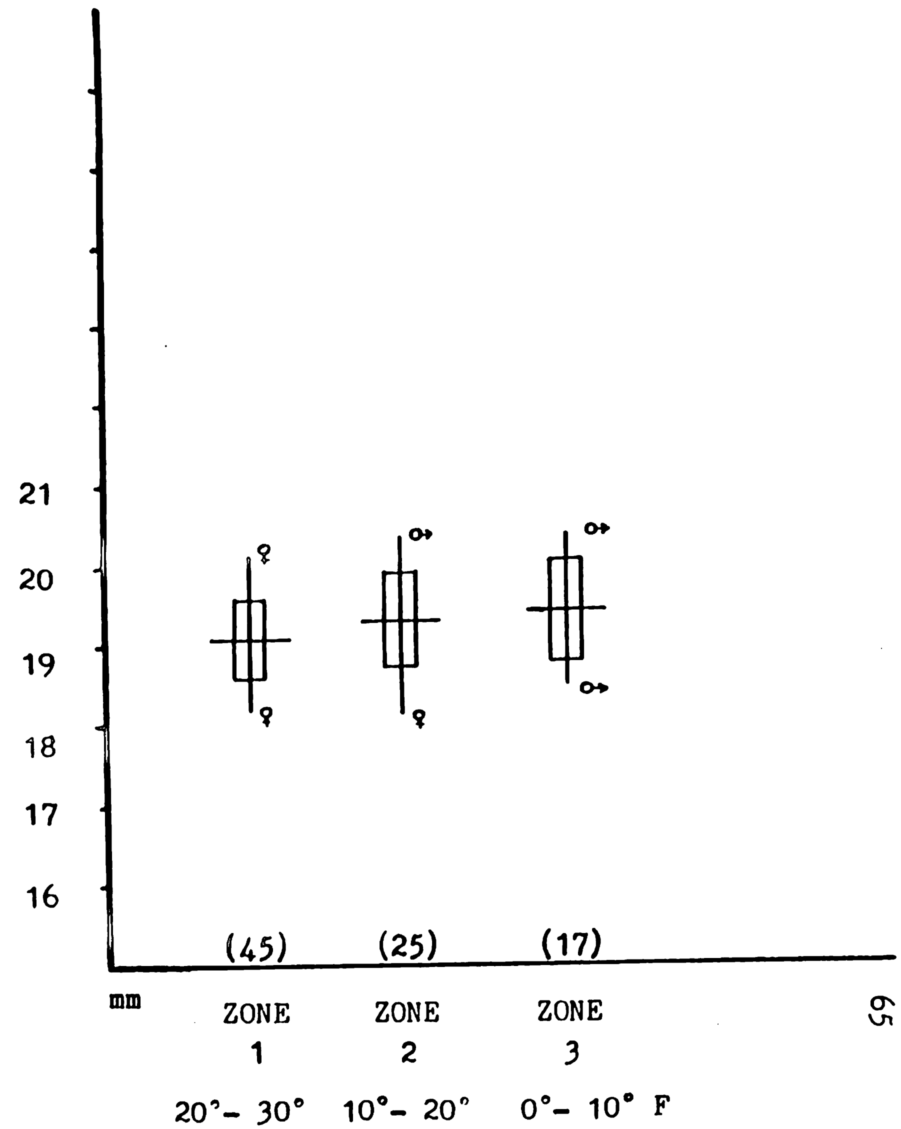


## CRANIAL BREADTH

*Spermophilus spilosoma*

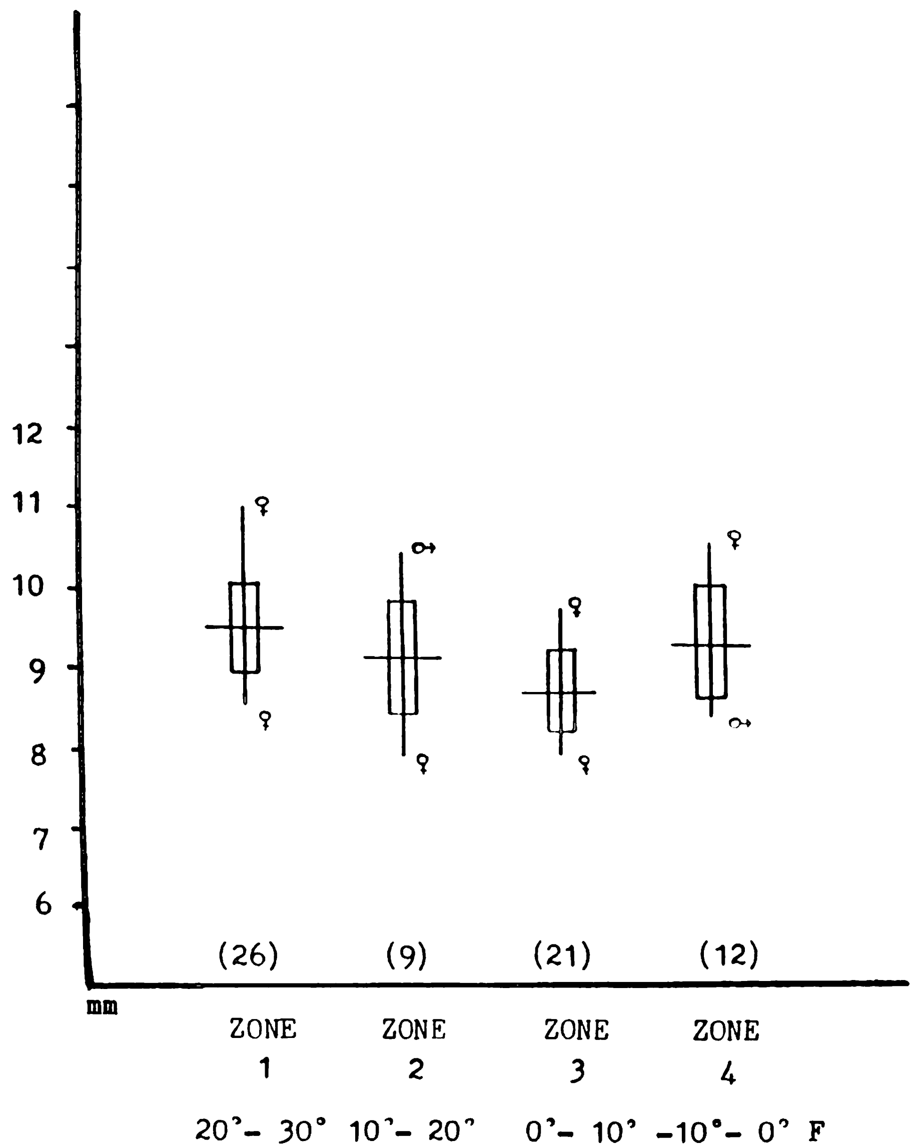



*Spermophilus mexicanus*

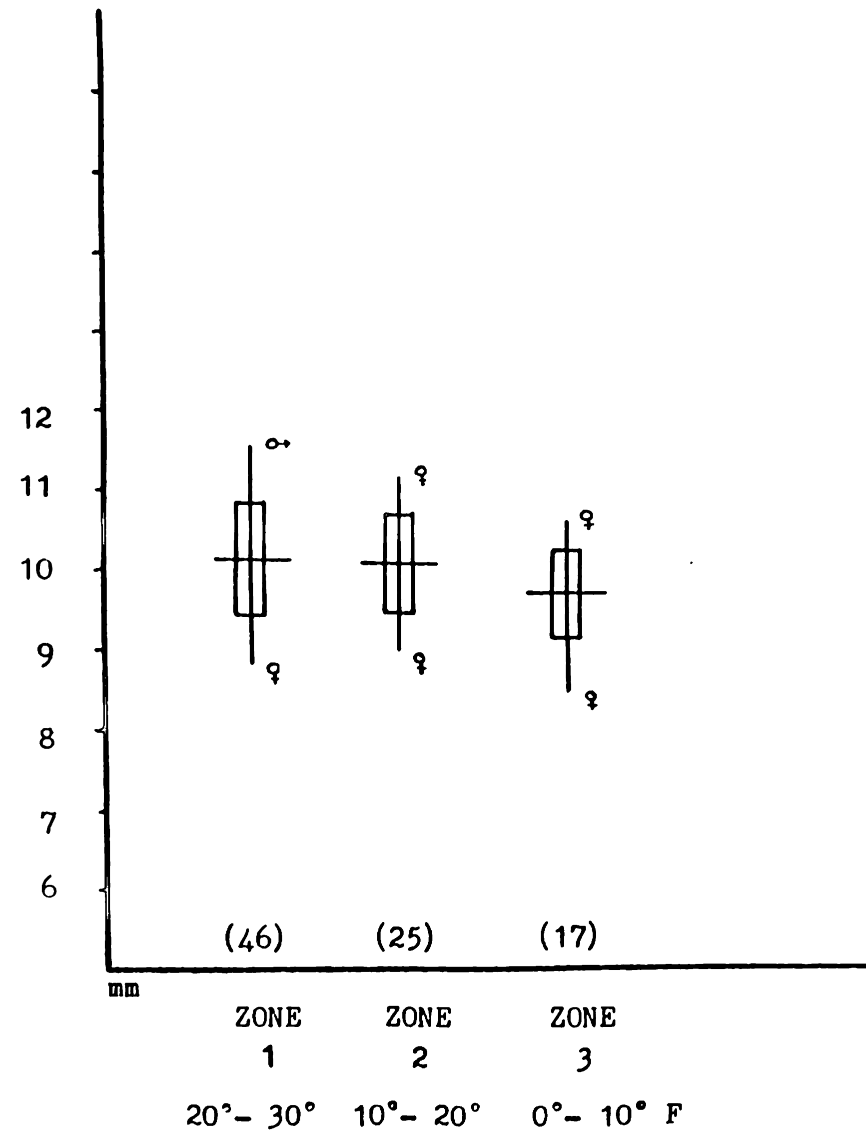


# INTERORBITAL BREADTH

Spermophilus spilosoma

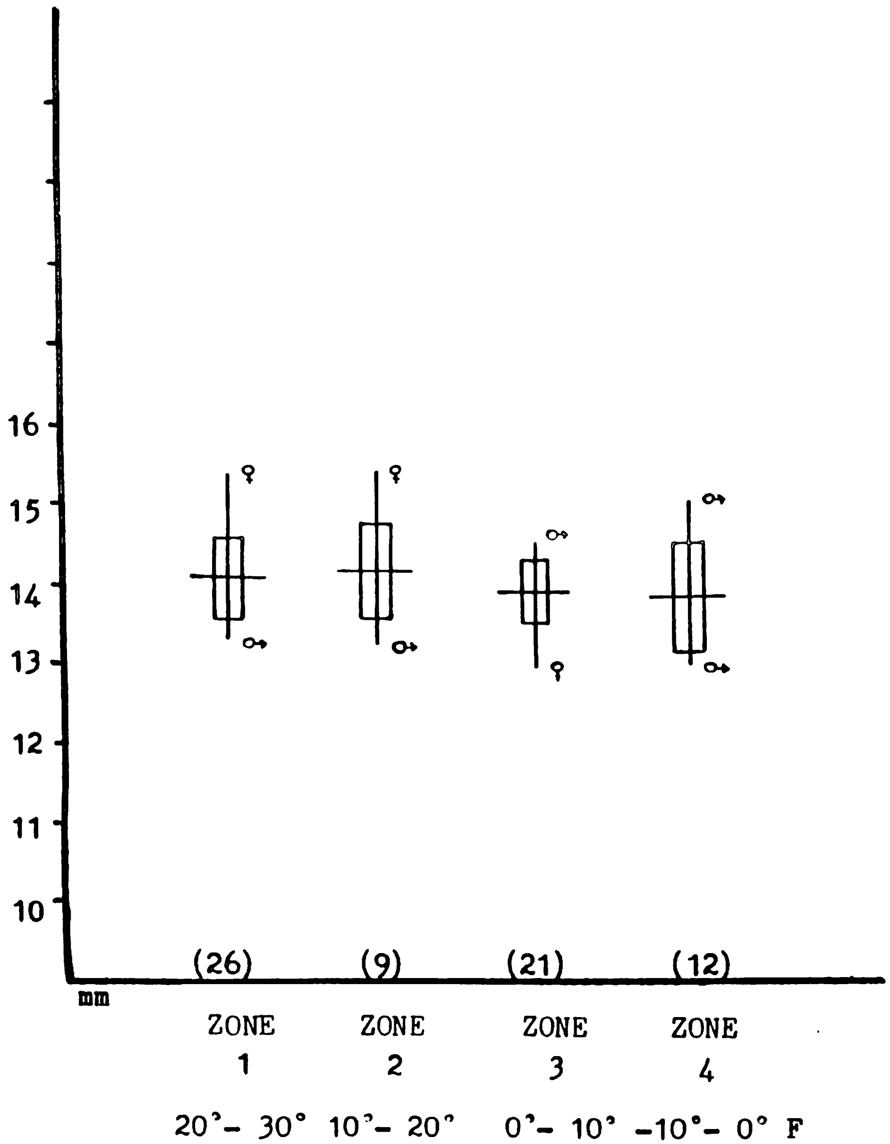



Spermophilus mexicanus

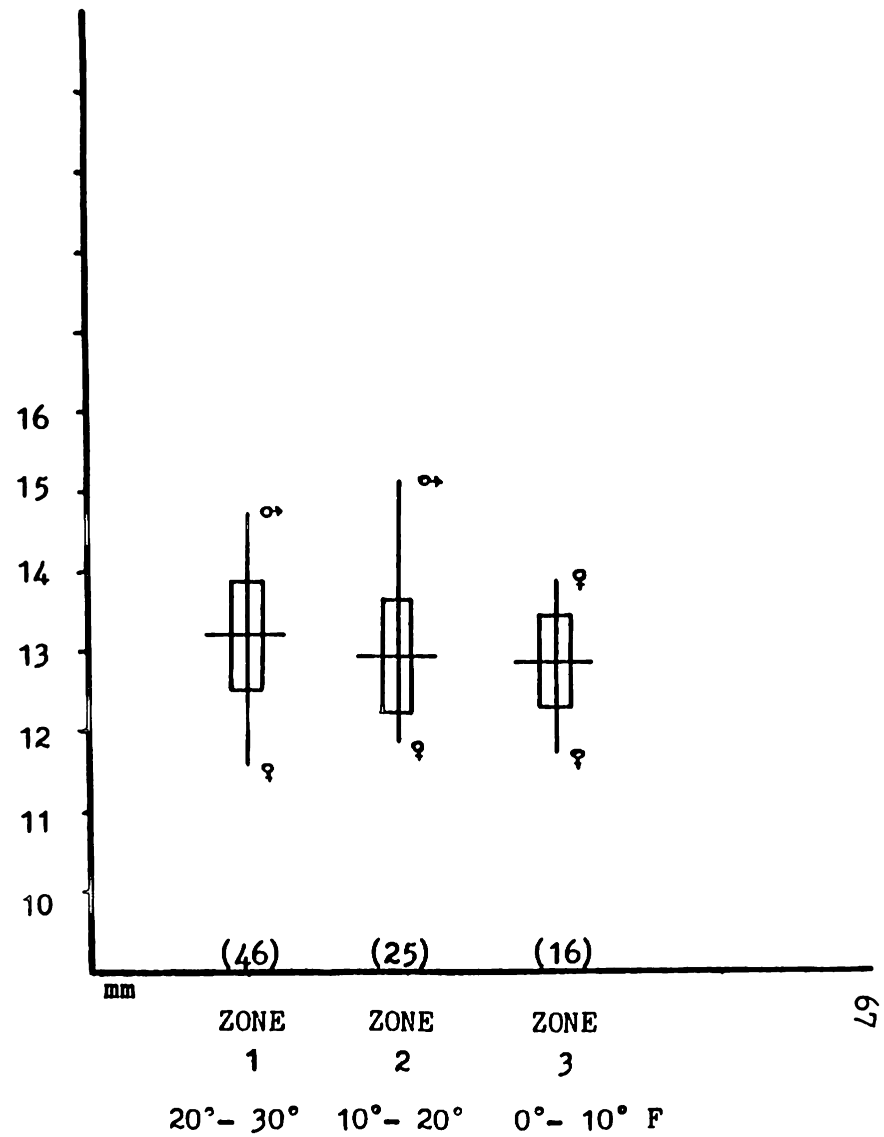


