THE TAXONOMIC STATUS OF TWO ISOLATED POPULATIONS OF VESPERTILIONID BATS (ANTROZOUS AND PIPISTRELLUS) IN WESTERN OKLAHOMA

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

Two populations of vespertilionid bats (*Antrozous* and *Pipistrellus*) occur within the political boundaries of Oklahoma. Both populations are separated from their nearest related form by several hundred miles of territory seemingly unsuitable for their occupation. The taxonomic and philosophical problems posed by the discovery of these disjunct populations are the subject of this report.

Acknowledgement is extended to Dr. Bryan P. Glass for his direction and assistance and to Dr's. Roy W. Jones, George A. Moore, and Imy V. Holt for their advice and criticism. The author is grateful to Claud M. Ward for permission to quote his descriptions of certain standards of measurement which appear in an unpublished thesis from the Oklahoma Agricultural and Mechanical College, entitled "Species Of The Genus *Myotis* In Oklahoma."

Viola S. Shantz (U. S. Fish and Wildlife Service), Donald F. Hoffmeister (Univ. of Illinois), E. Raymond Hall (Univ. of Kansas), Hugo Rodeck (Univ. of Colorado Museum), and P. F. Spangle (Biologist, Carlsbad Caverns National Park) loaned valuable museum specimens used in making comparisons with specimens from Oklahoma. The Oklahoma specimens were available in the collections of the Oklahoma State University Museum of Zoology. Claud M. Ward and Robert M. Sutton aided in the collecting of specimens. Transportation for field work was made possible through the National Institutes of Health (Grant No. E 819).

The Antrozous population is associated with outcrops of the Blaine Gypsum formation of Oklahoma and Kansas where rocky bluffs and caverns provide necessary habitat requirements. The Pipistrellus population is limited to the granitic Wichita Mountains.

A population of Antrozous also occurs in Cimarron County, Oklahoma. The problem dealt with in this report is concerned with the taxonomic relationship between these two populations, and the relationship of them both to the species Antrozous pallidus found in other parts of the southwestern United States.

The species Pipistrellus hesperus has not, heretofore, been reported from Oklahoma or any locality east of the Pecos River in New Mexico and Texas. Since the newly discovered population is related to that species, its taxonomic position within that species group is to be determined.

The idea has been proposed by Schwartz (1955) that geographic isolating mechanisms do not operate with the same force upon wide-ranging bats as they do upon more sedentary earth-bound mammals. He used this argument in support of his proposed merger of several isolated nominal species of the genus Tadarida into one polytypic, wide-ranging species, T. brasiliensis. It would seem that the principle that permits unification of a population of Tadarida from the southeastern United States with one from Texas would apply equally to two related populations divided by the high plains of Texas and Oklahoma, provided that in other respects the relationships between them can be shown to be of the order usually recognized as being of only subspecific significance. It is from this philosophical viewpoint that these disjunct populations of Antrozous and Pipistrellus have been examined.

REVIEW OF THE LITERATURE

Antrozous.

The genus Antrozous Allen (1862) was based on the type of Vespertilio pallidus Le Conte (1856), which differs from all other North American representatives of the Vespertilionidae in its truncate rhinarium bordered by a horseshoe-shaped nasal ridge, and in possessing only two lower incisors.

Up to the present five nominal forms of Antrozous have been described. A. pallidus (Le Conte) is the type species. A. p. cantwelli Bailey has never occupied any but subspecific rank. A. minor Miller and A. pacificus Merriam have at times been considered full species and at other times have been regarded as subspecies of A. pallidus. A. bunkeri Hibbard has always been ranked as a full species.

Antrozous bunkeri Hibbard (1934) was based on 25 specimens collected in Barber County, Kansas.

A single specimen, collected in Cimarron County, Oklahoma, by Blair (1939) and assigned to A. p. pallidus, constitutes the first Oklahoma record. This distribution was later further substantiated by the collections of Glass (1949, 1957) also in the Black Mesa region of that county.

Prior to 1957 A. bunkeri had been recorded only from the vicinity of the type locality, except that Burt (1945) referred Blair's Cimarron County specimen to A. bunkeri. Twente (1955) banded eight Antrozous in Mays Cave, Barber County, Kansas, during 1952 - 1953, and mentioned

adjacent sites in the same county where the species had been observed. The first published record of A. bunkeri in western Oklahoma (exclusive of the panhandle) is that of Glass (1957).

Orr (1954) recognized two species of Antrozous, A. pallidus (Le Conte) and A. bunkeri Hibbard. He recognized four geographic races of A. pallidus with ranges as follows: A. p. pallidus (Le Conte), southeastern California and northeastern Baja California east to Colorado and Texas and south to south-central Mexico; A. p. cantwelli Bailey, southern British Columbia and eastern Washington south to northeastern California and northwestern Nevada; A. p. pacificus Merriam, northwestern Oregon south to northwestern Baja California; and A. p. minor Miller, central to southern Baja California.

The above classification was also recognized by Miller and Kellogg (1955) except that full specific rank was assigned to A. minor Miller.

Burt (1952) and Orr (1954) both have speculated that since the two species, A. pallidus and A. bunkeri, are very similar, they would ultimately prove to be conspecific.

Pipistrellus.

The genus Pipistrellus Kaup (1829) was based on the type of Vespertilio pipistrellus Schreber. It is represented by numerous species in the old world, but by only two, P. subflavus (Cuvier) and P. hesperus (Allen), in the western hemisphere. Pipistrellus subflavus, with its various subspecies, is found throughout the eastern United States and along the east coast of Mexico. No published records indicate that its range at any point overlaps that of P. hesperus, although Hall and Dalquest (1950) have reported that the ranges of the two virtually

adjoin in the vicinity of Del Rio, Texas. The latter species is an inhabitant of the dry desert and semi-desert of western North America.

Hatfield (1936) revised the Pipistrellus hesperus group of bats, recognizing five distinct subspecies: P. h. hesperus (Allen), P. h. merriami (Dobson), P. h. australis Miller, P. h. maximus Hatfield, and P. h. santarosae Hatfield. This classification was accepted unchanged by Hall and Dalquest (1950) in their synopsis of the genus.

According to Hall and Dalquest (1950), the geographic ranges of these subspecies are as follows: P. h. hesperus, intermontane region of the United States from south central Washington south to Baja California, and from southeastern California eastward to southeastern Utah; P. h. merriami, California west of the Sierra Nevada; P. h. australis, central Arizona south to Jalisco and including the southern half of Baja California; P. h. maximus, southern New Mexico, western Texas and probably the adjoining parts of Mexico; P. h. santarosae, New Mexico (excepting southern part) and western Colorado.

Miller and Kellogg (1955) presented the above classification with one addition, P. h. potosinus Dalquest. This form is known only from the western and central parts of San Luis Potosi, Mexico (Dalquest, 1951).

MATERIALS AND METHODS

Specimens

Specimens examined in this study were standard museum preparations consisting of skins and skulls. A few specimens were incomplete, however, consisting of skin only or skull only. The collection sites for all specimens have been listed in the appendix.

The following abbreviations have been used: United States National Museum, USNM; University of Illinois Museum of Natural History, IMNH; Kansas University Museum of Natural History, KU; University of Colorado Museum, CU; and Oklahoma State University Museum of Zoology, OAM.

Antrozous.

A total of 154 Antrozous from Oklahoma and Kansas were available for this study. All of the specimens from Oklahoma and most of the specimens from Kansas were collected by Dr. Bryan P. Glass, the writer, or various students at Oklahoma A. and M. College. The above specimens were in the collections of OAM.

Specimens of Antrozous were borrowed from the following museums: USNM, 13; IMNH, 7; KU, 6; CU, 2. Two specimens were also borrowed from the collection at Carlsbad Caverns National Park.

The following is a list of cave locations from which Antrozous were collected:

Alabaster Caverns: Sec. 33, T26N, R18W of I. M., five miles south, two miles west of Freedom, Woodward County, Oklahoma.

Mays Cave: two miles south-southwest of Aetna, Barber County, Kansas.

Pigeon Cave: Sec. 11, T5N, R1E of C. M., three miles east and one mile north of Kenton, Cimarron County, Oklahoma.

Tesequite Cave: Sec. 35, T5N, R1E of C. M., two miles east and three miles south of Kenton, Cimarron County, Oklahoma.

The name Tesequite is spelled Tesse Equite on some maps. The two are synonymous, and are derived from the name of a canyon near Kenton, Oklahoma. The former spelling is preferred as it was used thus by Blair (1939).

Pipistrellus.

A total of 27 specimens of Pipistrellus hesperus were collected from Greer, Kiowa, and Comanche Counties, Oklahoma. All except two were shot in flight. One was taken in a net set in front of a small cave, and one was a mummified specimen found by Mr. Arthur Halloran, biologist at the Wichita Mountains Wildlife Refuge, in one of the Easter Pageant buildings.

Specimens of Pipistrellus hesperus were borrowed from the following museums: USNM, 25; IMNH, 28. Four specimens also were borrowed from Carlsbad Caverns National Park.

Aging

Antrozous.

Only adult bats were used for comparison in this study. Differentiation between adults and subadults was accomplished by means of the method described by Miller (1897), in which progressive ossification of

the finger joints was utilized as an indication of increasing age. The method is of limited value in that ossification of the joints means ability to fly but not necessarily sexual maturity. However, since bats which are capable of flying have measurements within the range of adults, this criterion, rather than sexual maturity, was used to indicate adulthood for the purposes of this study.

The date of collection was also considered in determining age. Bats captured during the fall and winter were all capable of flying and consequently could be considered to be of adult size. Bats collected prior to mid-July could likewise be considered adult since the young normally do not start flying prior to that date.

Pipistrellus.

The same methods as described above, with the following exceptions, were used for determining the age of specimens of P. hesperus. In some specimens of P. hesperus, collected during late summer (August 13 to August 15), it was virtually impossible to distinguish between adults and subadults on the basis of ossification of the joints.

