COMPARATIVE POST-NATAL GROWTH IN COTTON RATS (GENUS SIGMODON)

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JORGE V. JIMENEZ JIMENEZ
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Jorge V. Jiménez-Jiménez

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ABSTRACT

COMPARATIVE POST-NATAL GROWTH IN COTTON RATS (GENUS SIGMODON)

By

Jorge V. Jiménez Jiménez

A comparative study of five species of cotton rats was made to determine similarities and differences in external and cranial morphology. These animals (a total of 610 individuals) were descendants of wild caught cotton rats from different localities of Mexico.

The growth rate of the body dimensions can be divided into three periods: From one to 40 days when there is a maximum increase in length for all the body dimensions; from 41 to 100 days when there is a moderate increase; and from 101 to adulthood (200-400 days) when there is practically no growth.

The skull of the cotton rat presents two well-marked patterns of growth (in the age periods of 1-100 days and 101 days-adulthood). At birth, the cotton rat skull is egg-shaped. During the first 20 days of post-natal life the skull expands rapidly in breadth and height. After 20 days, the skull begins to lengthen more rapidly changing the shape from a rounded and short structure at birth to an elongated structure characteristic of the adult cotton rat.

An aging formula was developed using nine (of 21) measurements taken. This formula may help, associated with other aging methods, to age individual wild-taken cotton rats.

Significant morphological differences were found when progeny of intersubspecific crosses were compared with their parent subspecies.

In comparing the growth rates of the population samples of the five species of cotton rats, the species can be divided into three groups. Sigmodon hispidus was represented by a population sample having large dimensions and was the largest cotton rat studied. Sigmodon alleni and S.fulviventer were smaller and showed similar growth rates. Sigmodon leucotis and S.ochrognathus were smallest and also showed a similar pattern of growth. The differences found indicates that S.leucotis and S.ochrognathus are perhaps most remote from the supposed parent stock (presumably resembling S.hispidus). Sigmodon alleni and S.fulviventer, on the other hand, appear close to S.hispidus in morphological development and thereby may be more closely related to S.hispidus.

When comparing morphological characteristics with the preferred habitats of the species, it is found that the smaller and shorter-tailed species (S.leucotis and

S.ochrognathus) live usually in shallow, rocky soils on sparsely-vegeted slopes whereas the other three species prefer deep soils and abundant grass or shrub cover. Possible reasons for these differences are discussed.

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Jorge V. Jiménez Jiménez

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INTRODUCTION

The study of the comparative ontogenesis of rodents at the interspecific level has been largely neglected, although a few works exist on age and growth phenomena in single species. One such work (Chipman, 1965) details age determination in Sigmodon hispidus, but this form is not compared with other species in the genus. Thus, the variability of five species of Sigmodon as laboratory-raised animals of known ages has provided a unique opportunity to: (1) use comparative growth studies as a measure of phylogenetic relationships in rodents; (2) develop an aging formula which makes it possible to determine approximate ages of cotton rats of all five species; and (3) to study growth rates of the progeny of subspecific crosses.

Rodents of the genus Sigmodon are of medium size (225 to 330 mm. in total length) and have short tails (less than one-half total length). The animals are robust with short, round ears. The pelage is coarse and grizzled, light brown to dark grey. The tips of the plumbeous-based hairs of the underparts vary from white to fulvous to grey.

The skull has a heavy rostrum and prominent supraorbital ridges continuing posterolaterad as temporal ridges. The molar teeth are high-crowned with long, narrow S-shaped enamel loops on the occlusal surfaces. Cotton rats are the dominant grass-eating and runway-making rodents that are found from sea level to more than 3,200 meters in south temperate and tropical North America, through Central America, and, that reach the southernmost limit of their distribution in Perú.

The species of Sigmodon are classified into two natural groups, the S.hispidus group (one species) and the S. fulviventer group (four species).

Cotton rats of the S.hispidus group have a semi-naked tail, with coarse annulations that are only partly obscured by a short scattered hairs. Animals of this group mainly inhabit south temperate and tropical zones. In these regions, they are widely distributed and have an almost continuous range. Sigmodon hispidus is the only species of group although several subspecies are recognized.

Cotton rats of the S.fulviventer group have a tail with dense hair that conceals the annulations. They inhabit the tropical, temperate and boreal regions in southwestern United States and western México (see Baker, 1969). The group includes the four species: S.alleni, S.fulviventer, S.leucotis and S.ochrognathus.

The cotton rats studied in this work were all caught in México, (see Figure 1) in the following localities: S.hispidus--Tuxpán (Nayarit); S.alleni--Jachatengo (Oaxaca); S.fulviventer--La Barca (Jalisco), Coyotes, Boquilla, Canatlán (Durango), Gallego (Chihuahua), Ibarra (Guanajuato); S.leucotis--Coyotes (Durango); S.ochrognathus--Boquilla (Durango).

Most of our knowledge of the development, growth and life history of the cotton rats is limited to S.hispidus. Little is known concerning the other species, S.alleni, S.fulviventer, S.leucotis and S.ochrognathus. The wide distribution of S.hispidus in the United States has made this species more available for biologists to study. But investigations of S.hispidus have been limited largely to studies of basic life history in the laboratory (Svihla, 1929; Meyer, 1942; Meyer and Marsh, 1943) and under natural conditions (Odum, 1955; Sealander and Walker, 1955; Goertz, 1965).

Ovulation in S.hispidus occurs during the late period of the vaginal estrous. The gestation period is 27 days. Six and one-half to 12 hours after partum ovulation may again take place, with copulation following within 3 to 6 hours. The reproductive rate in the hispid cotton rat is approximately one litter every 59 days (Sealander and Walker, 1955). Feral females in the United produce offspring from

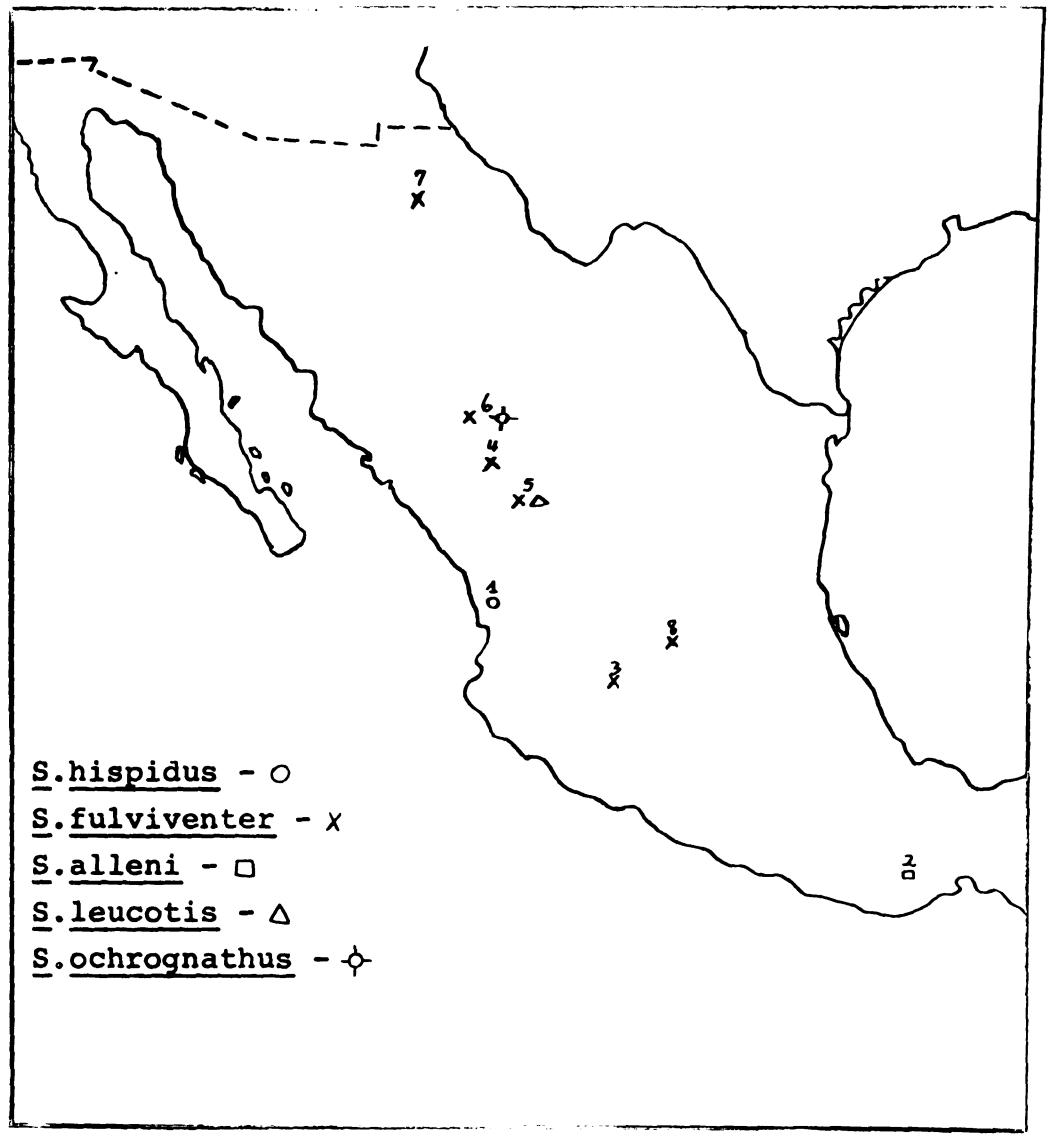


Figure 1. Map showing the approximate geographical locations of the species of Sigmodon. Numbers on the map refer to the following localities: 1. Tuxpán, Nayarit; 2. Juchatengo, Oaxaca; 3. La Barca, Jalisco; 4. Canatlán, Durango; 5. Coyotes, Durango; 6. Boquilla, Durango; 7. Gallego, Chihuahua; 8. Ibarra, Guanajuato.

early spring until late autumn. The number of young per litter vary from one to twelve and differ relative to the species studied and whether the litter is born in nature or in the laboratory (Brimley, 1923; Svihla, 1929; Meyer and Meyer, 1944; Odum, 1955; Sealander and Walker, 1955; Hoffmeister, 1963; Goertz, 1965).