POSTORBITAL BREADTH

Spermophilus spilosoma

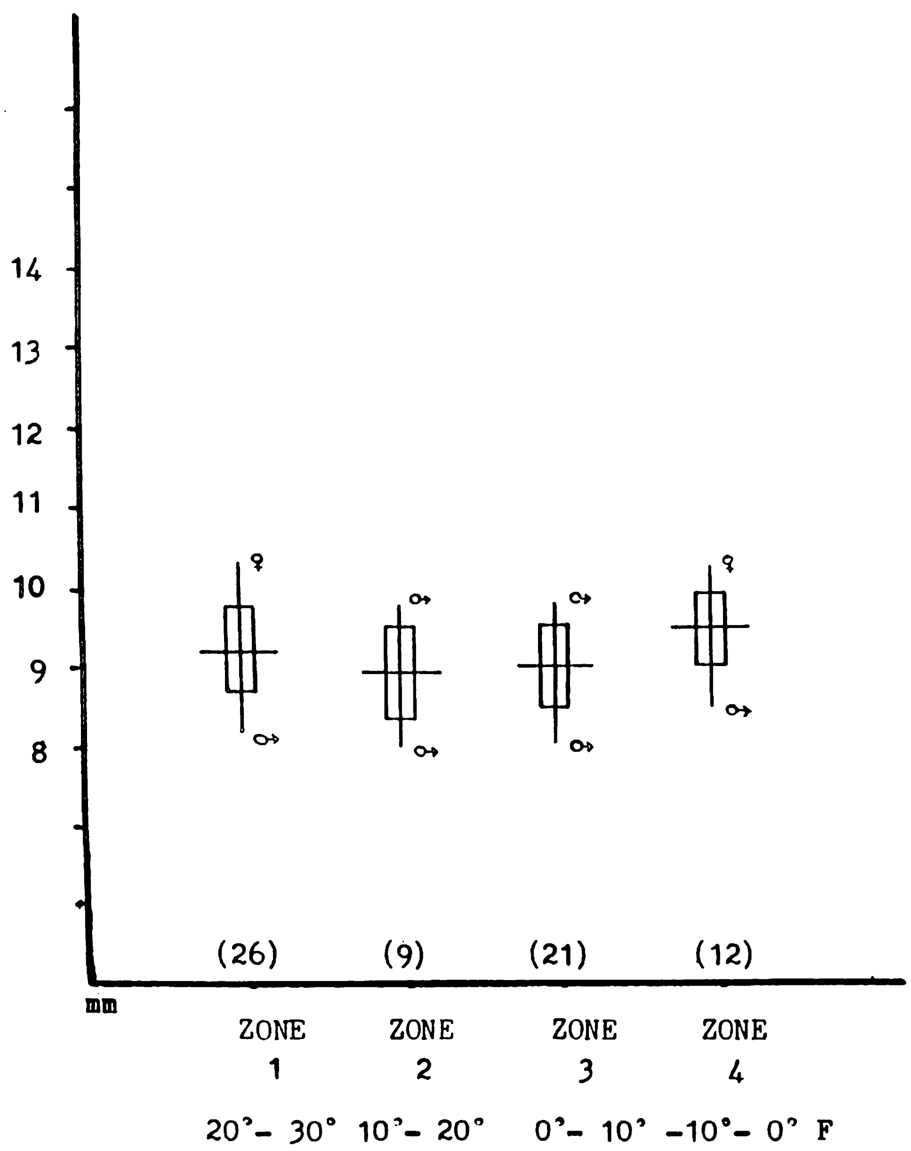



Spermophilus mexicanus

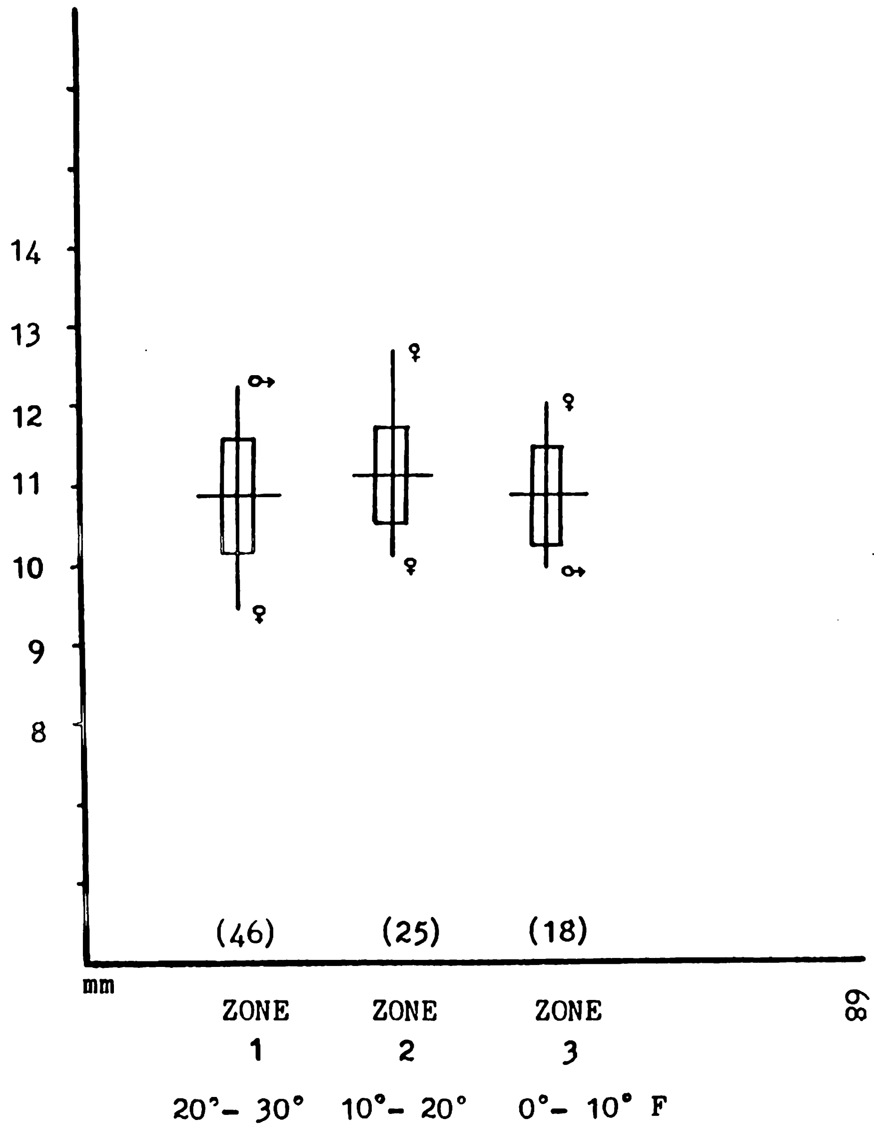


UPPER DIASTEMA LENGTH

Spermophilus spilosoma

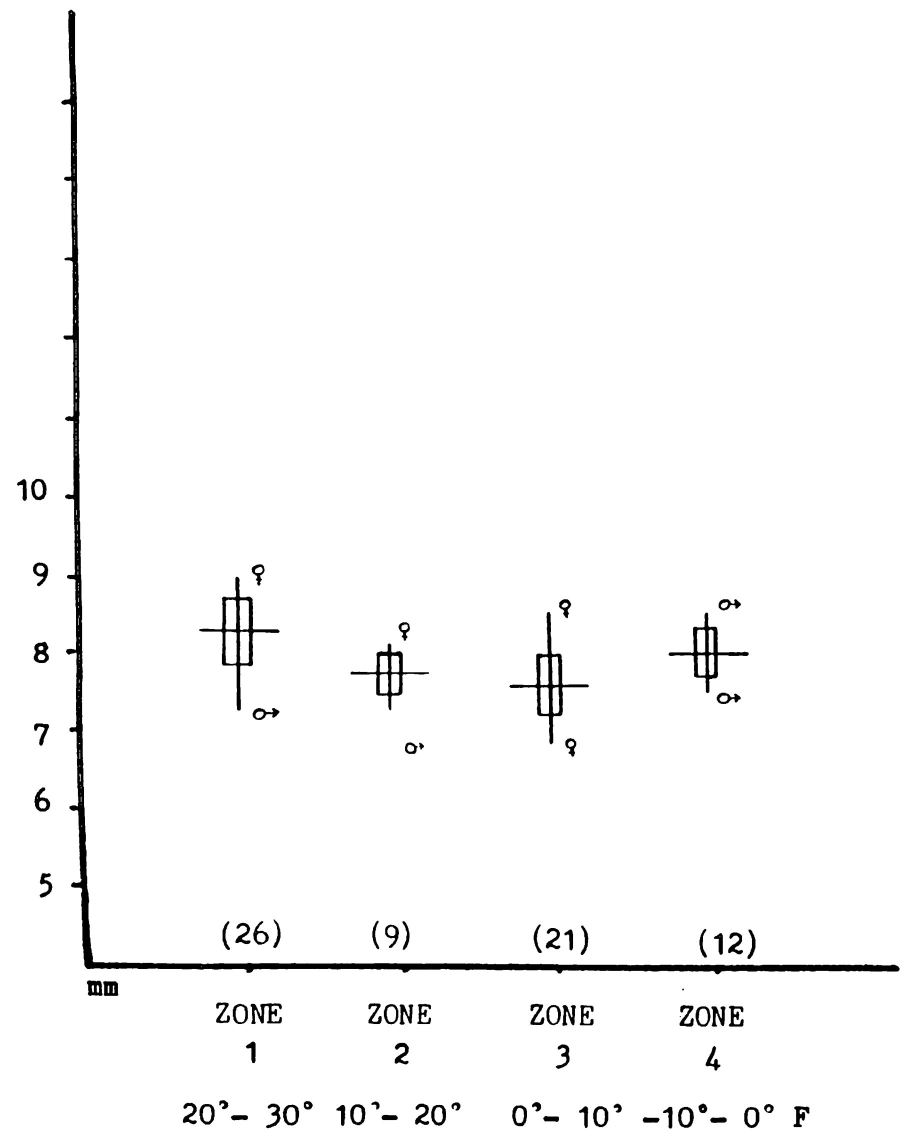



Spermophilus mexicanus

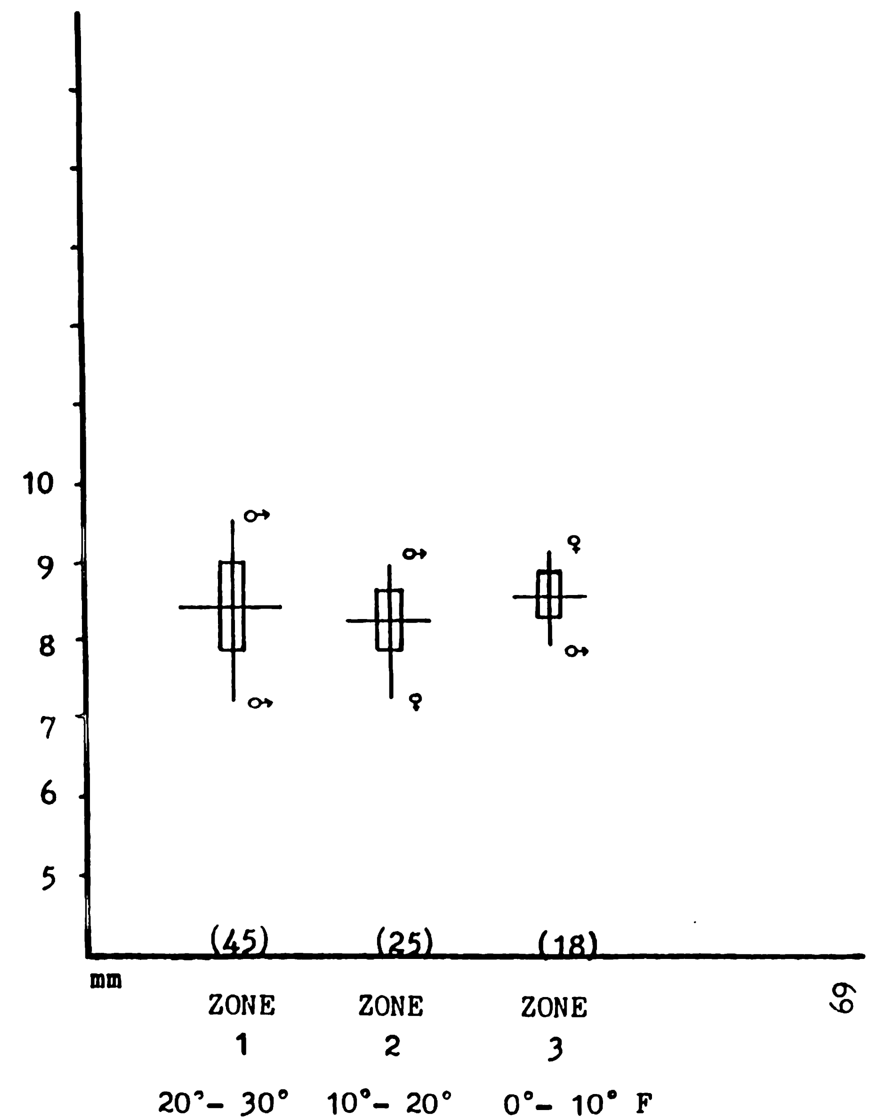


MAXILLARY TOOTHROW LENGTH