In such dubious cases, an additional factor was found useful in determining age. The body hairs of P. hesperus are bicolored, with a line of demarcation between the colors of the root and tip regions. In adults the root region is intense black, and there is a sharp line of demarcation between the root and tip regions. In subadults the root region is dull black which shades gradually into the coloration of the tip. The overall appearance of the hair in subadults is more woolly and dull, and lacks the glossy texture found in adults. One dubious specimen

was classified as an adult from collection data which indicated that it had suckled young.

Treatment of the Populations

Antrozous.

Specimens of Antrozous which were collected from areas of relatively close geographical proximity were grouped together. This was done in order to facilitate the analysis of data. The grouping was considered justifiable since bats are flying mammals and their movements are not as limited as strictly as in terrestrial mammals. The majority of the collection sites fell into three groups which have been designated as Groups I, II, and III (see Figure 1).

The collecting sites for Group III were the most widely spread. However, they all lie within the area considered to be the heart of the range of Antrozous pallidus pallidus and the areas intervening between the localities are largely suitable habitat for the species. It has been assumed, therefore, that the sample used represents a single population within which gene-flow is relatively uninterrupted.

Five additional specimens of Antrozous were examined: three from Greer County, Oklahoma; one from Mohave County, Arizona; and one from Moffatt County, Colorado. These bats were not included in the various groupings because of geographical isolation. The measurements of the Oklahoma specimens for almost every character fell within the range of Group I. The Arizona and Colorado bats, on the basis of measurements, could have been included in Group III.

The measurements of individuals within each group were segregated according to sex and each sex was treated separately. Extreme and

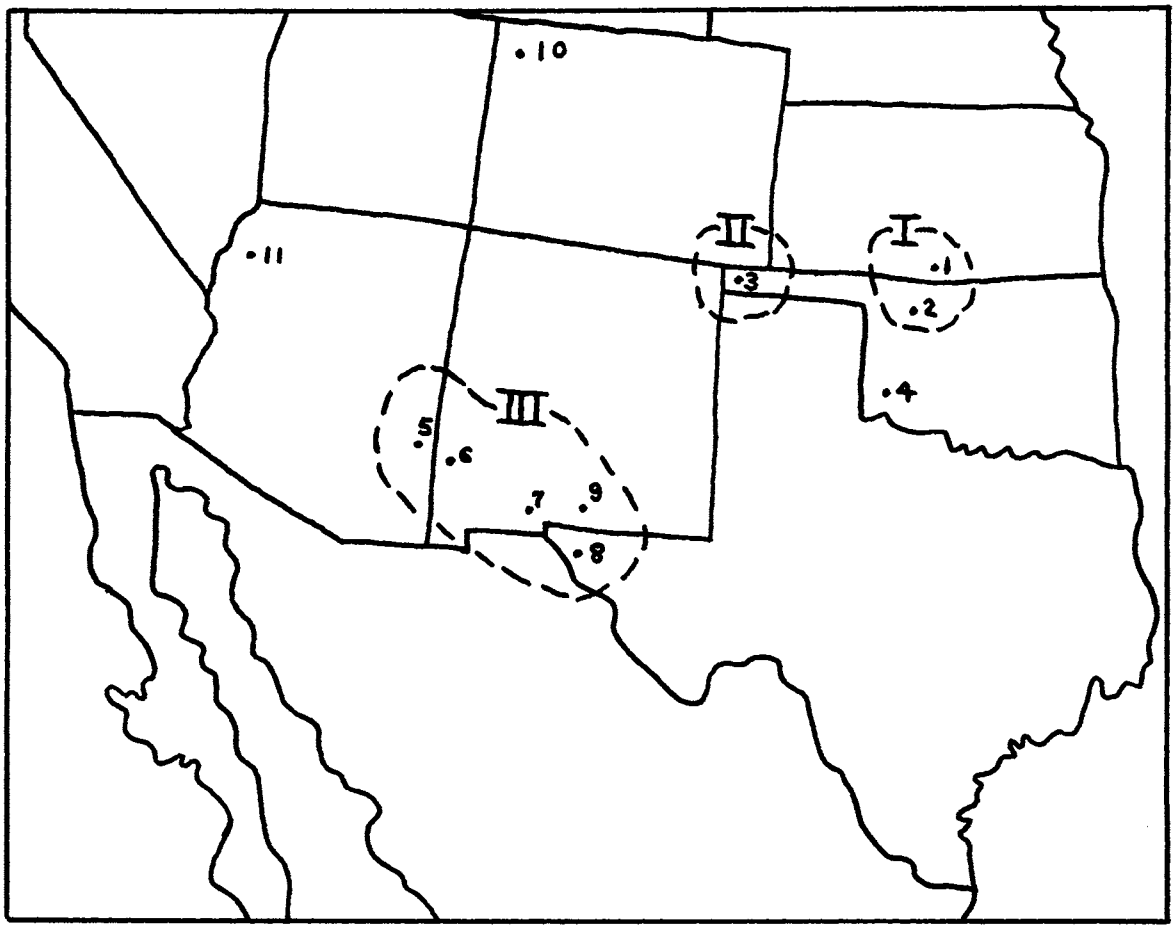

Figure 1. Collection sites (County and State) of specimens of Antrozous.

Legend:

1. Barber Co., Kans.
2. Woodward Co., Okla.
3. Cimarron Co., Okla.
4. Greer Co., Okla.
5. Graham Co., Ariz.
6. Grant Co., New Mex.
7. Dona Ana Co., New Mex.
8. Hudspeth Co., Tex.
9. Otero Co., New Mex.
10. Moffatt Co., Colo.
11. Mohave Co., Ariz.

(Roman numerals, I, II, and III, indicate grouping of population samples.)

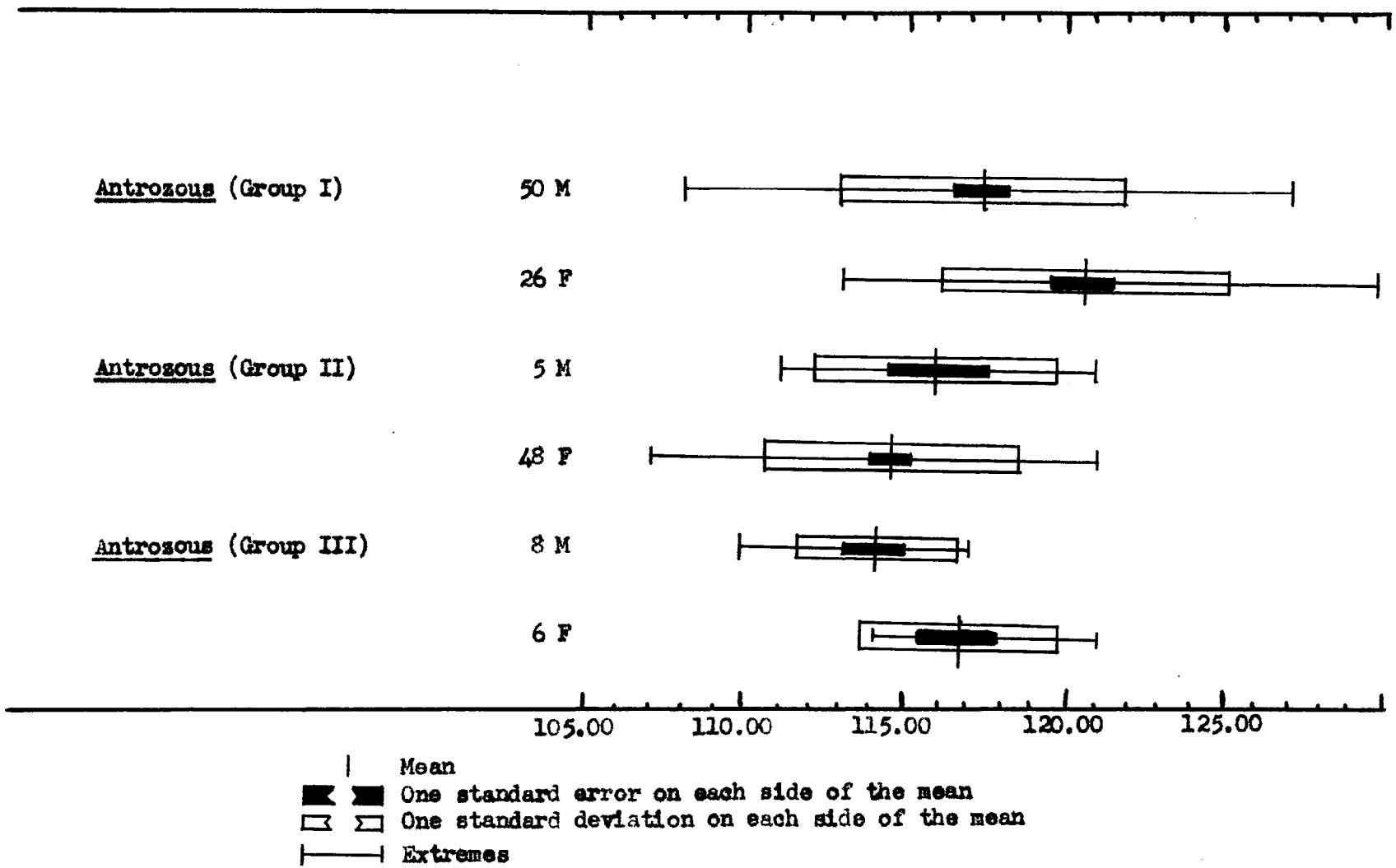

Figure 2. Total length, in millimeters, in forms of Antrozous.