At birth, the young is completely covered with a fine coat of light colored and adpressed hair, thickest about the head region. By the second day hairs begin to stand up. The dorsal region of head, body and tail is generally slate-grey, while the skin of the undersurfaces of these regions is pink. The newly born cotton rats weight from 4.5 grams to 8 grams (Svihla, 1929; Hoffmeister, 1963). Growth is rapid, the young gain as much as 2 grams per day (Meyer, 1942). The time at which cotton rats reach sexual maturity is variable. Size is not a good criterion, because cotton rats may breed at about 40 days, at which time they are still undergoing rapid growth (Asdell, 1946). Haines (1961) believes that cotton rats are sexually mature when their tail is at least 100 mm. long and the hind-foot is at least 32 mm. long. Baker (1969) concludes that a cotton rat less than 75 days old is a juvenile, between 75 and 200 days is a young adult, between 200 and 300 days old is an adult, and more than 300 days old is an old adult.

MATERIAL AND METHODS

The Michigan State University Museum has a large series of known-age skulls and skins of Sigmodon. The ages of these species range from young of one day old to very old adults (as much as 1129 days old). These animals are descendants of cotton rats wild-caught in México and kept under laboratory conditions. A total of 610 specimens were studied and were grouped as shown in Table 1.

Measurements

A total of 21 measurements were taken on each specimen. The external measurements (length of the head and body, tail and hind-foot) were taken from the specimen labels. Measurements of the skull mainly follow Hall (1946). All measurements were taken by the authors using a vernier caliper to an accuracy of 0.1 mm.

Brief descriptions of the measurements taken are as follows:

Length of head and body--the total length of the rat from tip of the nose to the end of the tail (not including the hairs) minus the length of the tail.

Table 1. Number of laboratory-raised cotton rats used in study.

Species	Locality	Specimens in Each Age-Class								
		1 d	10 d	20 d	30 d	40 d	50 d	100 d	adult	total
S.hispidus	Nayarit: 27 km. SE Tuxpan	7	6	6	4	8	6	6	27	70
S.alleni	Oaxaca: 13 km. SSW Juchatengo	6	9	6	4	5	9	6	33	78
S.fulviventer	Chihuahua: Gallego	3	3	2	-	4	6	5	30	53
	Durango: 11 km. NNE Boquilla	10	3	1	5	2	5	1	30	57
	Durango: 9 km. NNW Canatlán	-	-	4	3	2	-	-	32	41
	Durango: Hda. Coyotes	6	6	3	3	2	5	6	29	60
	Guanajuato: 8 km. SW Ibarra	6	9	8	8	9	5	6	20	71
	Jalisco: 2 km. NW La Barca	6	6	6	7	7	6	5	25	68
S.leucotis	Durango: Hda. Coyotes	4	5	2	-	2	-	3	31	47
S.ochrognathus	Durango: 3 km. NE Boquilla	6	5	6	-	5	6	6	31	65

Length of the tail--the distance from the upper base of the tail to the tip, not including the hairs.

Length of the hind-foot--length of the left hind-foot from the heel to the end of the middle claw.

Greatest length of the skull--the length from the tip of the nasals to the posterior bulge of the braincase.

Height of skull--perpendicular distance between the greatest convexity of the parietal bones at the median, and a junction-line formed by a glass slide situated horizontal to the basioccipital and basisphenoid bones (on the ventral surface) minus the width of the glass slide.

Condylo-basal length--distance along the midline of the skull from a line connecting the anteriormost portions of the premaxillae to a line connecting the posteriormost margin of the occipital condyles.

Basal length--distance on skull from the anteriormost inferior border of the foramen magnum to a line connecting the anteriormost parts of the premaxillary bones.

Basilar length--distance on skull from the anteriormost inferior border of the foramen magnum to a line connecting the posteriormost margin of the alveoli of the first upper incisors.

Palatal length--distance from the anterior parts of the premaxillary bones to the anteriormost point on the posterior border of the palantine bones.

Palatilar length--distance from the posteriormost margins of the alveoli of the first upper incisors to the anteriormost point of the posterior border of the palatine bones.

Postpalatal length--least distance from the indentation at the posterior end of the palatine bones to the anteriormost border of the foramen magnum.

Length of the rostrum--distance connecting the posterior margin of the anterorbital bridge of the maxillary bones with the tip of the nasal bone on the same side.

Width of rostrum--greatest distance connecting the most prominent lateral projections of the rostrum at the anterior border of the infraorbital foramina.

Least interorbital breadth--the width of the most constricted part of the interorbital space.

Interparietal width--the greatest width across the interparietal bones.

Breadth of braincase--breadth of the skull across the mastoid processes.

Zygomatic breadth--the greatest distance between the lateral borders of the zygomata.

Alveolar length of the maxillary tooth-row--the length of the alveoli of the three upper molariform teeth.

Length of the diastema--the distance from the posterior margin of the alveoli of the upper incisor to the anterior

margin of the alveolus of the first cheek tooth.

Length of the incisive (anterior palatine) foramina--the greatest length of this foramina.

Length of nasals--the greatest length of the nasal bones.

Body weight was not taken into consideration because under laboratory conditions this value is particularly changeable and depends largely on feeding (Gebczynska, 1964), and because body weight is not a uniform variable of age and therefore should not be used for analysis of age structure in small mammals populations (Dunaway and Kaye, 1964).

Procedures

The external and skull measurements obtained were then used to:

1. Determine the similarities and differences between males and females in the five species of Sigmodon. The Wilcoxon Matched-Paired Signed-Ranks Test, at 0.05 level, was used.
2. Analyze comparatively the graphed growth-curves of the body length, tail length and hind-foot length in all species of Sigmodon to determine the actual increase (and percent increase) in body dimensions daily and during the first 200 days of life.

3. Determine the comparative rate of increase (and percent increase) through time of the three principal regions of the skull of the five species of cotton rats.
4. Analyze the growth of the palatal region by comparing the changes through time of the alveolar length of the maxillary tooth-row, the diastema length and the palatal length.
5. Determine the comparative increase in the rostral length using the ratio: length of the incisive foramen/length of the diastema.
6. Determine the comparative increase in the skull breadth in the five species of cotton rats by relating the growth of the zygomatic breadth and the breadth of the braincase.
7. Analyze comparatively the interparietal space and the interorbital area, expressed as ratios of breadth of the braincase.
8. Derive an aging-formula by the Multiple Linear Regression Method (Abbreviated Doolittle or Gaus-Doolittle Method) to help to determine approximately the age of a cotton rat on the basis of external size and skull dimensions.
9. Study statistically (using the Wilcoxon Rank-Sum Test) the crosses between conspecific parents from geographically-separated populations.

COMPARATIVE GROWTH OF COTTON RATS

Cotton rats of each species, born and reared in captivity in the Michigan State University Museum Live Animal Colony, were killed at intervals and prepared as study specimens. The specimens of each species were first segregated as to sex and then each sex-group was divided into eight age-groups: one day, ten days, twenty days, thirty days, forty days, fifty days, one hundred days, and adults (200-400 days).

The averaged means for the various measurements taken were obtained for each age-group and used in all the statistical calculations.

Sexual Dimorphism

To determine if sexual dimorphism occurs (at least in the population samples used herein) growth curves of the three external dimensions were plotted in Figures 2-6. The Wilcoxon Matched-Paired Signed-Ranks Test was applied (see Table 2) to determine significant differences between the sex-groups even though sample sizes were small in some age-groups. Sigmodon hispidus showed significant sexual differences at the 0.05 percent level in body length