Spermophilus spilosoma

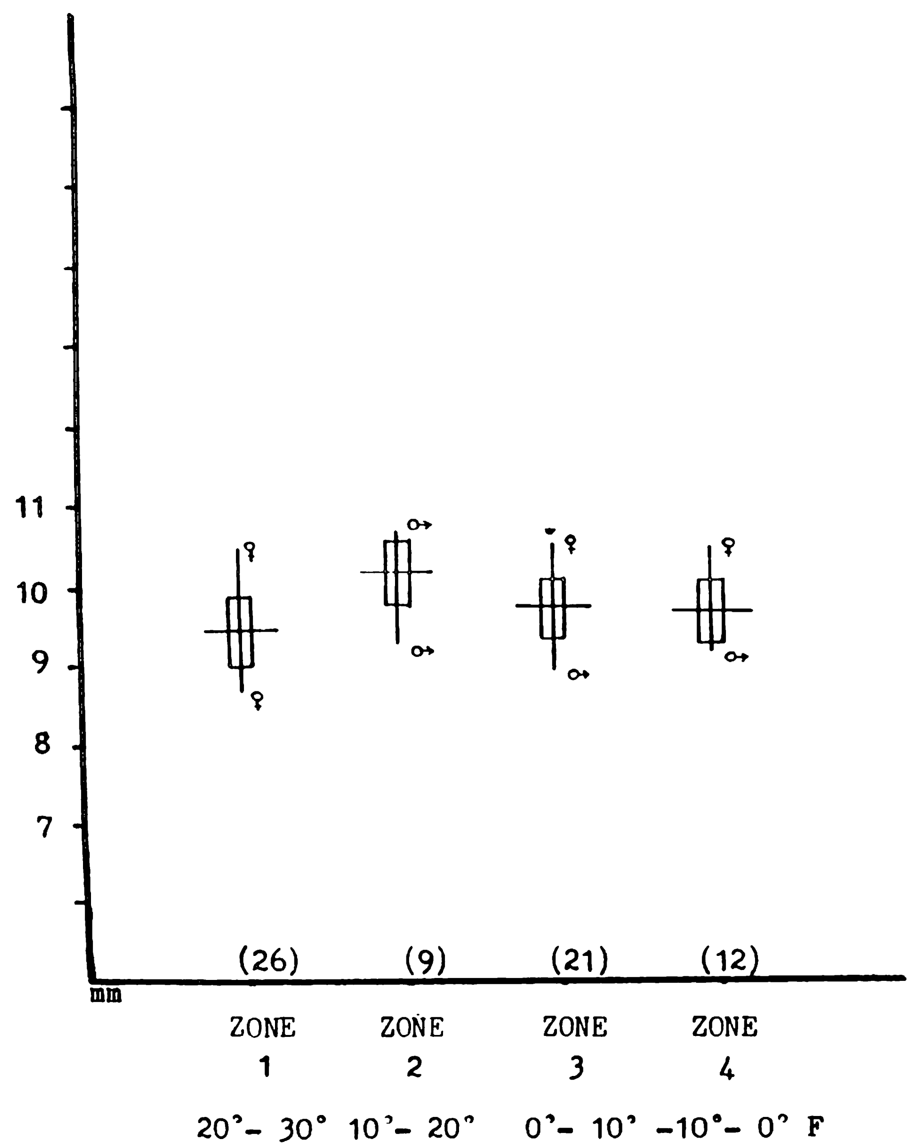



Spermophilus mexicanus

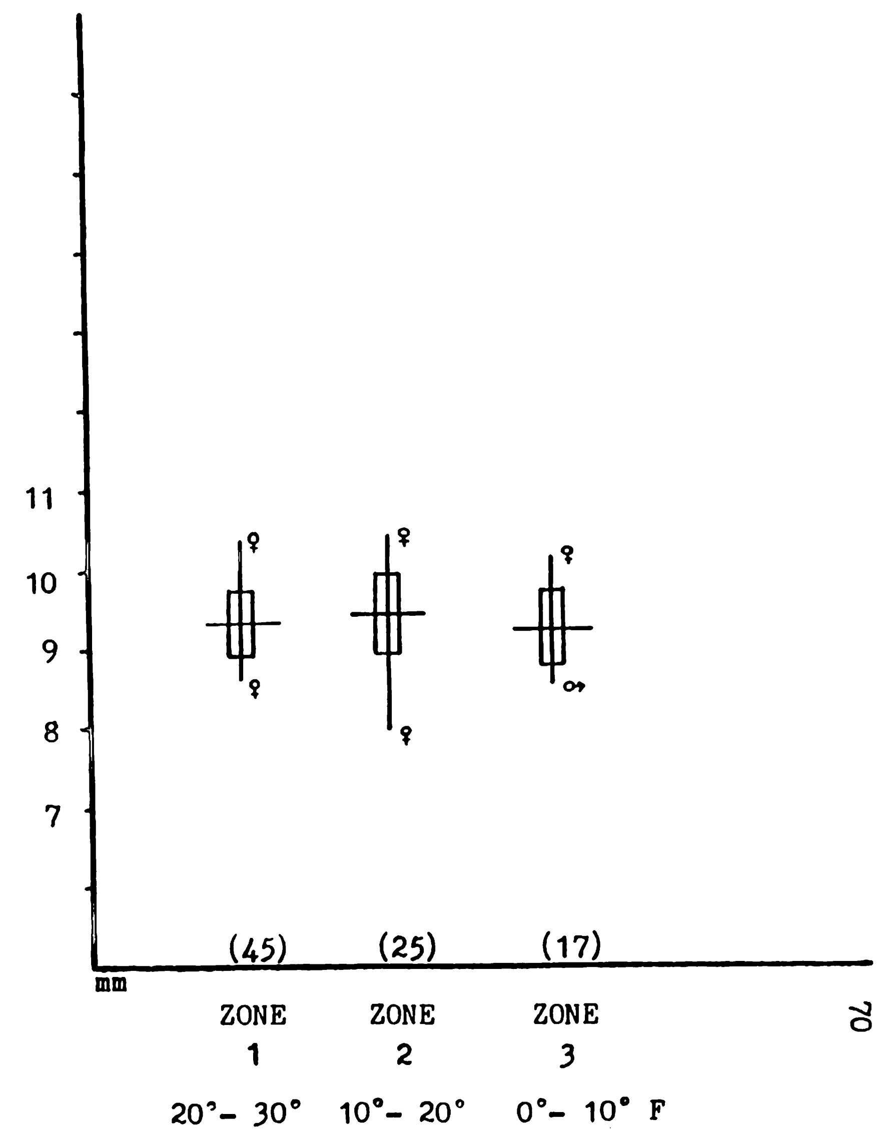


BULLAR LENGTH

Spermophilus spilosoma

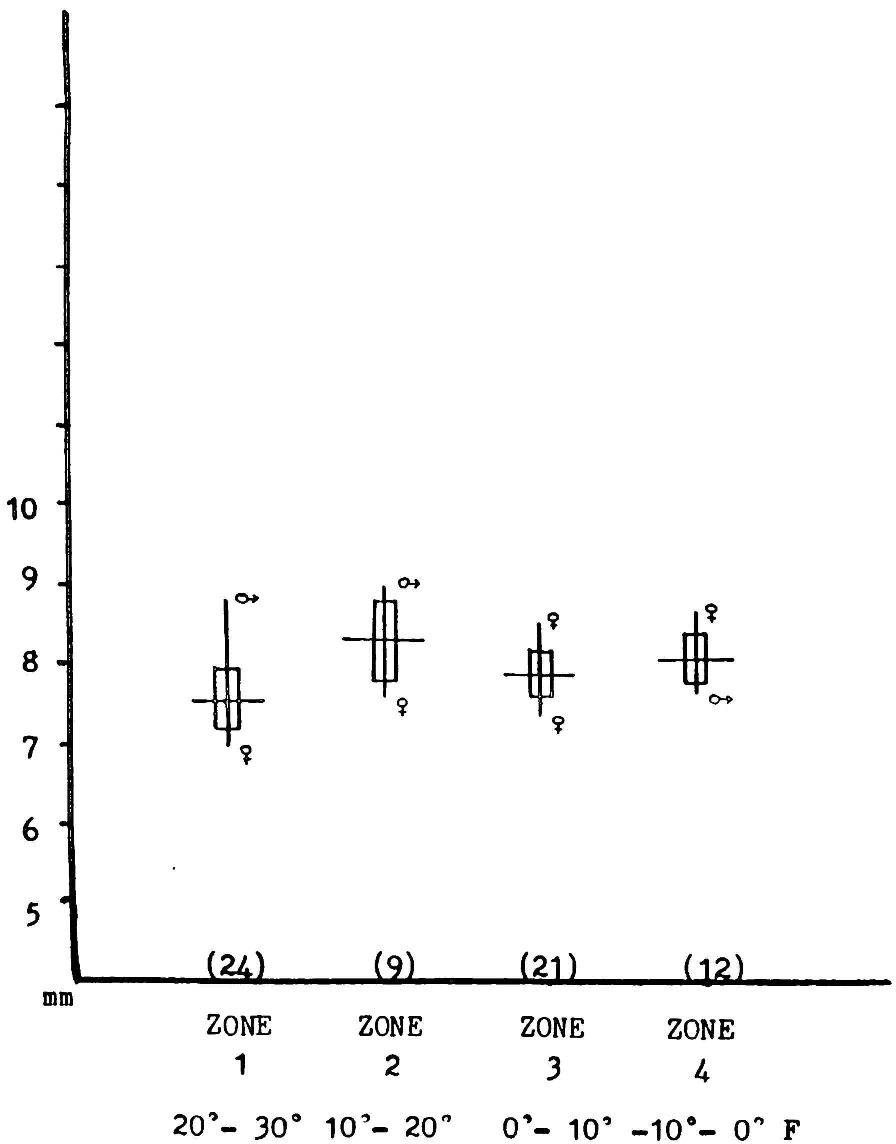



Spermophilus mexicanus

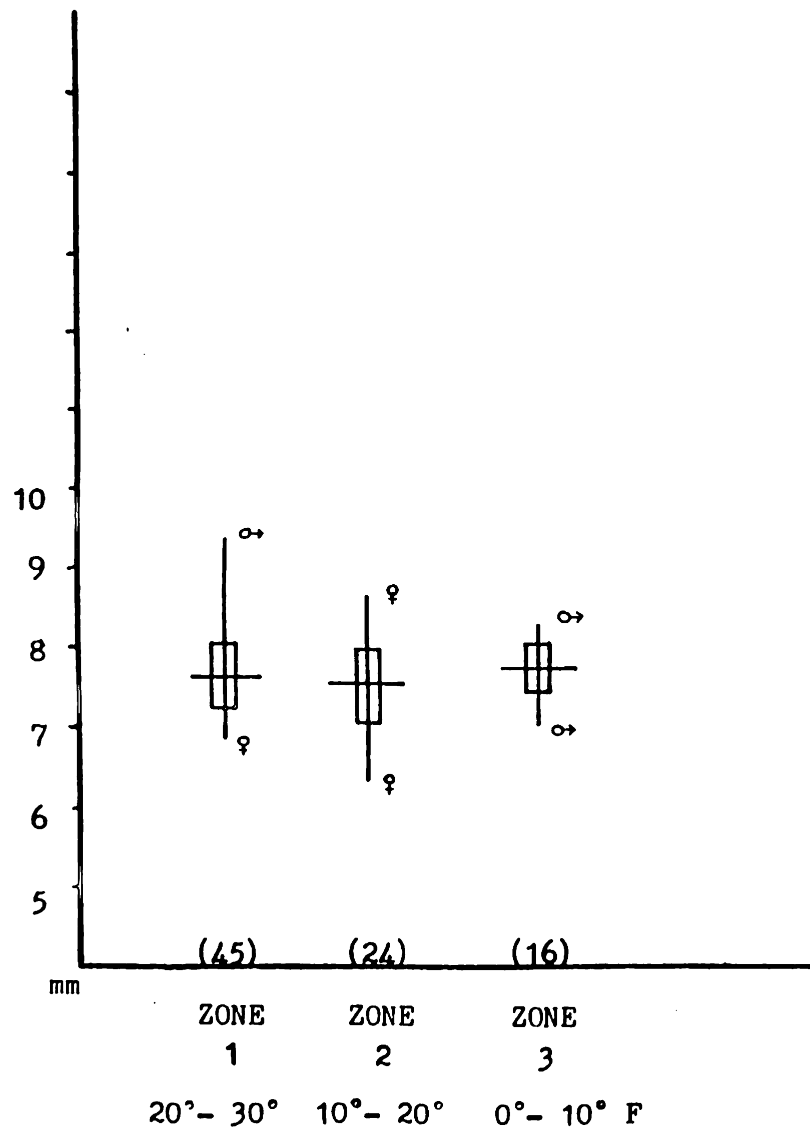


# BULLAR BREADTH

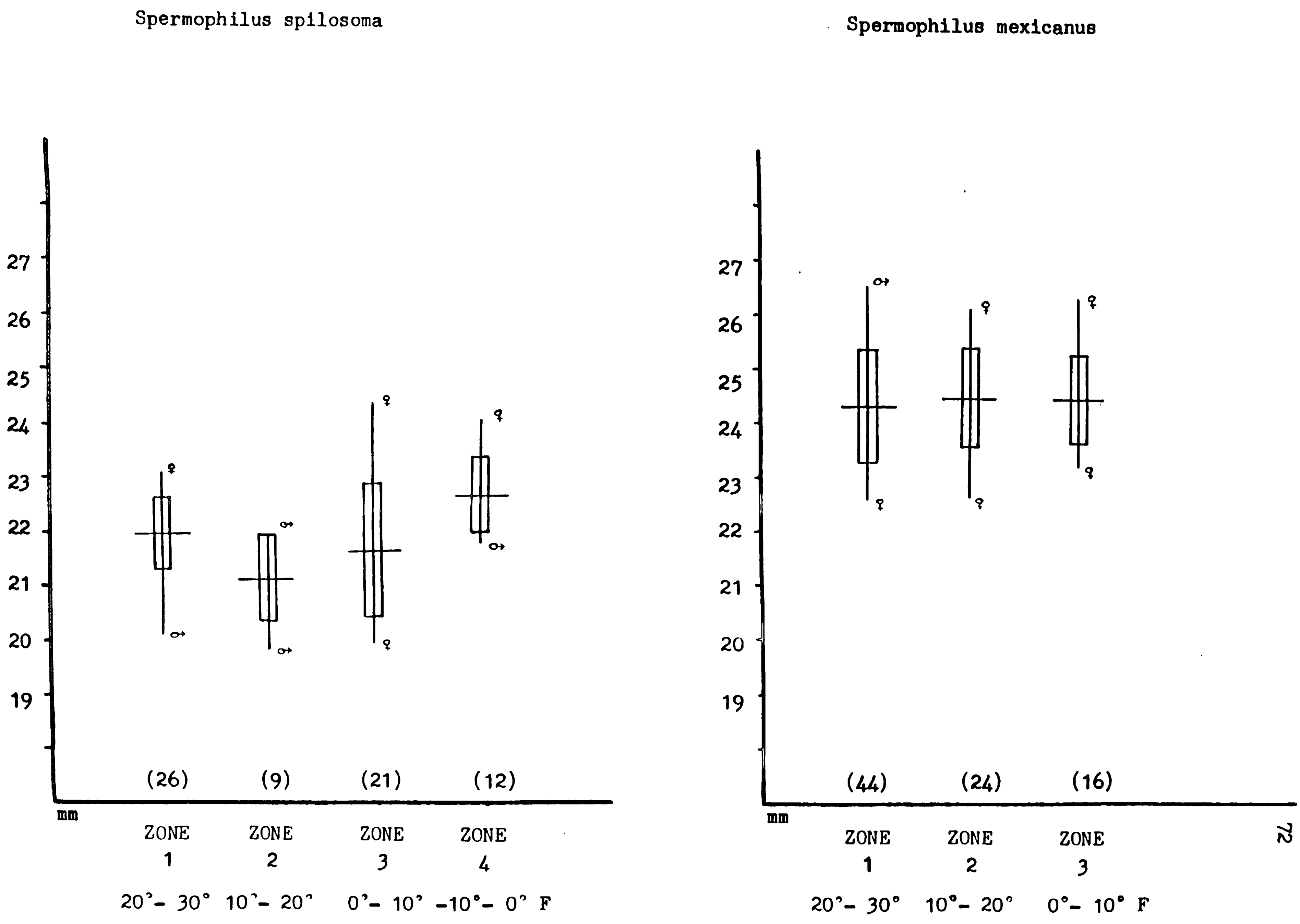
*Spermophilus spilosoma*