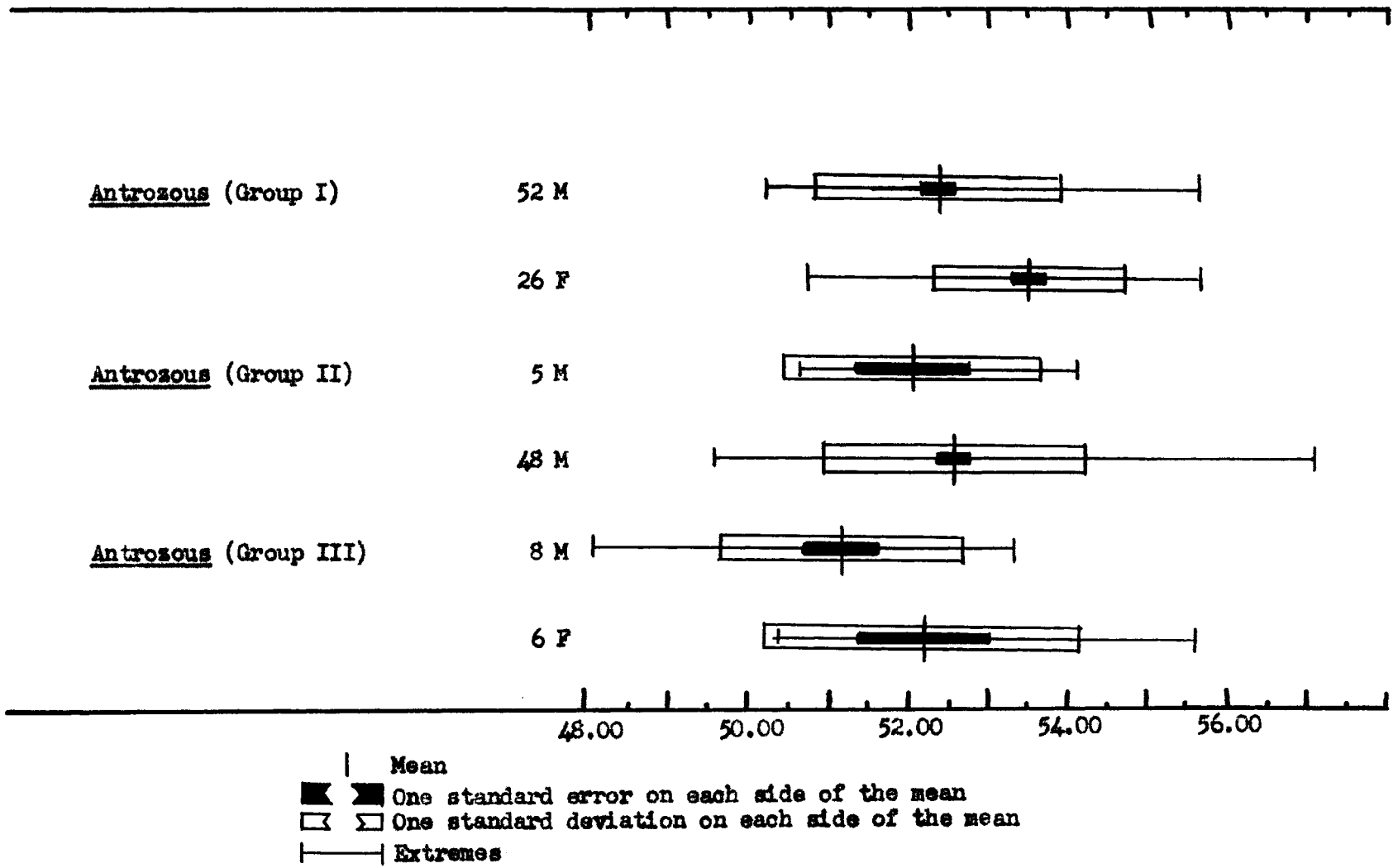

Figure 3. Length, in millimeters, of the forearm in forms of Antrozous.

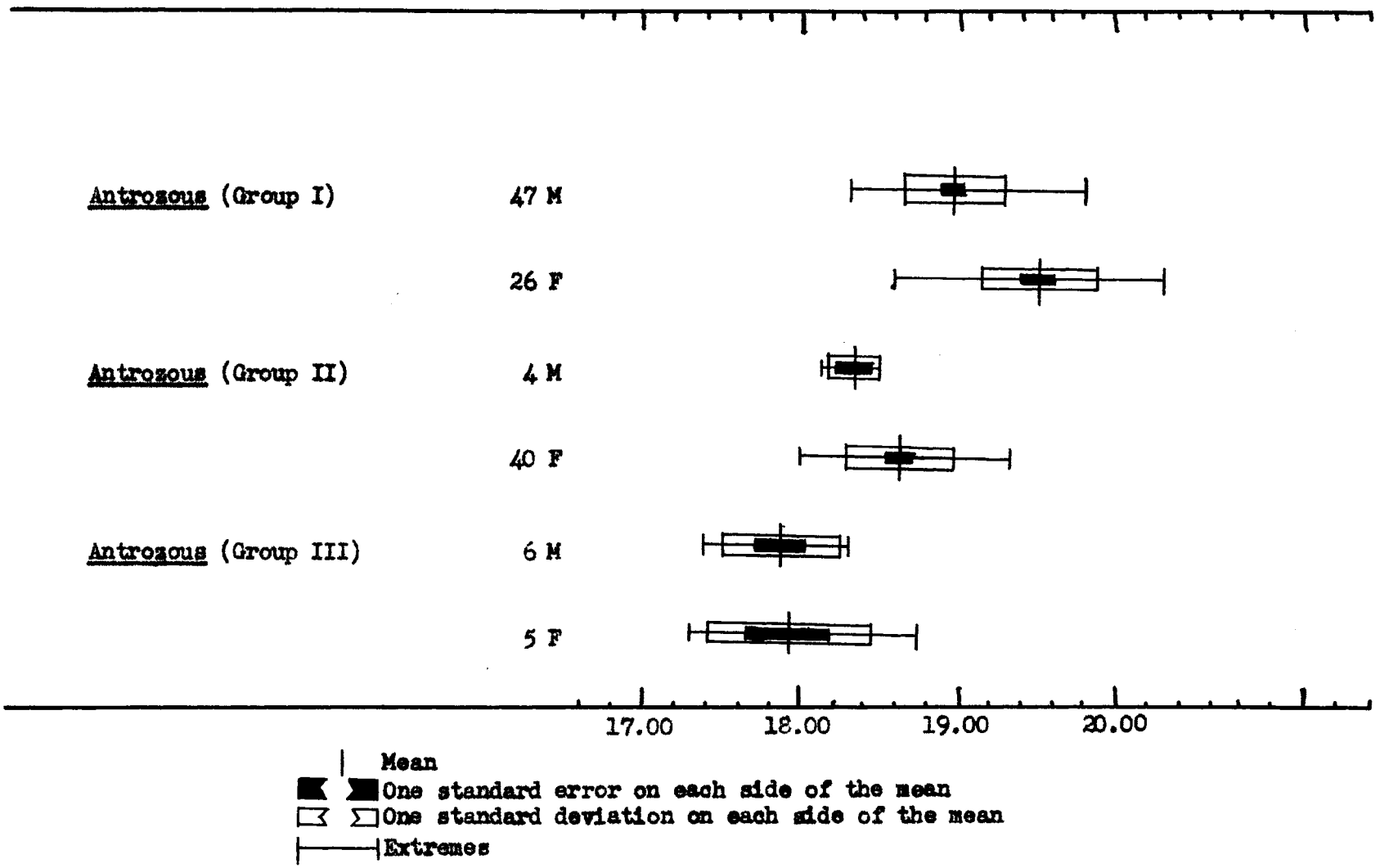

Figure 4. Condylobasal length, in millimeters, in forms of Antrozous.