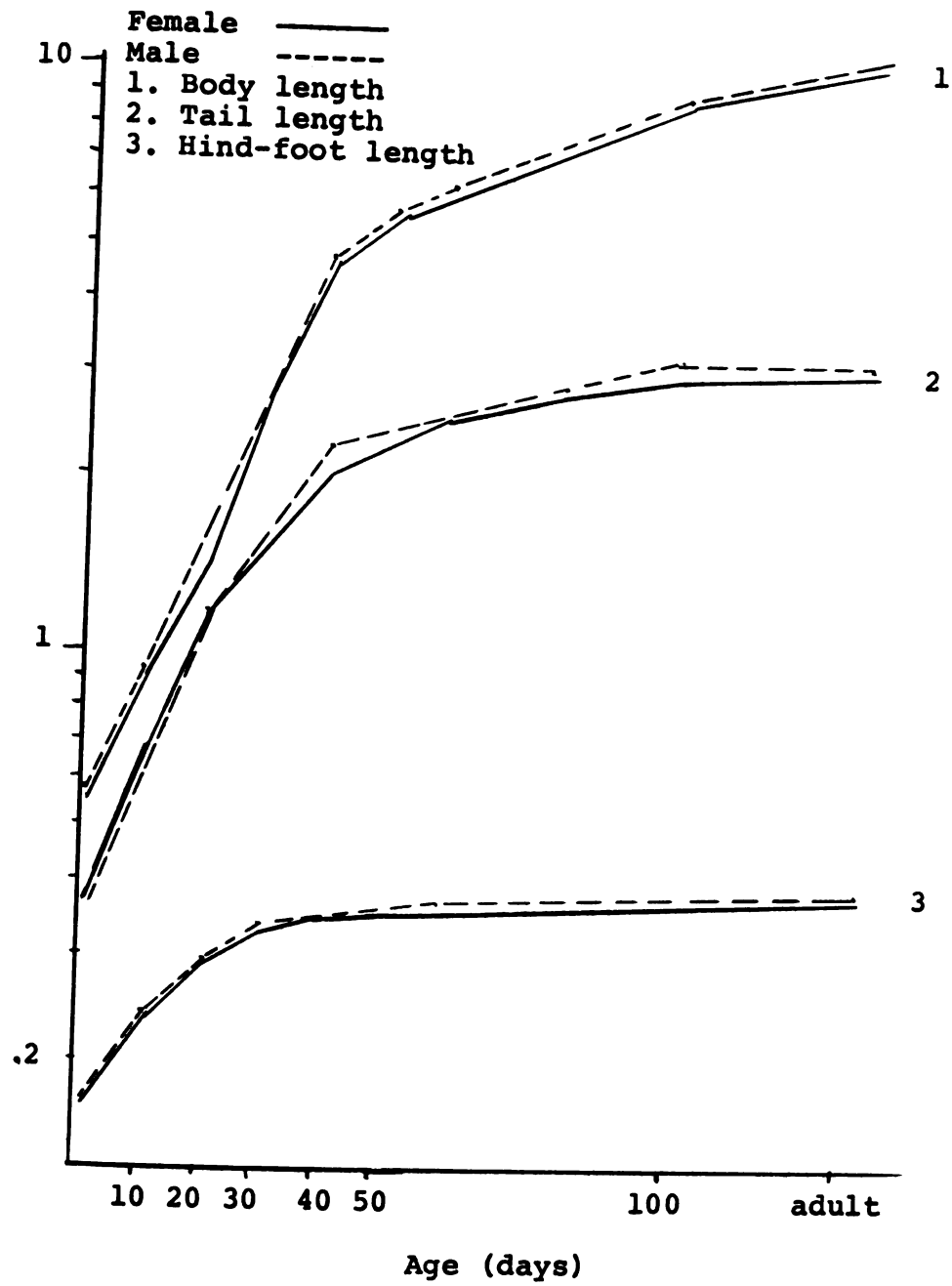


Figure 2. Growth in dimensions of body, tail, and hind-foot in males and females of Sigmodon hispidus.

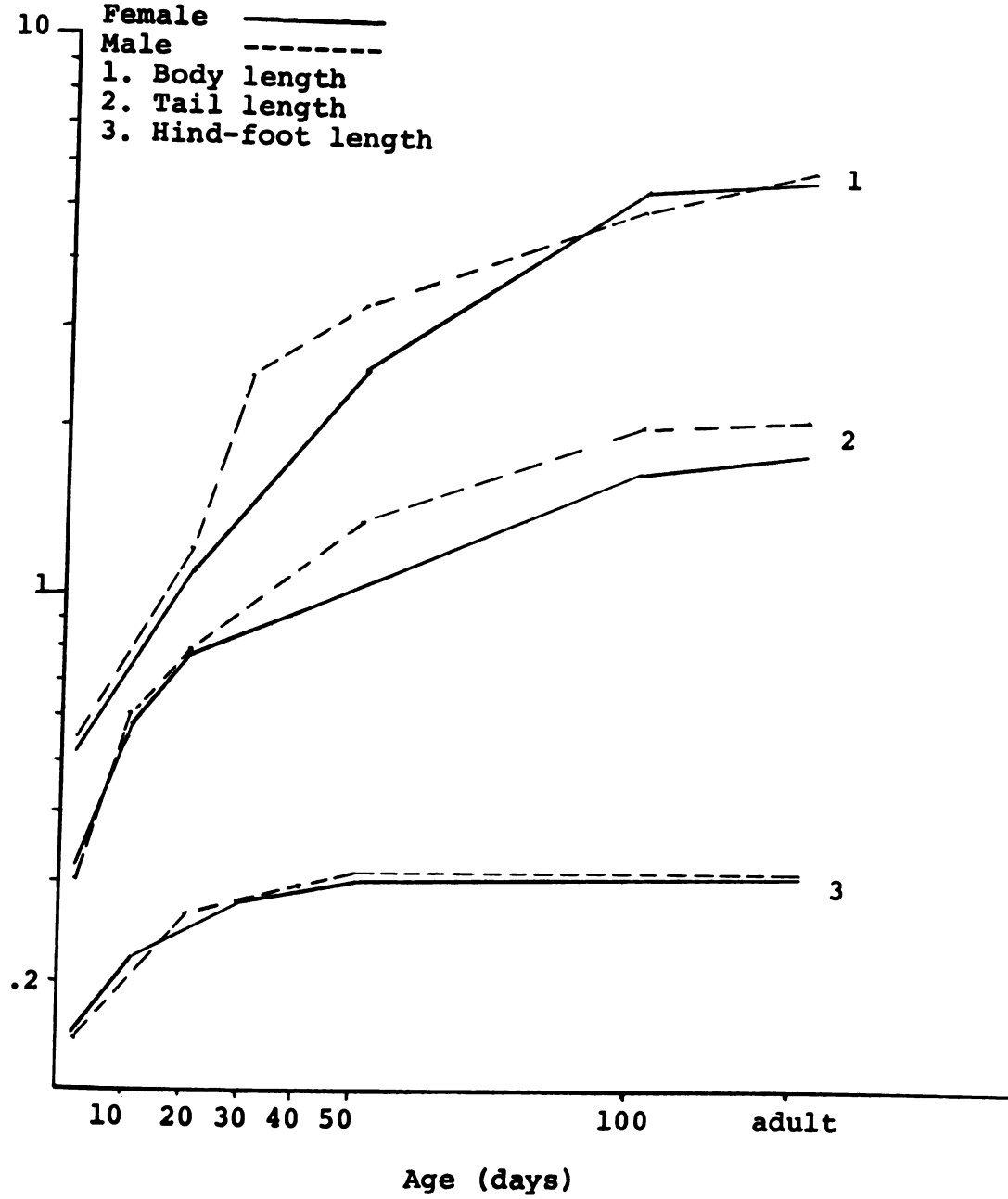


Figure 3. Growth in dimensions of body, tail, and hind-foot in males and females of Sigmodon alleni.

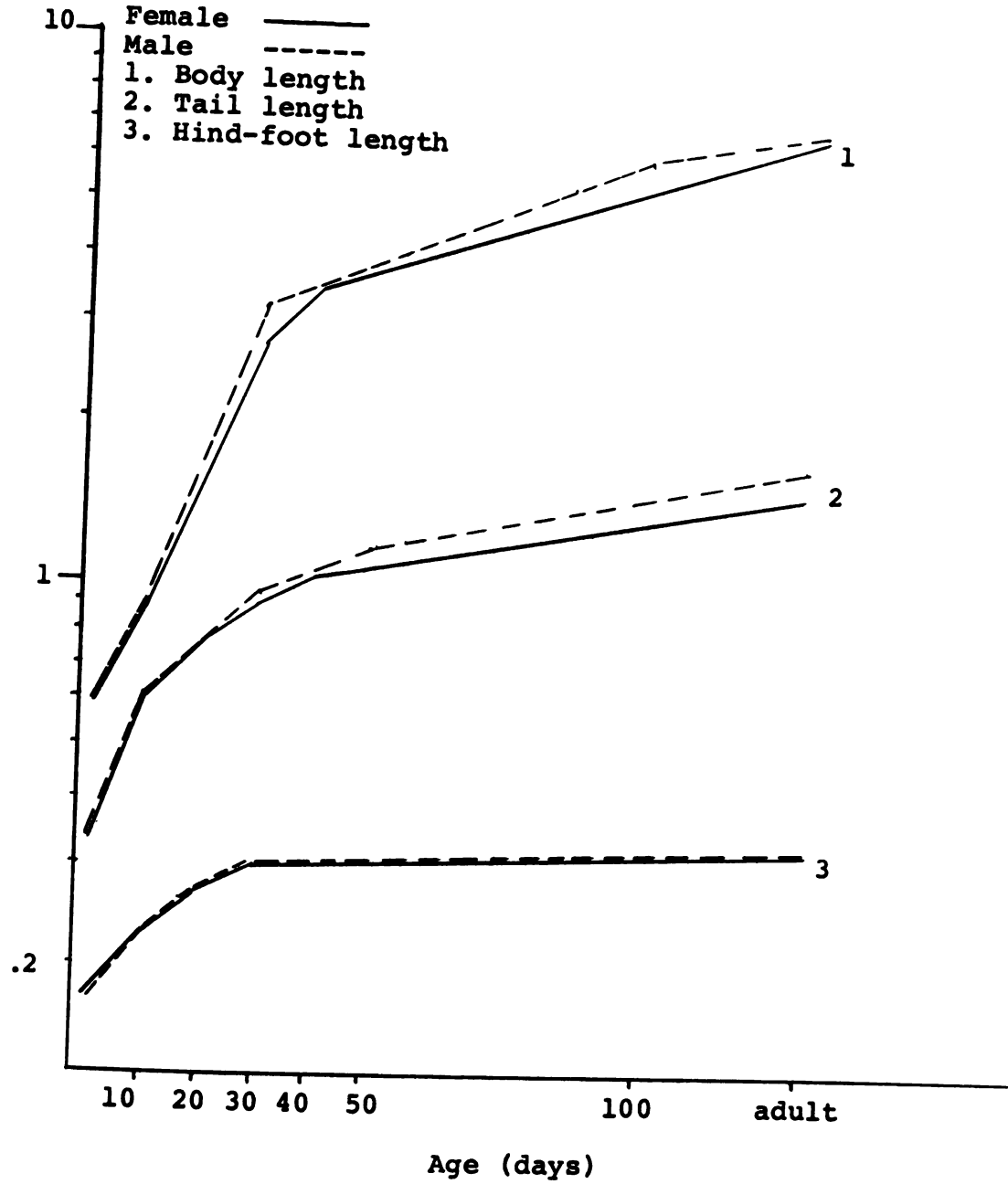


Figure 4. Growth in dimensions of the body, tail, and hind-foot in males and females of Sigmodon fulviventer.