*Spermophilus mexicanus*



## MANDIBLE LENGTH



## VITA

Karen Marie Watts, daughter of Frances Helland Watts and Robert Graham Watts, was born on August 23, 1953 in San Antonio, Texas. Following her graduation from Saint Mary's Hall High School in San Antonio in 1971, she attended Texas A&M University in College Station, Texas, and received the degree of Bachelor of Science (Biomedical Science), Cum Laude, from the College of Veterinary Medicine in 1975.

In 1976 she was employed at the San Antonio Zoological Gardens & Aquarium as a small mammal keeper. After leaving there in 1978, she held the position of Research Technician with the Institute of Comparative Medicine (Texas A&M) at Baylor College of Medicine, Houston, Texas. From 1979 until 1985, she worked as a primate keeper and supervisor for the City of Houston at the Houston Zoological Gardens.

She spent three years in community service in Houston for the Junior League of Houston, Inc. producing, researching and writing public service announcements and programs with KUHT television, after which she returned to San Antonio and resumed her education at Trinity University as a postgraduate student in communication. During Trinity's 1990 summer session, she studied in Mainz, West Germany. In 1991, she entered the graduate program in

biology at Incarnate Word College. She was a teaching assistant for Anatomy and Physiology I lab in 1993.

Her article, "The Arrival of Abraham", was published in Hou-Zoo and Animal Kingdom, June/July 1982.

Associate Producer, Child Abuse: Breaking the Cycle (a 1987 simulcast by KUHT and KRIV, Houston, Texas.

Sustainer, Junior League of San Antonio, Inc.

Member, American Society of Mammalogists

Texas Society of Mammalogists

Delta Phi Alpha