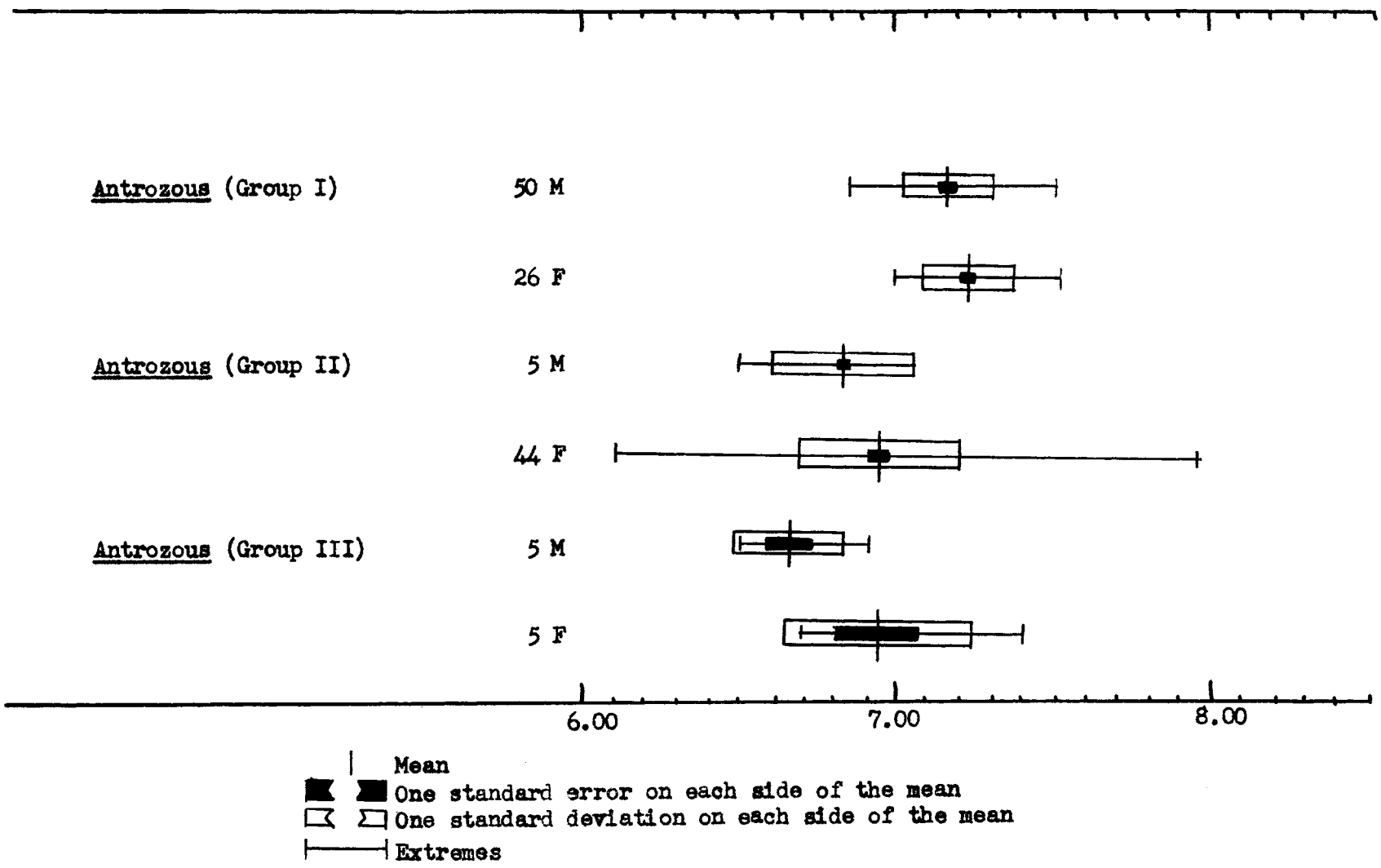

Figure 5. Length, in millimeters, of the maxillary tooth row in forms of Antrozous.

average measurements, as well as one standard error and one standard deviation from the mean, of selected skin and skull measurements were calculated for each group and the results graphically represented in Figures 2, 3, 4, and 5.

Pipistrellus.

Specimens of P. hesperus were grouped according to subspecific categories. The Oklahoma population was arbitrarily assigned subspecific rank (Group IV) and compared with representatives of all other recognized subspecies. Collection sites and geographical groupings have been shown in Figure 6.

Upon determining the forms which the Oklahoma population most closely resembled it was more carefully compared to P. h. santarosae (Group V) and P. h. maximus (Group VI). Measurements of selected skin and skull characters for Groups IV, V, and VI were then treated statistically to determine one standard deviation from the mean. The average and extremes of these measurements, as well as standard errors and standard deviations have been graphically represented in Figures 7, 8, 9, and 10.

Measurements

External measurements other than length of forearm were obtained from the specimen labels attached to the study skins. The measurements were assumed to have been taken by the original collector. Forearm and skull measurements were made by the author using a dial caliper graduated in tenths of a millimeter. Measurements of less than one-tenth of a millimeter were estimated. External measurements were taken of the total

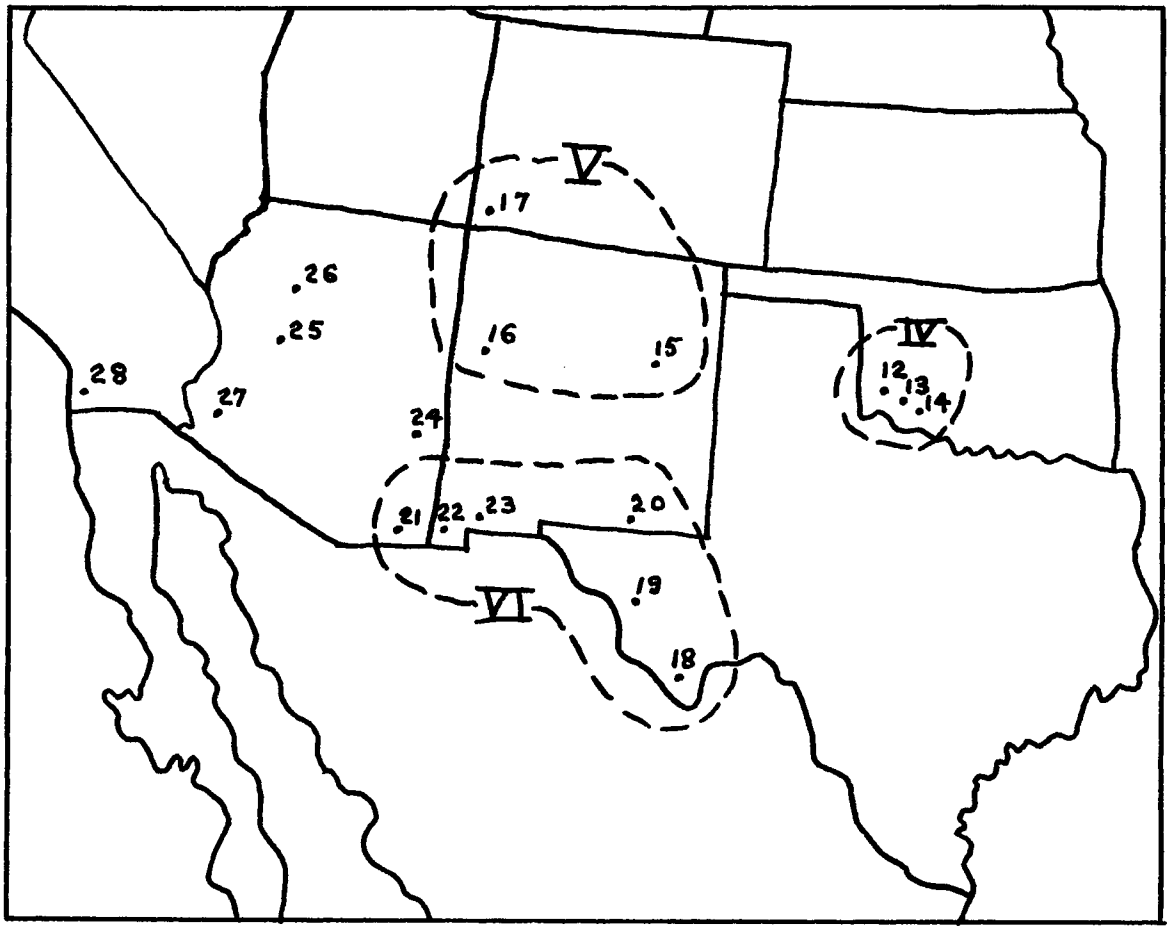

Figure 6. Collection sites (County and State) of specimens of Pipistrellus hesperus.

Legend:

12. Greer Co., Okla.
13. Kiowa Co., Okla.
14. Comanche Co., Okla.
15. Guadalupe Co., New Mex.
16. Valencia Co., New Mex.
17. Montezuma Co., Colo.
18. Brewster Co., Tex.
19. Jeff. Davis Co., Tex.
20. Eddy Co., New Mex.
21. Cochise Co., Ariz.
22. Hidalgo Co., New Mex.
23. Luna Co., New Mex.
24. Graham Co., Ariz.
25. Yavapai Co., Ariz.
26. Coconino Co., Ariz.
27. Yuma Co., Ariz.
28. San Diego Co., Calif.

(Roman numerals, IV, V, and VI, indicate grouping of population samples.)

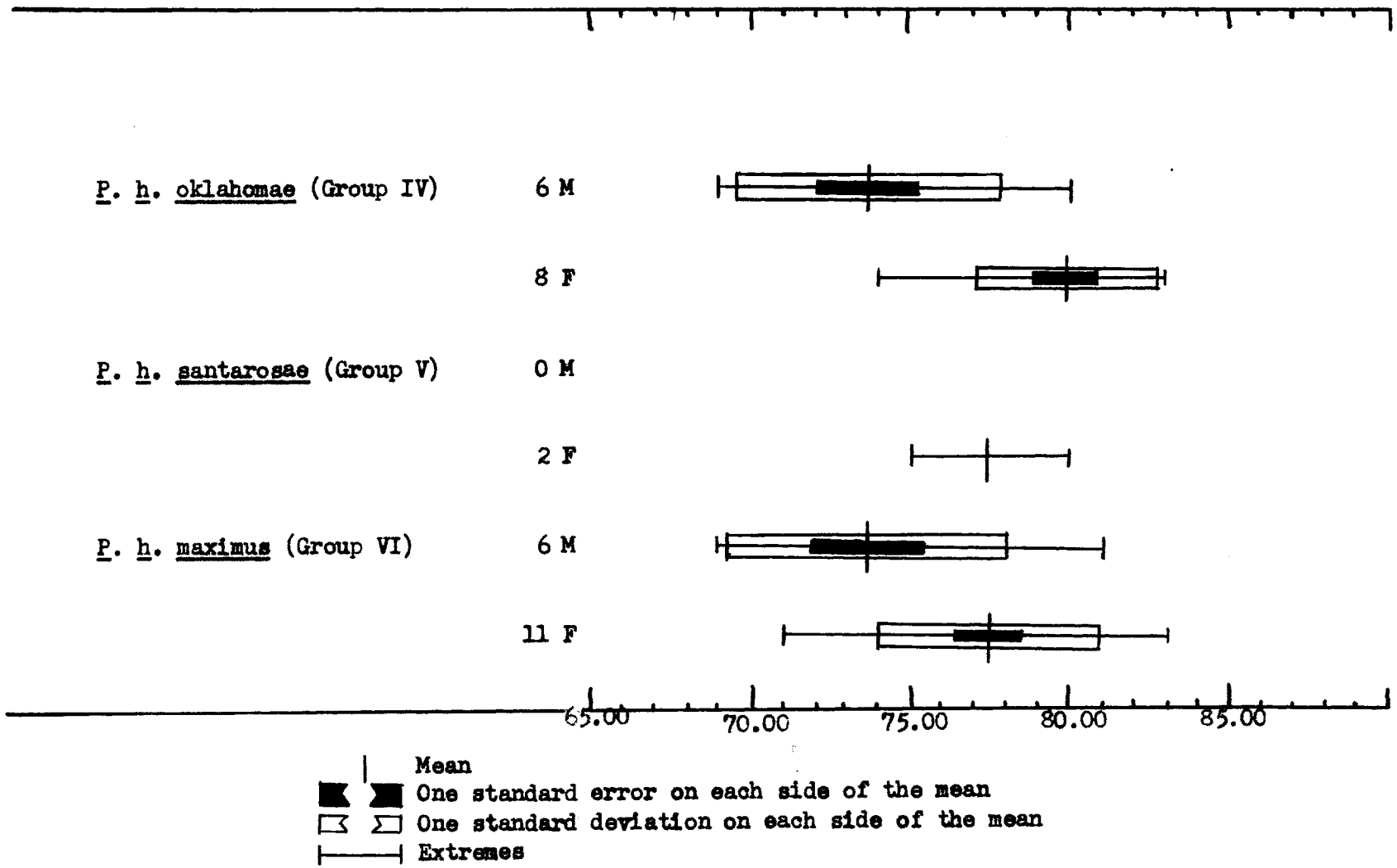

Figure 7. Total length, in millimeters, in forms of Pipistrellus hesperus.