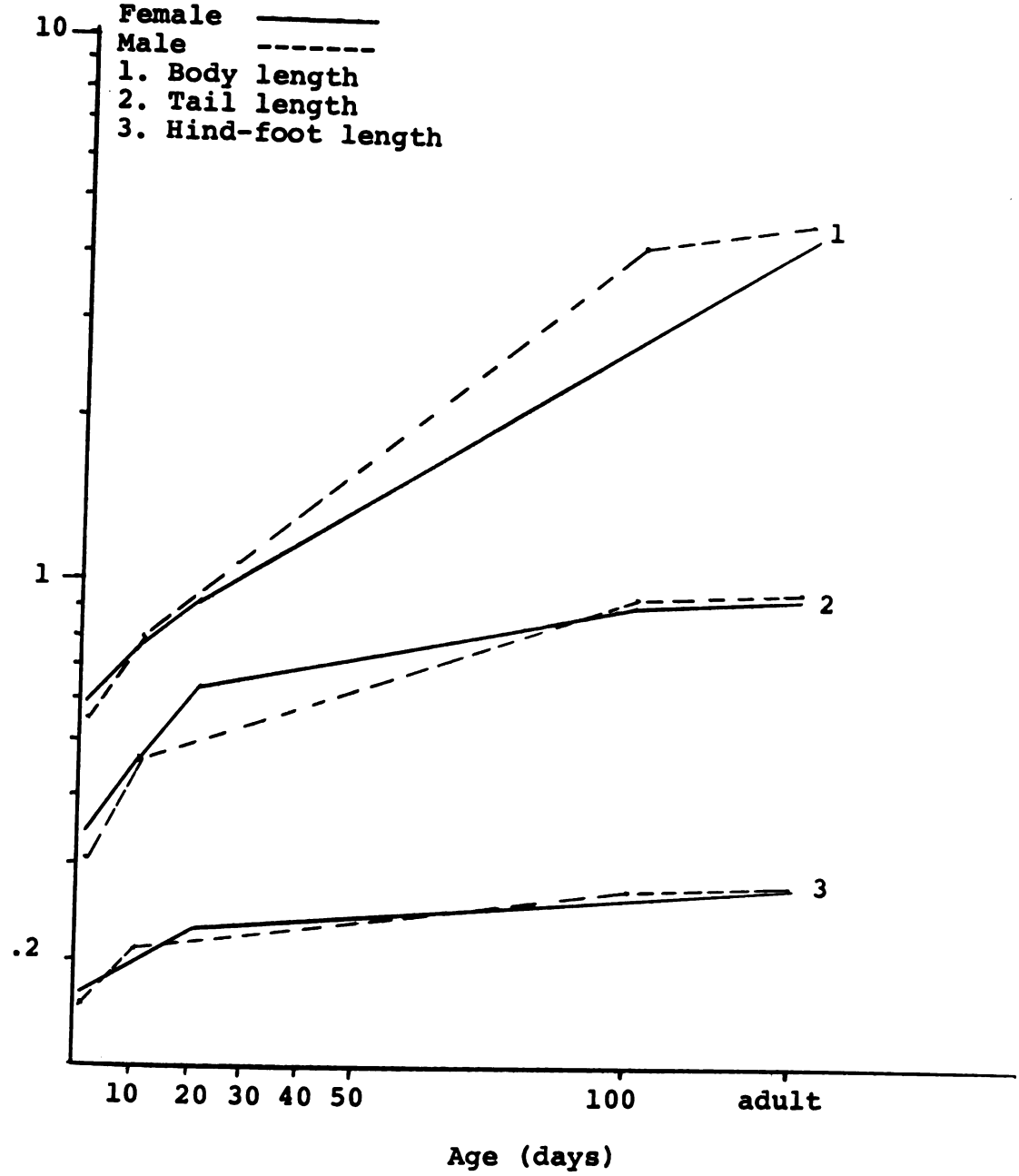


Figure 5. Growth in dimensions of the body, tail, and hind-foot in males and females of Sigmodon leucotis.

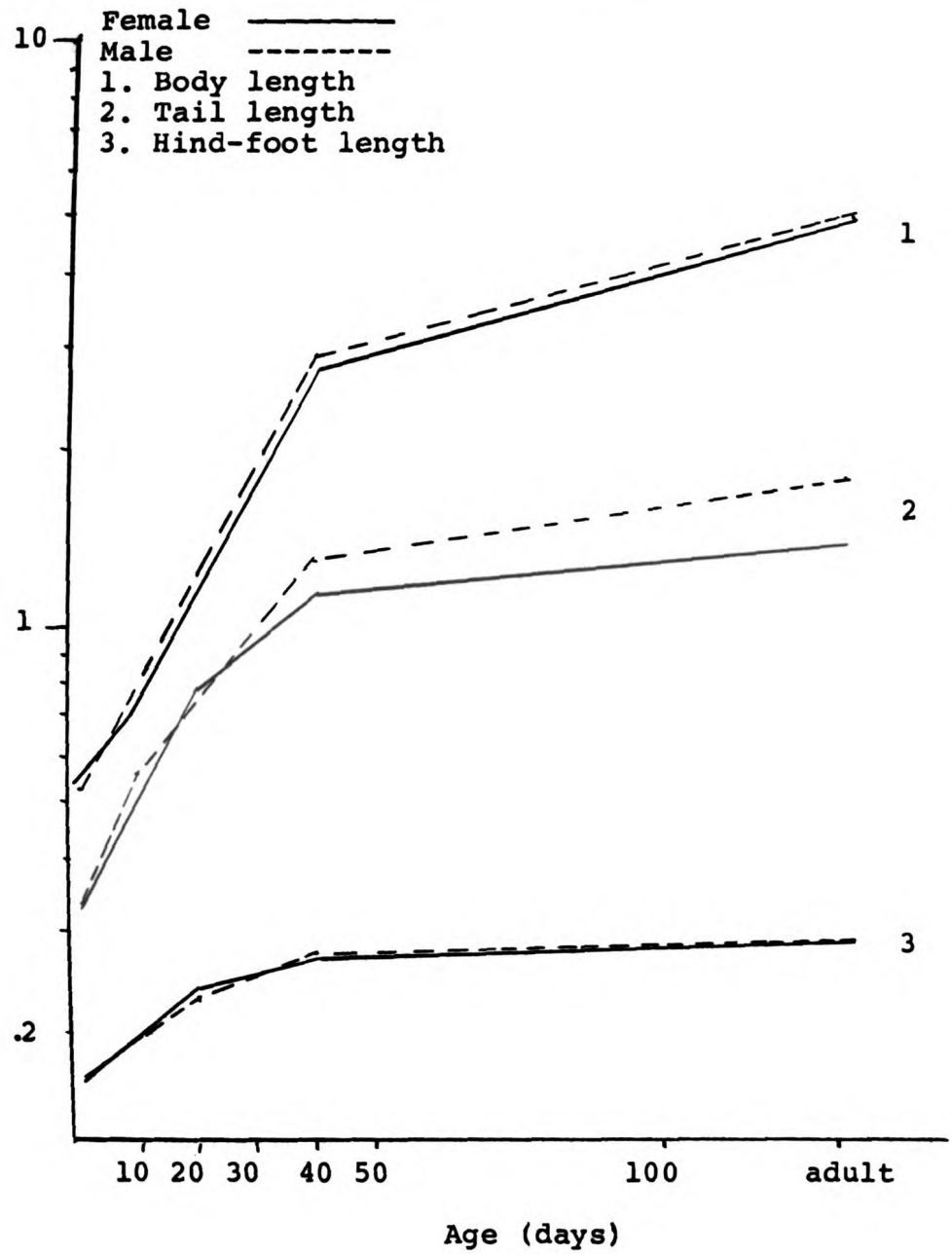


Figure 6. Growth in dimensions of the body, tail, and hind-foot in males and females of Sigmodon ochrognathus.

Table 2. External dimensions and skull measurements showing significant differences between males and females in the five species of Sigmodon.

	S.hispidus	S.alleni	S.fulviventer	S.leucotis	S.ochrognathus
Length of body	x	-	-	-	-
Length of hind-foot	x	-	-	-	-
Greatest length of skull	-	x	-	-	-
Palatal length	-	x	-	-	-
Length of rostrum	-	x	-	-	-

x = significant difference.

(Chipman, 1965 and McIntire, 1944) and in length of the hind-foot, and S.alleni showed significant sexual differences at 0.05 percent level for greatest length of skull, palatal length and length of the rostrum. Because the sample size is small, all measurements for the following graphs and tables are based on combined sexes.

Comparative Growth of External Dimensions

It was found that in the ontogeny of the cotton rat that the rate of growth may be divided in all species into three distinct age periods: 1-40 days, 41-100 days, 101 days-adulthood. In the first period growth is rapid, in the second growth is reduced, and in the third growth almost ceases.