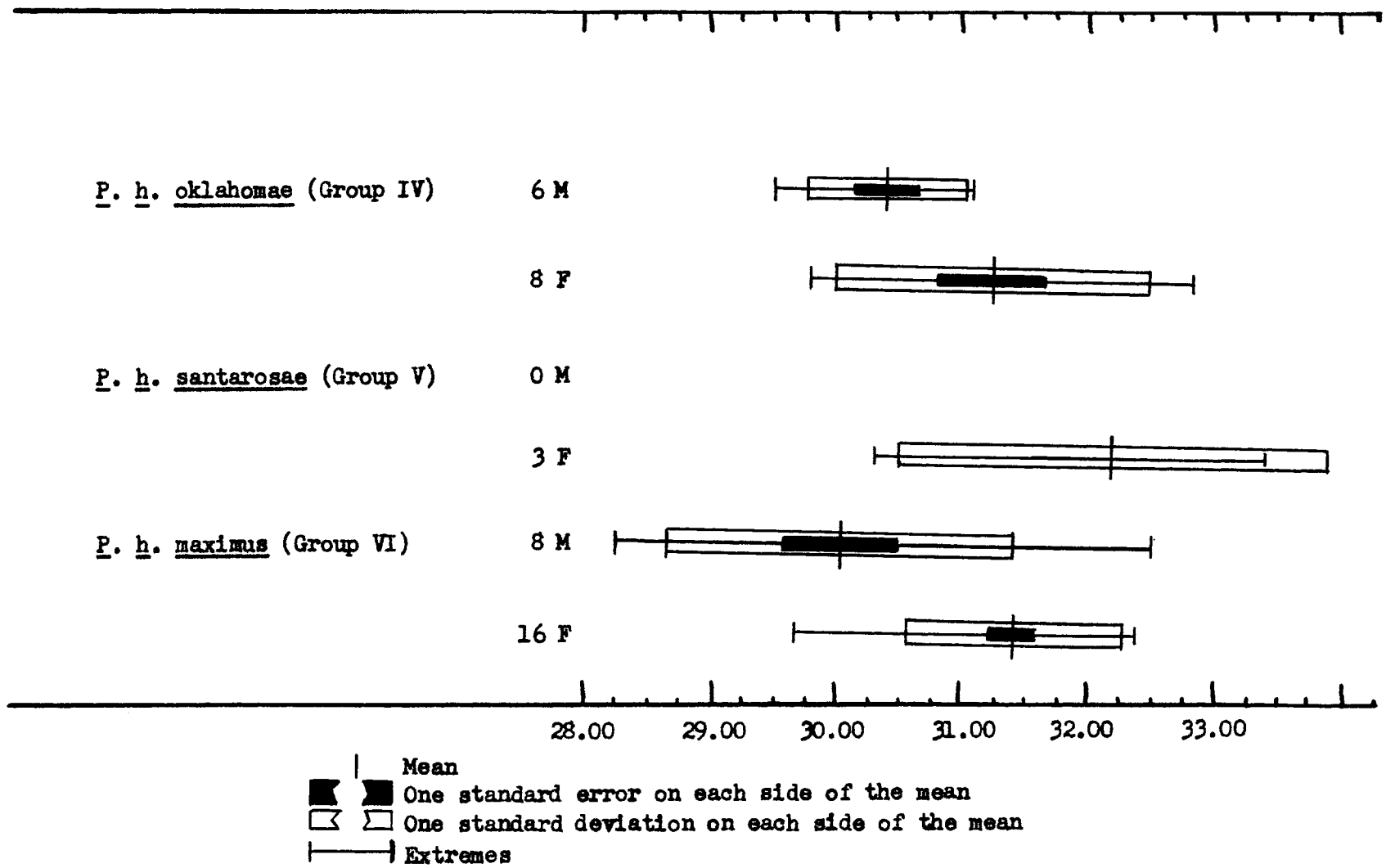

Figure 8. Length, in millimeters, of the forearm in forms of Pipistrellus hesperus.

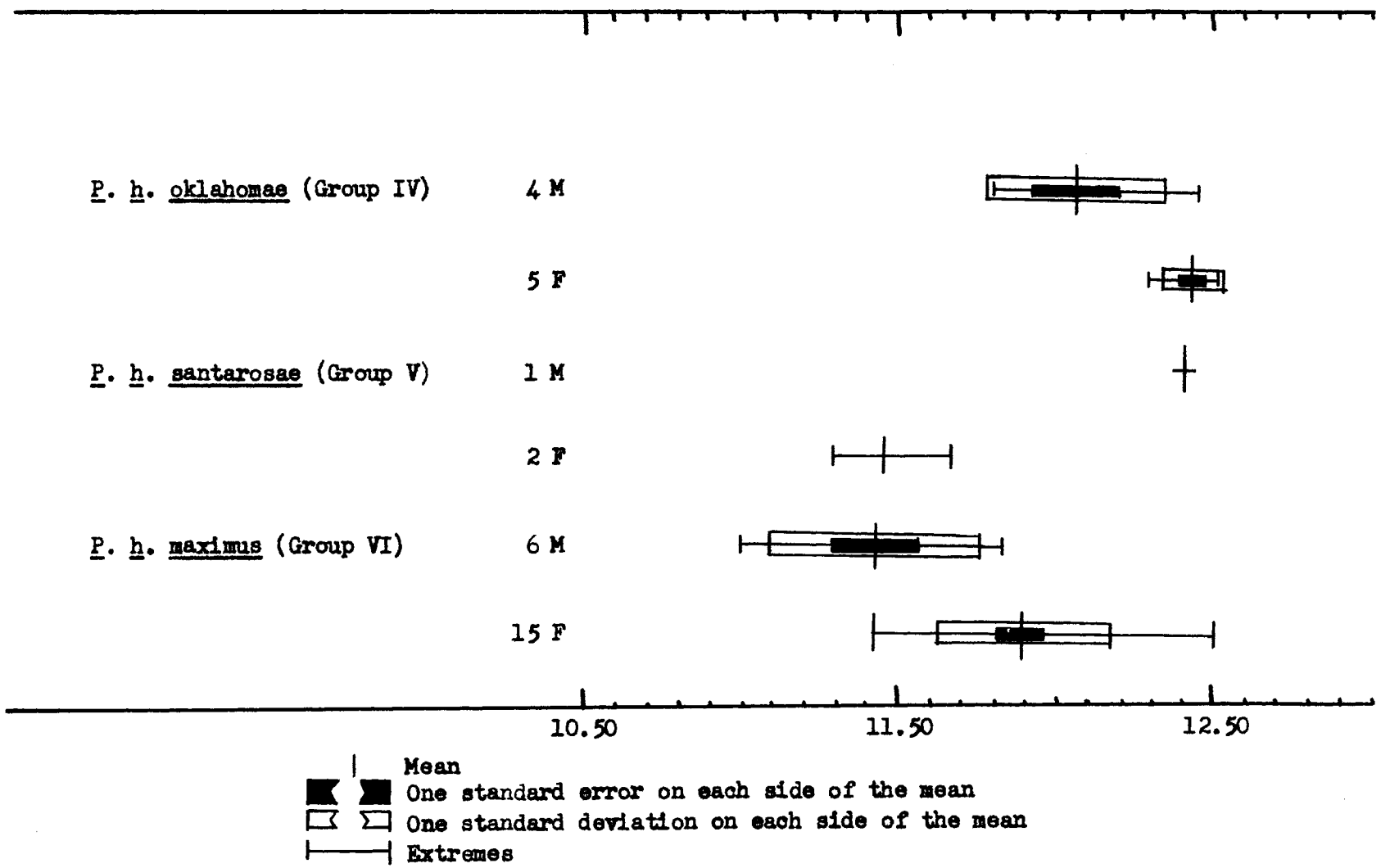

Figure 9. Condylobasal length, in millimeters, in forms of Pipistrellus hesperus.

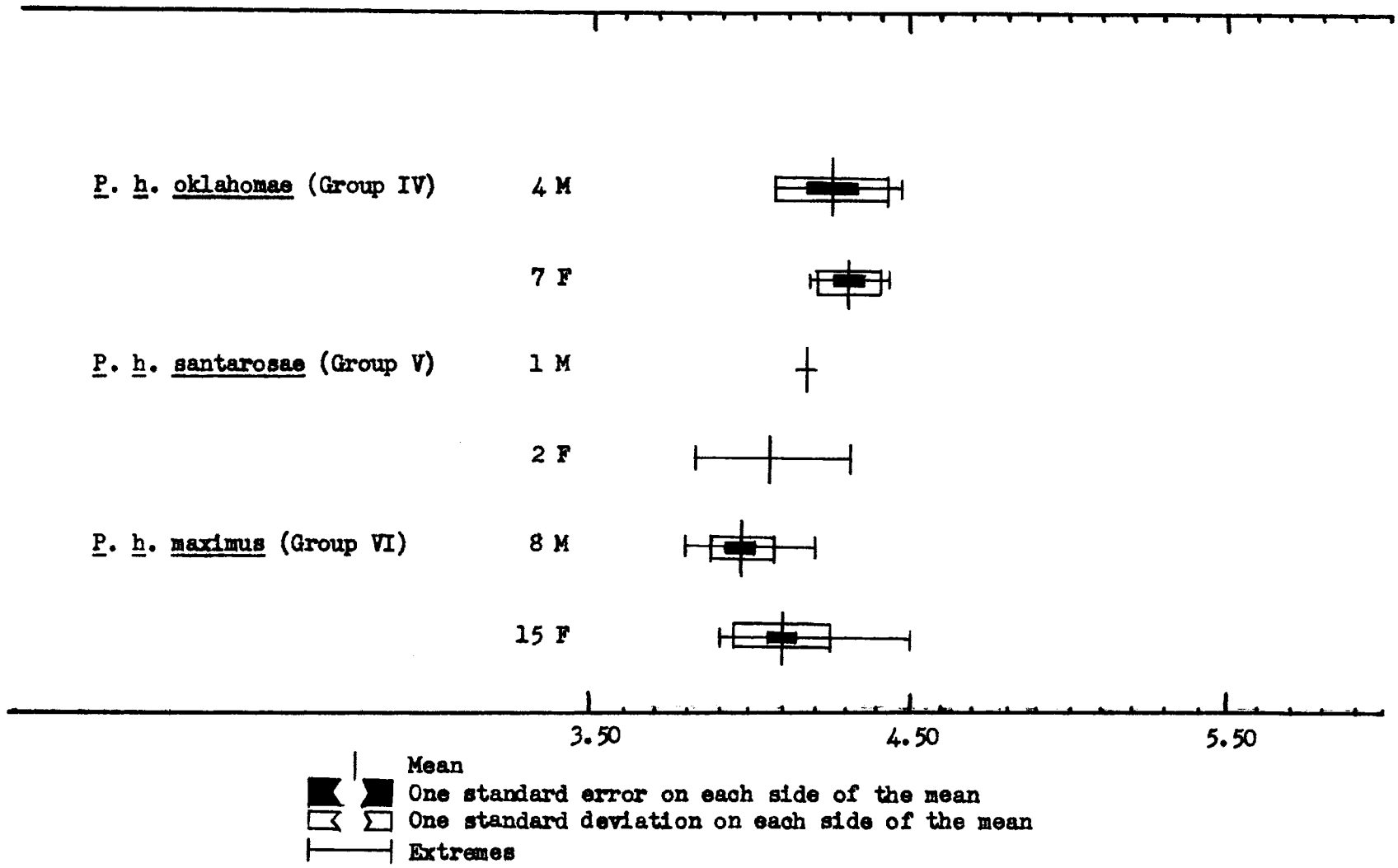

Figure 10. Length, in millimeters, of the maxillary tooth row in forms of Pipistrellus hesperus.

length, tail, hind foot, ear from notch, and tragus. These measurements are well standardized and have been described by Cockrum (1955). Whenever structures were bilaterally symmetrical, measurements of the left side were taken. The forearm was measured as "the length of the bone and covering skin, from the end of the elbow to a shallow but distinct notch on the inside of the wrist which marks the end of the bone" (Ward, Unpublished Thesis).

The following skull measurements were taken:

Total length: greatest distance along the longest axis of the skull, excluding incisors.

Condylobasal length: distance from the anterior edge of the incisive alveolus to the posteriormost margin of the occipital condyle.

Maxillary tooth row: distance from the front face of the canine, excluding cingulum, to the posteriormost point on the last molar.

Zygomatic breadth: greatest distance between the outside margins of the zygomatic arches, taken perpendicular to the long axis of the skull.

Interorbital constriction: width of the interorbital constriction at its narrowest point.

Maxillary breadth at M^3: greatest distance between the outside surfaces of the third molars.

Mastoid breadth: greatest width of the skull across the mastoid bones or processes.

Mandibular tooth row: distance from the front surface of the canine, excluding cingulum, to the posteriormost point on the last molar.

In making color comparisons both Ridgway (1912) and Maerz and

Paul (1930) were used. In this study, capitalized color nomenclature is from Ridgway. Color terms from other sources have not been capitalized.

Measurements of the various samples of both Antrozous and Pipistrellus were treated in the same way. When the measurements had been made they were tabulated according to sex from each locality, and the means for each sex computed for each measurement. Inspection of these data indicated that certain characteristics showed considerable separation of means and might be of diagnostic value. These were studied further, using the coefficient of difference of Mayr, Linsley and Usinger (1953). The Coefficient of Difference, C D, is determined by dividing the sum of the standard deviations into the difference between the means. The method is useful in determining subspecific distinctness, or lack of it, where populations have overlapping characters. Where

C D = Coefficient of Difference

M = Mean

S D = Standard Deviation

a and b = Individual populations respectively

$$C\ D = \frac{M_b - M_a}{S\ D_a + S\ D_b}$$

The conventional level of subspecific difference is where the C D equals 1.28. Populations are considered to be subspecifically distinct if the C D value between them is 1.28 or higher, and to be within one subspecies if the C D value between them is lower than 1.28. The authors further stated that "the coefficient of difference is a useful guide . . . but all borderline cases should be evaluated in the light of additional information." Geological isolation is an example of a factor which they suggest may influence final decisions concerning the taxonomic status

of a population for which the C D value approximates but does not equal 1.28.

To test further the significance of the apparent differences between the samples, the means of the measurements of the three groups were compared. The standard error was calculated for each of the measurements of each sex.

$$S\ E\ m = \frac{S\ D}{\sqrt{N}}$$

S D = Standard Deviation

N = number of specimens

Mayr, Linsley and Usinger (1930) stated that two samples are probably different statistically if the difference between the means is twice the sum of the standard errors and almost certainly so if the same value is three times as great.

Each of the characters treated in this way was also graphically tabulated showing means, extremes, one standard error and one standard deviation on either side of the mean (Figures 2 - 5 and 7 - 10).

In each of the two genera studied, the measurements analyzed for C D value and standard error were total length, length of forearm, condylobasal length, and length of maxillary tooth row.

DISCUSSION

Comparisons between Samples of *Antrozous*

The taxonomic problem in the genus *Antrozous* has resolved primarily into one involving the relationship between groups I and II, and the relationships of both of these to group III.

In the original description of *A. bunkeri*, no adult males were examined. This study has shown that there is a distinct difference in measurements between the two sexes, which might lead to misleading conclusions if females of one form were to be compared with males or a mixed sample of another.

The C D values derived from measurements taken from the three population groups have been presented in Tables I, II, and III.

TABLE I

COEFFICIENT OF DIFFERENCE VALUES BETWEEN GROUPS I AND II

	Males		Females	
Measurements	C D value	Joint non-overlap (%)	C D value	Joint non-overlap (%)
Condylobasal length	1.16	88	1.22	89
Maxillary tooth row	0.94	83	0.70	76
Total body length	0.17	*	0.73	77
Forearm	0.11	*	0.31	*

*Less than 75 per cent joint nonoverlap.

TABLE II

COEFFICIENT OF DIFFERENCE VALUES BETWEEN GROUPS II AND III

	Males		Females	
Measurements	C D value	Joint non-overlap (%)	C D value	Joint non-overlap (%)
Condylobasal length	0.85	80	0.76	78
Mixillary tooth row	0.44	*	--	--
Total body length	0.30	*	0.08	*
Forearm	0.29	*	0.10	*

*Less than 75 per cent joint nonoverlap.

TABLE III

COEFFICIENT OF DIFFERENCE VALUES BETWEEN GROUPS I AND III

	Males		Females	
Measurements	C D value	Joint non-overlap (%)	C D value	Joint non-overlap (%)
Condylobasal length	1.48	93	1.72	96
Maxillary tooth row	1.65	95	0.64	*
Total body length	0.48	*	0.54	*
Forearm	0.41	*	0.40	*

*Less than 75 per cent joint nonoverlap.

According to Mayr, Linsley and Usinger (1953), a C D value of 1.28 indicates that there is 90 per cent of joint nonoverlap between two populations which have partially overlapping measurements. C D values of less than 0.67 (75 per cent joint nonoverlap) are obviously considered insignificant of subspecific distinctness.

Variation in condylobasal length was the most useful character for distinguishing between Groups I, II, and III. Measurements of the maxillary tooth row, total body length, and length of forearm had greater overlap and were not useful as distinguishing characters (Tables I, II, and III). This similarity between measurements indicates a closer relationship between the three groups than was previously recognized.

When the condylobasal lengths of males of Group II were compared with those of males of Group III, the C D value was less than the conventional level of subspecific distinctness. The same was true when females of the two groups were compared. The two groups, therefore, do not deserve to be separated subspecifically. In other words, on the basis of condylobasal length the Cimarron County group belongs to the subspecies A. p. pallidus.

To further test the status of Group II, measurements of condylobasal length were compared with Group I. When the males of Group I were compared with the males of Group II, the C D value was 1.16. When females of the two groups were compared, the C D value was 1.22 (Table I). These C D values are very close to, but not quite in excess of 1.28. Similar values between Groups II and III, however, are considerably less than 1.28 (Table II). The C D values between Groups I and III, for both males and females, greatly exceed 1.28 (Table III).

The standard errors derived from measurements taken from the three population groups have been presented in Tables IV, V, and VI.

Comparison of the standard errors shows significant differences between the measurements of the populations. Using condylobasal length as the most useful character for distinction, Group I is different statistically from Group II and Group III (Tables IV and V). A similar

TABLE IV

COMPARISON OF THE MEANS AND STANDARD ERRORS
BETWEEN GROUPS I AND II

	Total length			Length of forearm	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	1.42	4.58	Males	0.34	1.86
Females	6.20	2.90*	Females	0.90	0.96

	Maxillary tooth row			Condylobasal length	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	0.34	0.24	Males	0.59	0.26*
Females	0.28	0.14*	Females	0.90	0.26*

*The difference between the means is more than three times the sum of the standard errors.