Average and extreme measurements of these dimensions for each age-group of each species are listed in Appendix A. Some irregularities in these measurements reflect actual differences in size between animals of the same age (especially in S.leucotis), the small number of specimens in some age-groups, the possible shrinkage after death of some individuals, and the human error in making the measurements. However, in Figures 7-9 these irregularities are "smoothed-out" in an effort to present what is suspected to be normal growth patterns.

Body Length. These curves (Figure 7) rise steeply from the first day to near 100 days of age. There is rapid growth to about 40 days, but between 40 to 100 days, the rate of most species is slower. From 100 days to the adult stage, the increase in body length is practically insignificant in all species, with exception of S.hispidus, whose growth rate seems to increase steadily throughout life. Sigmodon hispidus has the largest body length of all the cotton rats studied, although S.fulviventer equals it in growth during the first 40 days. Body growth in S.alleni is similar in the first 10 days to that of S.leucotis and S.ochrognathus. But after ten days, the rate of growth of S.alleni increases and equals that of S.fulviventer. Growth in S.leucotis and smaller S.ochrognathus are similar.

Sigmodon hispidus (Table 3) at 40 days old has reached 70.6 percent and at 100 days 86.8 percent of the adult body size. Sigmodon alleni and S.fulviventer at 40 days reach respectively, 41.5 and 50.6 percent of their full growth; at 100 days they reach 95.1 and 95.9 percent. This indicates that S.fulviventer grows more rapidly than S.alleni up to 40 days, but from 40 to 100 days the reverse is true with S.alleni surpassing S.fulviventer in growth rate (19.5 and 13.0 percent, respectively). A similar reversal is noted between the smaller S.leucotis and S.ochrognathus. Mostly daily growth was achieved in the 1-40 days period (1.35 mm.

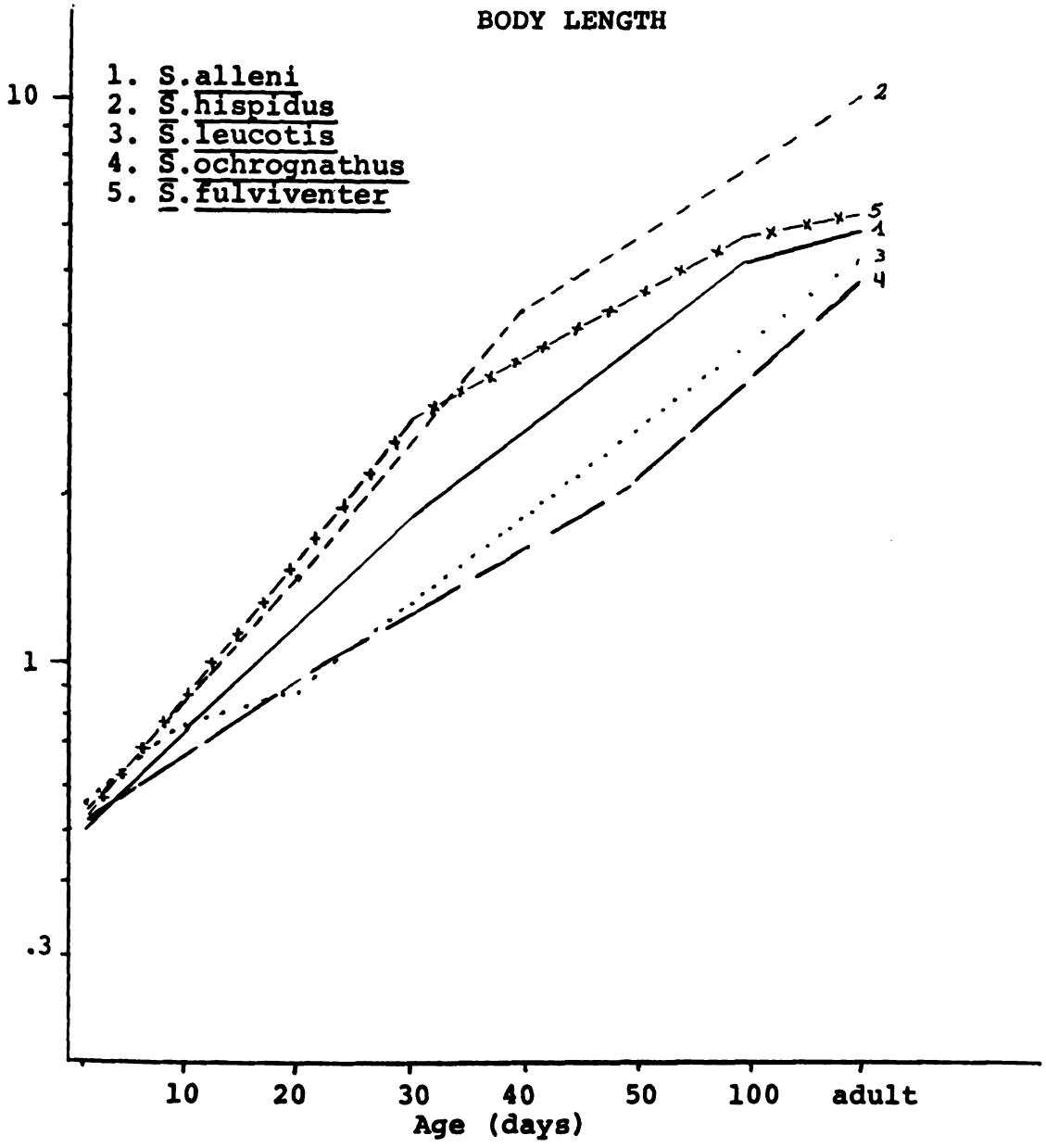


Figure 7. Graph of the curves of the body length for all the five studied species of Sigmodon.

Table 3. An analysis of growth-rates in cotton rats as shown by measurements of the length of the body, tail, and hind-foot of different age classes of animals.

Species	Age-Groups	X body length	% body length	Incr of %	Incr in mm/d	X tail length	% tail length	Incr of %	Incr in mm/d	X H-F length	% H-F length	Incr of %	Incr in mm/d
S.hispidus	1 day	55.6	27.3	-	-	37.3	28.6	-	-	14.6	35.7	-	-
	40 d	143.8	70.6	43.3	2.20	116.6	89.5	60.9	1.98	36.4	89.0	53.3	0.54
	100 d	176.8	86.8	16.2	0.55	129.0	99.0	9.5	0.22	39.2	95.9	6.9	0.04
	adult	203.7	100.0	13.2	0.27	130.3	100.0	1.0	0.01	40.9	100.0	4.1	0.02
S.alleni	1 day	55.2	34.1	-	-	32.0	26.8	-	-	12.5	38.7	-	-
	40 d	122.3	75.6	41.5	1.67	98.8	82.6	55.8	1.67	30.0	92.9	54.2	0.43
	100 d	153.8	95.1	19.5	0.52	117.5	98.2	15.6	0.31	32.3	100.0	7.1	0.04
	adult	161.7	100.0	4.9	0.08	119.6	100.0	1.8	0.02	32.3	00.0	0.0	0.00
S.fulviventer	1 day	53.5	32.3	-	-	33.6	30.6	-	-	13.3	39.9	-	-
	40 d	137.4	82.9	50.6	2.09	96.0	87.5	56.9	1.56	31.4	94.3	54.4	0.45
	100 d	159.0	95.9	13.0	0.21	106.3	96.9	9.4	0.17	32.7	98.2	3.9	0.02
	adult	165.8	100.0	4.1	0.16	109.7	100.0	3.1	0.03	33.3	100.0	1.8	0.01
S.leucotis	1 day	57.8	37.6	-	-	32.0	31.7	-	-	14.0	46.4	-	-
	40 d	112.0	72.8	35.2	1.35	80.0	79.1	47.4	1.20	25.5	84.4	38.0	0.28
	100 d	141.0	91.6	18.8	0.48	86.0	85.1	6.0	0.10	27.3	90.4	6.0	0.03
	adult	153.9	100.0	8.4	0.13	101.0	100.0	14.9	0.15	30.2	100.0	9.6	0.03
S.ochrognathus	1 day	52.0	34.7	-	-	32.8	31.6	-	-	12.8	41.7	-	-
	40 d	128.4	85.6	50.9	1.91	102.0	98.3	66.7	1.73	28.0	91.2	49.5	0.38
	100 d	138.8	92.5	6.9	0.17	102.5	98.7	0.4	0.01	29.0	94.5	3.3	0.02
	adult	150.0	100.0	7.5	0.11	103.8	100.0	1.3	0.01	30.7	100.0	5.5	0.03

per day in S.leucotis to 2.2 mm. per day in S.hispidus); least was in the age period between 100 and 200-400 days.

Tail Length. The tail (Figure 8) exhibits much of the same type of growth in cotton rats as does body length. The tail increases rapidly in length in the younger animals (up to 40 days), but after this age, the rate of growth decreases abruptly.

The longest tail at all ages is shown by S.hispidus with S.alleni second. However, the tail of the latter has a similar growth pattern to that of S.fulviventer. Growth in tail length of S.ochrognathus is intermediate between S.fulviventer and S.leucotis. The latter species has the shortest tail.

The tail lengths of the five species of cotton rats reach, at the age of 100 days, from 85.1 percent (S.leucotis) to 99.0 percent (S.hispidus) of the adult tail length. The period of time from one day to 40 days shows the largest percentage of growth. The daily growth-rate was greatest in the age period between one to 40 days (1.98 mm. per day in S.hispidus).

Hind-foot Length. The hind-foot (Figure 9) also grows rapidly during early life. At about 40 days of age, there is no significative growth.