TABLE V

COMPARISON OF THE MEANS AND STANDARD ERRORS
BETWEEN GROUPS II AND III

	Total length			Length of forearm	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	1.88	5.08	Males	0.90	2.50
Females	2.15	3.64	Females	0.38	2.10

	Maxillary tooth row			Condylobasal length	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	0.17	0.34	Males	0.46	0.48
Females	0.00	0.34	Females	0.65	0.56

TABLE VI

COMPARISON OF THE MEANS AND STANDARD ERRORS
BETWEEN GROUPS I AND III

	Total length			Length of forearm	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	3.30	3.00	Males	1.24	1.50
Females	4.05	4.26	Females	1.38	2.10
	Maxillary tooth row			**Condylobasal length**	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	0.51	0.20*	Males	1.05	0.40*
Females	0.28	0.32	Females	1.55	0.60*

*The difference between the means is more than three times the sum of the standard errors.

comparison between females of Groups II and III shows the difference between the means to be twice the sum of the standard errors but not three times as great. The same value for males is less than twice as great. Comparison of other measurements between the two groups are all less than twice as great for both sexes (Table VI). Group II, therefore, is not different statistically from Group III.

In color, A. bunkeri and A. pallidus are very similar. The collar in the nuchal region, as described by Hibbard (1934), is present in specimens of both populations. The same is true of the light area in the interscapular region. Since the normal depression of the skin in the interscapular region of living bats is not present in dried study skins, the light area may be an artifact resulting from the method of preparation.

It is true, however, that the hairs of the interscapular region have only the extreme tips colored broccoli brown as Hibbard described. If in dried skins the hairs surrounding the scapular region are brushed upward the light area often disappears and there is a lessening in intensity of color of the collar. The ears may be dark, or light, in either population. Although there may be slight differences of color in the pelage of the two forms, there seem to be no greater differences between populations than between individuals from the same locality.

The geographic location of Group II is only approximately 250 miles from that of Group I, and approximately 350 miles from Group III. It might at first appear that the Cimarron County group, because of its geographic position, should be considered within the range of A. bunkeri. This is not actually true. The 250 miles intervening between the known range of A. bunkeri and the area in Cimarron County where Group II was secured is virtually featureless prairie, completely devoid of rocky prominences and canyons which seem to be the preferred habitat of this species. Cimarron County, on the other hand, is cleft with rocky canyons in the area where these bats have been found, and the same terrain continues virtually unchanged westward to the Rocky Mountains. The Oklahoma area is, therefore, an eastward extension of the suitable habitat for this species, and any apparent lack of records of occurrence from northern and eastern New Mexico may reasonably be attributed to neglect on the part of collectors.

Within the genus there is a clinal variation with slightly increasing measurements from west to east. The limits of suitable habitat have isolated A. bunkeri from other members of the genus.

The overlapping measurements and similarity in coloration of A. bunkeri and A. pallidus do not indicate validity of A. bunkeri as a full species. The differences which do exist are on a level usually considered subspecific, and A. bunkeri, therefore, should be reduced from specific to subspecific rank and more properly designated as Antrozous pallidus bunkeri Hibbard.

Status of Pipistrellus hesperus in Oklahoma

A distinct form of Pipistrellus hesperus has been found as an isolated population in Greer, Kiowa, and Comanche Counties, Oklahoma. In this study the Oklahoma form has been compared with specimens of all races of the species, except P. h. potosinus Dalquest.

P. h. potosinus is a subspecies which to date has been collected only from the Mexican state of San Luis Potosi. Dalquest (1953) described it as having dull brown pelage, with average measurements in millimeters for males and females, respectively, as follows: total length, 74, 80; condylobasal length, 12.2, 12.3; length of maxillary tooth row, 5.1, 5.2. Although the total and condylobasal lengths in Oklahoma specimens resemble those of P. h. potosinus, the maxillary tooth row measures considerably less (4.24, 4.30 in males and females respectively). The Oklahoma form has a bright reddish-brown pelage.

The Oklahoma form was compared with specimens of all five existing subspecies of P. hesperus from the United States. Upon comparison, the measurements of the Oklahoma form (Group IV) were found most closely to resemble P. h. santarosae (Group V) and P. h. maximus (Group VI). Groups V and VI are also nearest, geographically, to Group IV. Because of very obvious differences in size and coloration from the Oklahoma

form, P. h. hesperus, P. h. australis, and P. h. merriami, were not investigated further.

Average and extreme measurements, one standard error and one standard deviation on each side of the mean were calculated for the total body length, length of forearm, condylobasal length, and length of maxillary tooth row. The results are presented in Figures 7, 8, 9, and 10. Because of the great amount of overlap, the characters were further tested for C D values in the same way that was used for Antrozous (Table VII).

TABLE VII

COEFFICIENT OF DIFFERENCE VALUES BETWEEN GROUPS IV AND VI

	Males		Females	
Measurements	C D value	Joint non-overlap (%)	C D value	Joint non-overlap (%)
Condylobasal length	1.07	86	1.45	93
Maxillary tooth row	0.96	83	0.83	80
Total body length	—	—	0.29	*
Forearm	0.19	*	0.06	*

*Less than 75 per cent joint nonoverlap.

Variation in condylobasal length was the most distinguishing character between Groups IV and VI. Measurements of the maxillary tooth row, total body length, and forearm had greater overlap and were not useful as distinguishing characters (Table VII). Because of the lack of sufficient specimens, it was not possible to compare C D values with P. h. santarosae (Group V).

When the condylobasal lengths of males of Group IV were compared with the males of Group VI, the C D value was 1.07. When females of

the two groups were compared, the C D value was 1.45. The C D value for males was somewhat less than 1.28, but the same value for females was considerably more than 1.28.

The standard errors derived from measurements taken from the two population groups have been presented in Table VIII.

TABLE VIII

COMPARISON OF THE MEANS AND STANDARD ERRORS BETWEEN GROUPS IV AND VI

	Total length			Length of forearm	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	0.00	6.88	Males	0.38	1.46
Females	1.90	4.28	Females	0.12	1.30
	Maxillary tooth row			**Condylobasal length**	
	$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$		$(M_1 - M_2)$	$2(S E m_1 + S E m_2)$
Males	0.26	0.24	Males	0.64	0.54
Females	0.20	0.14	Females	0.55	0.24*

*The difference between the means is more than three times the sum of the standard errors.

Comparison of the standard errors shows significant differences between the measurements of Groups IV and VI. When measurements of the condylobasal length and length of the maxillary tooth row are compared, the difference between the means is twice the sum of the standard errors for both sexes. The value for condylobasal length is three times as great for females (Table VIII). Group IV, therefore, is different statistically from Group VI.

The Oklahoma population is best differentiated from its neighbors on the basis of color. A detailed description of coloration for the various subspecies of P. hesperus has been given by Hall and Dalquest (1950) in their synopsis of the genus. Briefly they are:

P. h. hesperus between Drab Gray and Smoke Gray, dorsally; between Smoke Gray and Pale Smoke Gray, ventrally.

P. h. merriami Buffy Brown to Army Brown, dorsally; Wood Brown to Buffy Brown, ventrally.

P. h. australis between Cinnamon Drab and Drab, dorsally; Wood Brown to Light Drab, ventrally.

P. h. maximus between Smoke Gray and Pale Drab.

P. h. santarosae between Buffy Brown and Wood Brown.

The color of the Oklahoma form may be described as follows: dorsum between Tawny-Olive and Isabella Color; venter near Cinnamon-Buff; head in region of ears Honey Yellow; hairs on body distinctly bicolor, intense black basally; membranes Blackish Brown. According to Maerz and Paul (1930) the following plate numbers may be applied: dorsum, Plate 13, between D-10 and K-7; venter, Plate 14, between I-10 and L-8; head in region of ears, Plate 12, between A-11 and J-6.

There is considerable geographic separation between the Oklahoma population and the other races of the species. Approximately 350 miles of apparently unsuitable habitat separates the Oklahoma population from its nearest related form, P. h. santarosae. The Oklahoma population constitutes the easternmost extension of the range of the species.

Although the C D value for condylobasal length in males is slightly less than 1.28, the same value for females exceeds this value (Table VII). These values, therefore, approach separability as outlined by Mayr,

Linsley and Usinger (1930). On the basis of wide geographic separation and marked differences in coloration, it seems that the Oklahoma population is sufficiently distinct from the other forms of the species to warrant recognition, and may be known as

Pipistrellus hesperus oklahomae new subspecies

Type. Adult female (skin and skull), Oklahoma State University Museum of Zoology No. 2863; from the north side of Granite Mountain, Granite, Greer County, Oklahoma; collected by Bryan P. Glass, June 2, 1955; original number, 1634. (The type is to be deposited permanently in the Biological Survey Collections of the United States National Museum.)

Distribution. Greer, Kiowa, and Comanche Counties, Oklahoma, in the granitic Wichita Mountains.

Diagnosis. Size large for the species; females slightly larger than males. Total body length averaging 73.83 in males, 79.62 in females; length of forearm averaging 30.40 in males, 31.24 in females. Skull with length of maxillary tooth row averaging 4.24 in males, 4.30 in females; condylobasal length averaging 12.08 in males, 12.44 in females. Color reddish-brown, brighter on head, lighter beneath.

Measurements (in mm.). Type: total length, 83; tail, 32; hind foot, 7; ear from notch, 13; tragus, 7; forearm, 32.80; total length of skull, 12.80; condylobasal length, 12.52; maxillary tooth row, 4.21; zygomatic breadth, 8.21; interorbital constriction, 3.50; maxillary breadth at M^3, 5.56; mastoid breadth, 6.82; mandibular tooth row, 4.70.