Sigmodon leucotis has the smallest hind-foot at all ages, except in the one day age-group, and S.hispidus has

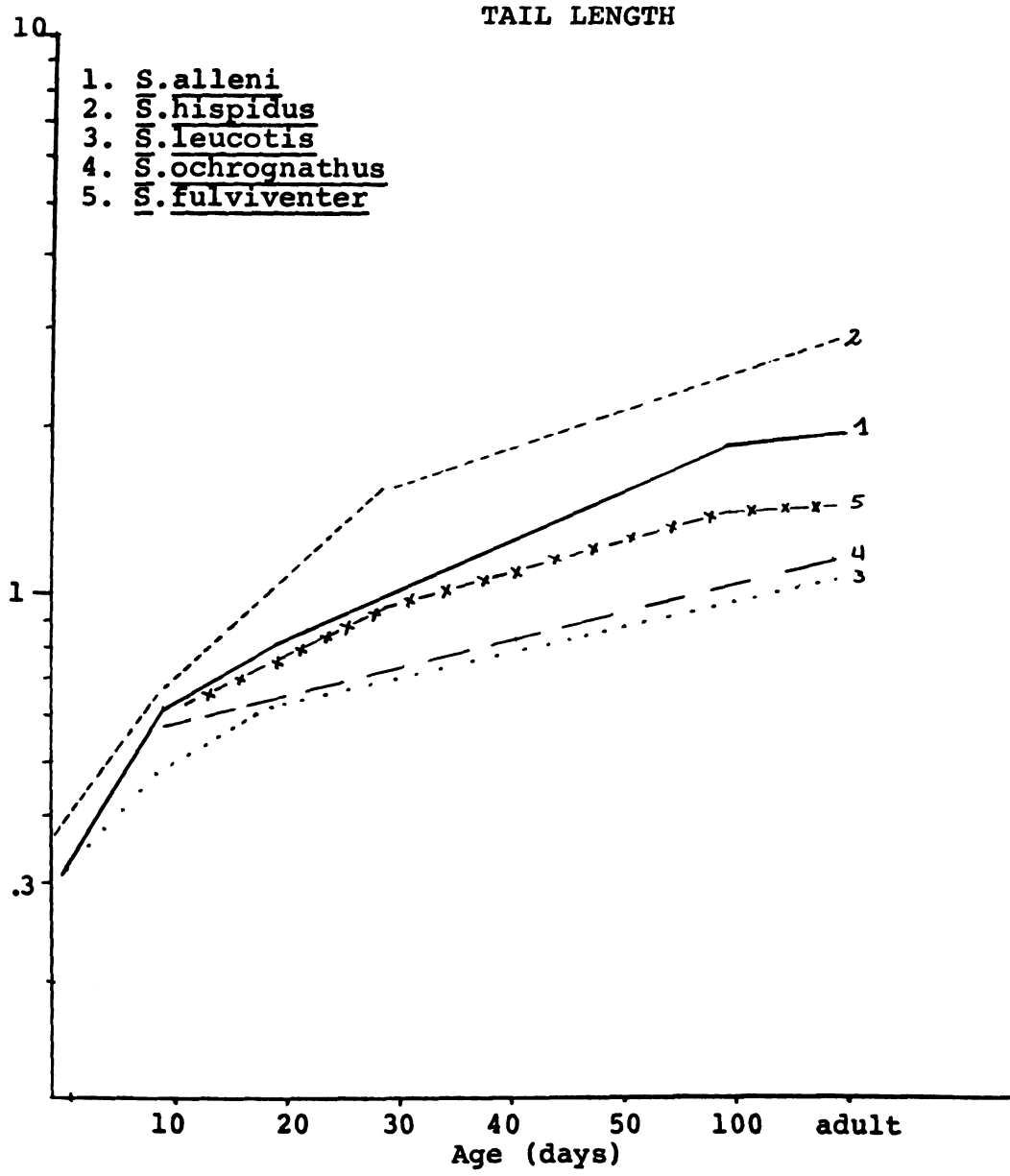


Figure 8. Graphs of the curves of tail length for all five species studied of Sigmodon.

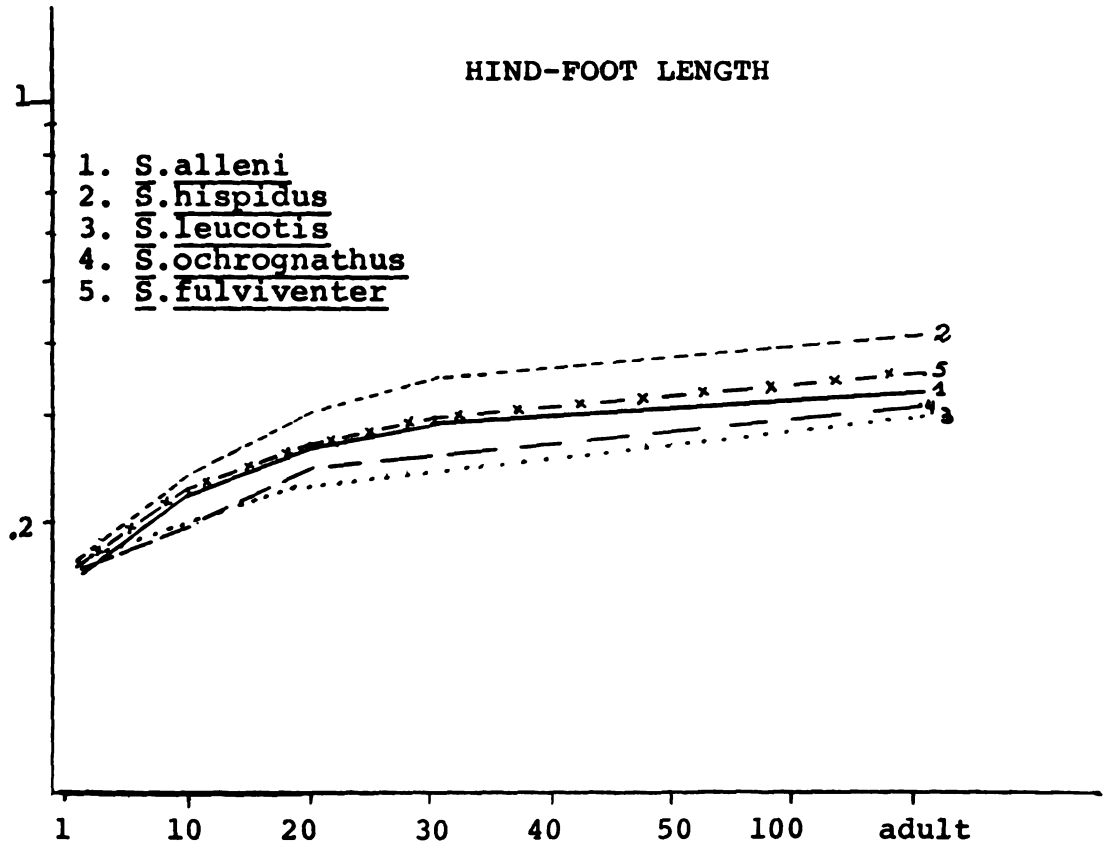


Figure 9. Graphs of the curves of hind-foot length for all the five studied species of Sigmodon.

the largest. Hind-foot growth in S. fulviventer is similar to that in S. alleni while those of S. ochrognathus and S. leucotis are least. The hind-foot length reaches adult size by the time the cotton rats are 100 days old (94.5 percent in S. ochrognathus and 100 percent in S. alleni). The daily growth rate in this age period varied between species from 0.28 mm. to 0.54 mm. per day and was practically none in older animals.

Comparative Growth of Skull

The growth patterns of the cotton rats are the result of: (1) early rapid expansion in the dorsal and lateral aspect of the braincase, and (2) slower growth of longer duration resulting in the elongation of the base of the braincase and the forward projection of the rostrum.

During the first 20 days of life, rapid growth of the dorsal part of the braincase is the major factor determining cranial form. After this early expansion, however, the slower but steadily lengthening of the base of the braincase and rostrum result in a reduction in the rounded dorsal profile, correlated with the flattening and diminution in the relative height of the cranium and with the posterior elevation of the occiput and fronto-nasal area (Baer, 1954).

The growth relationships between different parts of the skull are shown in Figures 10-11. The rostrum is represented by the length of the nasal bones. The dimensions of the

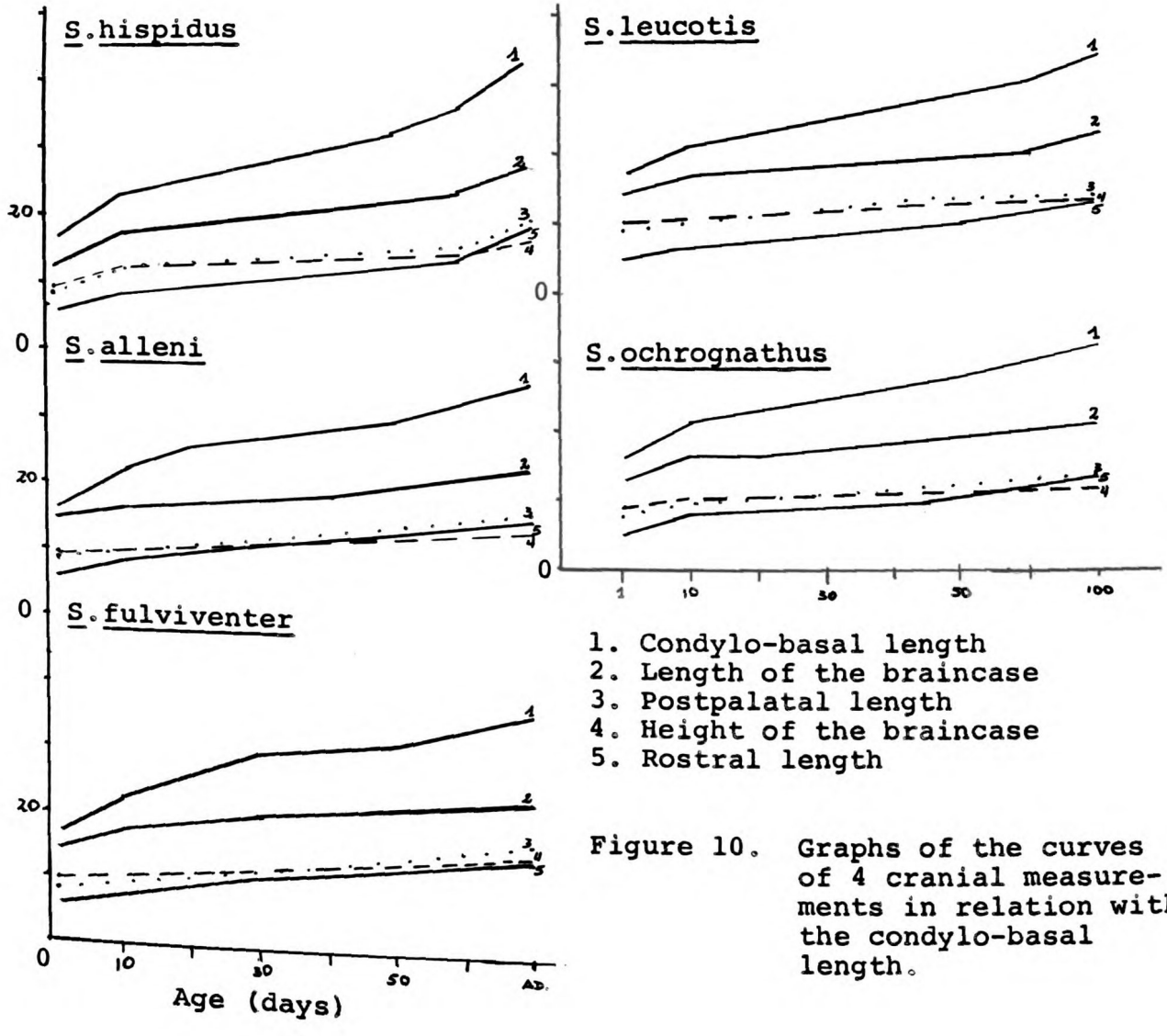
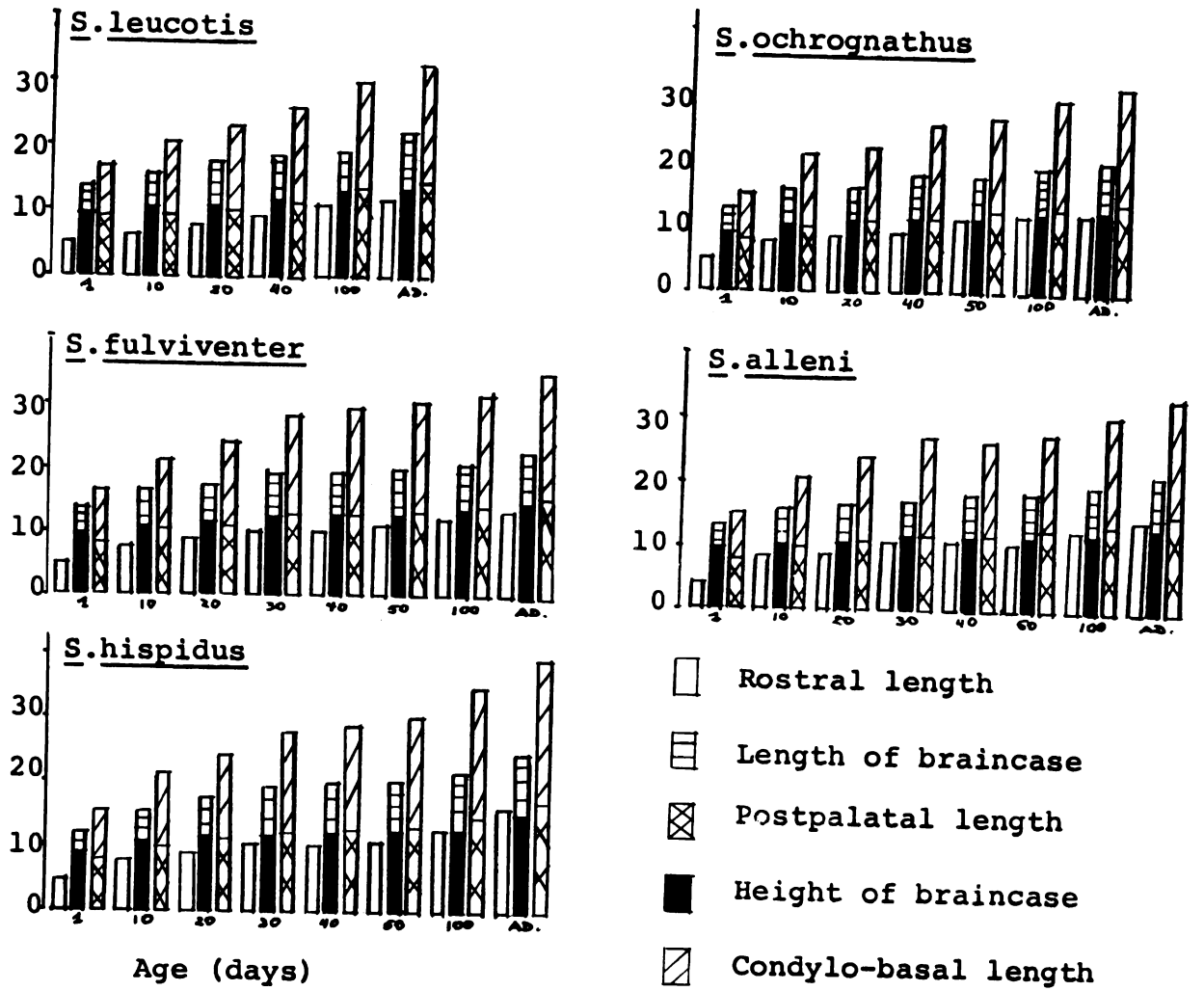


Figure 10. Graphs of the curves of 4 cranial measurements in relation with the condylo-basal length.

Figure 11. Histrogram of the relationships of growth between the rostral length, the length of the braincase, the height of the braincase, the postpalatal length with the condylo-basal length.


S.leucotis
S.ochrognathus
S.fulviventer
S.alleni
S.hispidus
30
20
10
0
1
10
20
40
50
100
AD.
Age (days)
Rostral length
Length of braincase
Postpalatal length
Height of braincase
Condylo-basal length

braincase are obtained by measuring the length of the braincase (greatest length of the skull minus the length of the nasals), the height of the braincase, and the basal length of the braincase (postpalatal length).

The skull (as shown by the condylo-basal length) increases in length throughout the life of the cotton rats. This is further demonstrated by taking measurements of the length of the rostrum and three aspects of the braincase (see Tables 4-8 and Figure 11).

The lengthening of the rostrum with age was found to be directly correlated with the increase in condylo-basal length; however, other cranial dimensions grow progressively slower as the age of the cotton rat increases (illustrated in Figure 11). The rostral length increases in S.hispidus only 9.9 percent of the condylo-basal length in the first 200 days of life, in other cotton rats to a maximum of 13.2 percent in S.alleni.

At one day old, S.alleni has proportionally the longest braincase (90.0 percent of the condylo-basal length) in relation to skull length; S.hispidus has the smallest (75.8 percent). However, at 200-400 days, S.leucotis has the longest (67.1 percent) while S.alleni has the shortest (62.4 percent). The braincase length grows slowly from 13.0 percent of the condylo-basal length in S.hispidus to 27.6 percent in S.alleni during the 1-200 day period.

Table 4. Development with age of the rostrum and the braincase (expressed in percentages) in relation to the skull lengthening (expressed in terms of the condylo-basal length) in Sigmodon hispidus.

Age	Condylo-basal length	Length of rostrum (%)	Length of braincase (%)	Postpalatal length (%)	Height of the braincase (%)
1 day	16.1	30.4	75.8	47.8	52.8
10 days	21.7	35.5	75.1	45.6	49.8
20 days	25.1	37.2	72.8	44.4	46.4
30 days	28.4	37.0	69.7	43.7	42.6
40 days	30.0	38.0	68.0	43.3	42.0
50 days	31.3	37.4	67.1	43.5	41.2
100 days	34.6	38.6	65.8	43.5	37.7
adult	40.9	40.3	62.8	42.5	38.6

Table 5. Development with age of the rostrum and braincase (expressed in percentages) in relation to the skull lengthening (expressed in terms of the condylo-basal length) in *Sigmodon alleni*.

Age	Condylo-basal length	Length of rostrum (%)	Length of braincase (%)	Postpalatal length (%)	Height of the braincase (%)
1 day	15.0	29.3	90.0	54.7	56.7
10 days	21.1	36.0	73.9	46.0	45.5
20 days	24.6	32.9	67.1	45.5	43.1
30 days	26.6	39.8	63.9	44.4	42.5
40 days	26.9	40.1	66.2	44.6	42.8
50 days	28.4	41.9	66.9	44.7	40.9
100 days	31.4	41.7	64.3	43.9	39.2
adult	34.3	42.6	62.4	44.3	38.5

Table 6. Development with age of the rostrum and braincase (expressed in percentages) in relation to the skull lengthening (expressed in terms of the condylo-basal length) in Sigmodon fulviventer.