Average and extreme cranial measurements (in mm.) for males, five from Greer Co. and one from Kiowa Co., are: total length of skull, 12.74 (12.60 - 12.93); condylobasal length, 12.08 (11.79 - 12.45); maxillary tooth row, 4.24 (4.07 - 4.48); zygomatic breadth, 8.06 (7.96 -

8.15); interorbital constriction, 3.56 (3.43 - 3.65); maxillary breadth at M^3, 5.33 (5.14 - 5.50); mastoid breadth, 6.72 (6.60 - 6.80); mandibular tooth row, 4.41 (4.30 - 4.49). Similar measurements for females, eight from Greer Co. and one from Comanche Co., are: total length of skull, 12.79 (12.50 - 12.95); condylobasal length, 12.44 (12.29 - 12.52); maxillary tooth row, 4.30 (4.19 - 4.44); zygomatic breadth, 8.38 (8.21 - 8.50); interorbital constriction, 3.66 (3.39 - 3.81); maxillary breadth at M^3, 5.47 (5.30 - 5.61); mastoid breadth, 6.84 (6.79 - 6.96); mandibular tooth row, 4.60 (4.46 - 4.71).

Color. Dorsum between Tawny-Olive and Isabella Color; venter near Cinnamon-Buff; head in region of ears Honey Yellow; hairs on body distinctly bicolor, intense black basally; membranes Blackish Brown. Young: dorsum Buffy Olive; venter Sudan - slightly lighter than dorsum; head sometimes slightly brighter than dorsum; hairs on body have poor line of demarcation between root and tip regions, dull Black in root region; membranes Blackish Brown.

Comparisons. Compared with a series of 48 adult specimens of the five different forms of the species, the Oklahoma series is distinctly more reddish and darker. The Oklahoma form is more brown than P. h. hesperus and P. h. maximus (which are gray), and more reddish than P. h. merriami, P. h. australis, and P. h. santarosae. The Oklahoma form is darker than P. h. santarosae, which it most closely resembles in color.

Specimens Examined. Pipistrellus hesperus oklahomae: from type locality, (Adults) four males and five females, (Young) one male; from other localities (Greer, Kiowa, and Comanche Counties), (Adults) two males and four females, (Young) two males and four females. P. h. santarosae: (Adults) one male and three females. P. h. maximus: (Adults) nine

males and eighteen females, (Young) two males and one female. P. h. australis: (Adults) two males, (Young) one male and four females. P. h. hesperus: (Adults) twelve males and two females, (Young) one male. P. h. merriami: (Adults) one male, (Young) one male.

Remarks. Two specimens of the type series will be deposited in each of the following museums: Biological Survey Collections (in addition to the type); University of Michigan Museum of Zoology; University of Kansas Museum of Natural History. The remainder will remain in the Oklahoma State University Museum of Zoology.

SUMMARY

1. The study was initiated in order to determine the taxonomic status of two vespertilionid bats (Antrozous and Pipistrellus) which occur as isolated populations in western Oklahoma.

2. In addition, it was found necessary to establish the validity of Antrozous bunkeri, a species previously found only in Barber County, Kansas.

3. A total of 291 bats were examined; 180 were from the Oklahoma State University collections, and 111 were borrowed. A complete list of the specimens examined appears in the appendix.

4. Specimens of Antrozous collected from areas of relatively close geographical proximity were grouped together (Groups I, II, and III). Specimens of P. hesperus were grouped according to subspecific status (Groups IV, V, and VI). This was done in order to facilitate the analysis of data.

5. Maps are included to show collection sites (County and State) and grouping of population samples (Figures 1 and 6).

6. The population sample groups were separated by sex, and each treated statistically. Average and extreme measurements, as well as standard errors and standard deviations, for selected measurements, are presented in Figures 2 - 5 and 7 - 10.

7. Standard error and coefficient of difference were used, when populations had overlapping measurements, to test subspecific distinctness.

8. The population from Cimarron County, Oklahoma, was found to be Antrozous pallidus pallidus.

9. The results of the study indicate that A. bunkeri should be reduced from specific to subspecific rank and more properly designated as Antrozous pallidus bunkeri Hibbard.

10. A new subspecies, Pipistrellus hesperus oklahomae, is described from Greer, Kiowa, and Comanche Counties, Oklahoma.

11. The Oklahoma collections of A. p. pallidus and A. p. bunkeri, constitute the most eastern distribution record for the genus.

12. The Oklahoma collections of the new subspecies, P. h. oklahomae, constitute the most eastern distribution record for the species.

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APPENDIX

SPECIMENS EXAMINED

Antrozous (Population I).

KANSAS: Barber County: Mays Cave, 54 (32 Males, 22 Females) (OAM); Near Sun City, 6 (1 Male, 5 Females) (KU).

OKLAHOMA: Woodward County: Alabaster Caverns State Park, 24 (22 Males, 2 Females) (OAM).

Antrozous (Population II).

OKLAHOMA: Cimarron County: N. side Black Mesa, 6 mi. N. Kenton, 2 (1 Male, 1 Female) (OAM); Carrizzo Creek, 6 mi. N. Kenton, 3 (1 Male, 2 Females) (OAM); Asa Jones' barn, near Kenton, 5 (1 Male, 4 Females) (OAM); Pigeon Cave, 2 mi. E. and 1/2 mi. N. Kenton, 40 (3 Males, 37 Females) (OAM); Tesequite Canyon Cave, 3 mi. E. and 7 mi. S. Kenton, 21 (1 Male, 20 Females) (OAM).

Antrozous (Population III).

ARIZONA: Graham County: C N Ranch, 2 (1 Male, 1 Female) (IMNH); 6 mi. S. S. W. Pima, 3 (3 Males) (IMNH); Stockton Pass, 1 (1 Male) (IMNH).

NEW MEXICO: Dona Ana County: Las Cruces, 4 (3 Males, 1 Female) (USNM). Eddy County: Rattlesnake Spring, 2 (2 Males) (Collections of Carlsbad National Park). Grant County: Carlsbad Eddy, 4 (3 Males, 1 Female) (USNM); Silver City, 2 (2 Females) (USNM). Otero County: Garage at White Sands National Monument, 1 (1 Female) (IMNH).

TEXAS: Hudspeth County: Fort Hancock, 3 (1 Male, 2 Females) (USNM).

Antrozous (Miscellaneous).

ARIZONA: Mohave County: Fort Mohave, 1 (1 Female) (CU).

COLORADO: Moffatt County: Yampa River, Dinosaur National Monument, 1 (1 Male) (CU).

OKLAHOMA: Greer County: Quarry Pond, S. side Granite Mt., 3 (3 Males) (OAM).

Pipistrellus hesperus oklahomae (Population IV).

OKLAHOMA: Comanche County: East tower of Chapel, Easter Pageant Grounds, Wichita Mts. Wildlife Refuge, 1 (1 Female) (OAM); W. Cache Creek at S. Refuge boundary, 1 (1 Male) (OAM). Greer County: Custer Cave near Monument Works, 2 (2 Females) (OAM); N. side Granite Mt., 10 (5 Males, 5 Females) (OAM); Quarry Pond, S. Side Granite Mt., 3 (1 Male, 2 Females) (OAM); S. E. Corner Quartz Mt. State Park, 1 (1 Male) (OAM). Kiowa County: N. side Radziminski Mt., 4 (1 Male, 3 Females) (OAM).

Pipistrellus hesperus santarosae (Population V).

COLORADO: Montezuma County: Ashabaugh's Ranch, 1 (1 Female) (USNM).

NEW MEXICO: Eddy County: Walnut Canyon, 1 (1 Female) (Collections of Carlsbad National Park). Guadalupe County: Santa Rosa, 2 (1 Male, 1 Female) (USNM). Valencia County: Laguna, 1 (1 Female) (USNM).

Pipistrellus hesperus maximus (Population VI).

ARIZONA: Cochise County: Carr Canyon, 1 (1 Female) (IMNH); Golden Canyon, 1 (1 Female) (IMNH); Miller Canyon, 6 (4 Males, 2 Females) (IMNH); Mouth of Brown Canyon, 1 (1 Male) (IMNH).

NEW MEXICO: Eddy County: Carlsbad Cave, 2 (2 Females) (USNM); Walnut Canyon, 2 (2 Females) (Collections of Carlsbad Caverns National

Park). Hidalgo County: Animas Valley, 1 (1 Male) (USNM); Dog Spring, 5 (1 Male, 4 Females) (USNM); Guadalupe Canyon, 3 (3 Females) (USNM). Luna County: Florida Mts., 1 (1 Male) (USNM).

TEXAS: Brewster County: Alpine, 1 (1 Female) (USNM); Boquillas, 1 (1 Female) (USNM); Marathon, 3 (3 Females) (USNM). Jefferson Davis County: Davis Mts., 4 (3 Males, 1 Female) (USNM).

Pipistrellus hesperus australis.

ARIZONA: Graham County: 1 mi. E. Fort Grant, 3 (2 Males, 1 Female) (IMNH); Lebanon Res. #2, 3 (3 Females) (IMNH); Marijilda Camp Ground, 1 (1 Male) (IMNH).

Pipistrellus hesperus hesperus.

ARIZONA: Coconino County: Route #64, S. E. boundary Grand Canyon National Park, 1 (1 Male) (OAM); S. E. boundary Grand Canyon National Park, 4 (3 Males, 1 Female) (IMNH). Yavapai County: Camp Verde, 2 (2 Males) (IMNH); 1 mi. W. Camp Verde, 2 (2 Males) (IMNH). Yuma County: 15 mi. S. and 9 mi. W. Hope, 4 (4 Males) (IMNH); 4 mi. W. Yuma, 2 (1 Male, 1 Female) (OAM).

Pipistrellus hesperus merriami.

CALIFORNIA: San Diego County: Agua Caliente Spring, 2 (2 Males) (OAM).

VITA

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Master of Science

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