Age	Condylo-basal length	Length of rostrum (%)	Length of braincase (%)	Postpalatal length (%)	Height of the braincase (%)
1 day	16.2	28.4	82.1	46.3	55.6
10 days	21.5	32.9	75.5	44.4	49.4
20 days	24.7	35.6	71.3	44.1	45.7
30 days	28.3	35.0	69.6	44.5	43.1
40 days	29.1	37.1	67.7	43.6	43.0
50 days	30.2	37.4	66.6	43.4	42.4
100 days	32.4	37.7	65.4	43.5	41.0
adult	35.6	39.0	63.8	43.0	41.0

Table 7. Development with age of the rostrum and braincase (expressed in percentages) in relation to the skull lengthening (expressed in terms of the condylo-basal length) in Sigmodon leucotis.

Age	Condylo-basal length	Length of rostrum (%)	Length of braincase (%)	Postpalatal length (%)	Height of the braincase (%)
1 day	16.9	27.2	83.4	51.5	55.6
10 days	21.0	31.0	78.1	46.2	50.0
20 days	23.1	34.2	78.1	46.2	50.0
30 days	-	-	-	-	-
40 days	26.3	34.6	71.9	43.7	45.2
50 days	-	-	-	-	-
100 days	30.2	37.1	66.2	46.0	44.0
adult	33.7	38.0	67.1	43.3	41.8

Table 8. Development with age of the rostrum and braincase (expressed in percentages) in relation to the skull lengthening (expressed in terms of the condylo-basal length) in Sigmodon ochrognathus.

Age	Condylo-basal length	Length of rostrum (%)	Length of braincase (%)	Postpalatal length (%)	Height of the braincase (%)
1 day	15.3	28.8	83.7	47.1	56.9
10 days	21.2	34.4	74.5	46.7	48.1
20 days	22.5	36.9	72.0	45.8	46.7
30 days	-	-	-	-	-
40 days	26.3	34.6	68.4	42.6	43.7
50 days	27.8	36.7	67.3	46.0	41.7
100 days	30.2	40.4	65.6	44.0	41.1
adult	32.1	40.5	64.8	44.2	39.9

The basal part of the braincase (as shown by the post-palatal length) is even slower in lengthening in the first 200 days of life, 2.9 percent of the condylo-basal length in S.ochrognathus to 10.4 percent in S.alleni. Likewise, the dorso-ventral expansion (height) of the braincase is proportionately slower-growing in relation to the lengthening of the skull in the first 200 days after birth. In this period the least growth is in S.leucotis (13.8 percent of the condylo-basal length), the most in S.alleni (18.2 percent).

The changes in the cotton rat skull from a short, rounded structure at one day of age to an elongated, flattened condition at 200 days can be demonstrated by the histograms in Figure 11. The height of the braincase in one day old cotton rats is large in proportion to the other skull dimensions (i.e., rostral and postpalatal lengths), but the subsequent rate of growth to elongate the skull far exceeds that to heighten it. In fact, the measurements of postpalatal length becomes greater than the height of the skull by the time cotton rats are between 20 to 30 days old. The rostral length in the 200 day-old cotton rats exceeds the cranial height in all species of Sigmodon but S.fulviventer and S.leucotis.

Comparison of the growth of the height of the braincase and the length of the braincase using the ratios length of

braincase/height of the braincase and postpalatal length/ height of the braincase (Table 9) show that the antero-posterior dimension of the braincase and the postpalatal length grow progressively more rapidly than does the height of the braincase.

The length of the skull can be expressed in terms of the condylo-basal length, which may be divided into the palatal and postpalatal lengths. The ratio of the post-palatal length to the condylo-basal length and the ratio of the palatal length to the condylo-basal length are inversely related in all species of Sigmodon and for all age-groups studied. When the skull lengthens the rostrum maintains the same pattern of growth while the braincase shows a progressive reduction in relative size (see Table 10).

The ratios of the least interorbital breadth and the interparietal breadth to the breadth of the braincase in the different species of Sigmodon are shown in Table 11. The measurements of the breadth of the braincase at one day old varies between 64.5 percent to 73.9 percent of the total adult stage in the five species of cotton rats studied. At the same age, the dimensions of the least interorbital breadth are from 75.0 percent to 88.4 percent of the condition of the adults. The interparietal breadth of the

Table 9. Comparison of growth of height and length of braincase.

Age	S.hispidus (1)	S.hispidus (2)	S.alleni (1)	S.alleni (2)	S.fulviventer (1)	S.fulviventer (2)	S.leucotis (1)	S.leucotis (2)	S.ochrognathus (1)	S.ochrognathus (2)
1 day	1.43	0.90	1.58	0.96	1.47	0.83	1.50	0.92	1.47	0.82
10 days	1.50	0.91	1.62	1.01	1.52	0.89	1.56	0.92	1.54	0.97
20 days	1.56	0.95	1.55	1.05	1.55	0.96	1.61	0.93	1.54	0.98
30 days	1.59	0.97	1.50	1.04	1.61	1.03	-	-	-	-
40 days	1.61	1.03	1.54	1.04	1.57	1.01	1.58	0.96	1.56	0.97
50 days	1.62	1.05	1.65	1.10	1.57	1.02	-	-	1.61	1.10
100 days	1.74	1.15	1.64	1.12	1.59	1.06	1.50	1.04	1.59	1.07
adult	1.62	1.10	1.62	1.15	1.55	1.04	1.60	1.03	1.62	1.10

(1) - length of braincase/height of the braincase.

(2) - postpalatal length/height of the braincase.

Table 10. Comparative lengthening (expressed in percentage of condylo-basal length) of the rostrum and braincase.

	One day old		Adult stage	
	Palatal	Postpalatal	Palatal	Postpalatal
S.hispidus	52.2%	47.8%	57.5%	42.5%
S.alleni	45.3	54.7	55.7	44.3
S.fulviventer	53.7	46.3	57.0	43.0
S.leucotis	48.5	51.5	56.7	43.3
S.ochrognathus	52.9	47.1	55.8	44.2

Table 11. Comparative broadening (expressed as ratios of the width of the braincase) of the interorbital area and interparietal space.

Species	Age	Breadth of braincase (1)	Least interorbital breadth (2)	Ratio (2)/(1)	Interparietal breadth (3)	Ratio (3)/(1)
S.hispidus	1 d	10.6	4.6	0.43	8.0	0.75
	10 d	12.5	4.6	0.36	9.4	0.75
	20 d	13.4	4.6	0.34	10.4	0.77
	30 d	13.7	4.8	0.35	10.3	0.75
	40 d	14.6	4.8	0.32	10.4	0.71
	50 d	14.8	4.8	0.32	10.9	0.73
	100 d	15.0	5.0	0.33	11.3	0.75
	adult	16.4	5.6	0.34	12.1	0.73
S.alleni	1 d	10.5	4.4	0.41	8.5	0.80
	10 d	12.1	4.5	0.37	9.9	0.81
	20 d	12.4	4.6	0.37	10.1	0.81
	30 d	12.5	4.6	0.36	10.6	0.84
	40 d	12.9	4.8	0.37	10.3	0.79
	50 d	13.0	4.9	0.37	10.9	0.83
	100 d	13.2	5.1	0.38	11.2	0.84
	adult	14.2	5.4	0.38	11.3	0.79
S.fulvi venter	1 d	10.2	3.9	0.38	8.5	0.83
	10 d	11.4	4.4	0.38	10.0	0.87
	20 d	13.1	4.4	0.33	10.5	0.80
	30 d	13.7	4.6	0.33	11.0	0.80
	40 d	14.1	4.6	0.32	11.2	0.79
	50 d	14.2	4.6	0.32	11.5	0.80
	100 d	14.5	4.8	0.33	11.5	0.79
	adult	15.7	5.2	0.33	12.7	0.80
S.leucotis	1 d	10.5	4.5	0.42	8.3	0.79
	10 d	12.3	4.5	0.36	9.3	0.75
	20 d	13.0	4.6	0.35	10.8	0.83
	30 d	- -	- -	- -	- -	- -
	40 d	14.0	4.6	0.32	10.5	0.75
	50 d	- -	- -	- -	- -	- -
	100 d	14.6	5.0	0.34	11.8	0.80
	adult	15.3	5.1	0.33	12.2	0.79
S.ochro-gnathus	1 d	9.8	4.2	0.42	7.7	0.78
	10 d	12.0	4.4	0.36	9.7	0.80
	20 d	12.6	4.3	0.34	9.6	0.76
	30 d	- -	- -	- -	- -	- -
	40 d	13.4	4.7	0.35	10.4	0.77
	50 d	13.5	4.6	0.34	10.7	0.79
	100 d	13.9	4.9	0.35	10.2	0.73
	adult	14.8	5.0	0.33	11.7	0.79

one-day old cotton rat is 65.8 percent to 75.2 percent as broad as the same region in the adult stage.

It is shown in Table 11 that the interorbital area and the interparietal space decrease slowly in breadth from birth to adulthood, (except in S.leucotis and S.ochrognathus) in relation to the broadening of the braincase.

Three measurements of the palatal region of Sigmodon were used to determine growth in this area during the first one hundred day of life (see Tablés 12-15).

The palatal length in S.hispidus and S.alleni according to Tables 14-15 more than doubles (102 and 104 percent respectively) in the first 40 days of life, while the other three species this increase is less, between 65 and 86 percent. The species seem in better accord when comparing growth in alveolar length (Table 12) with an increase between 50 and 67 percent in the first 40 days and almost no growth thereafter. However, the increase in length of the diastema (Table 13) shows marked variations between species, from 71 to 116 percent growth in the first 40 days. As shown in all three of these measurements, the palatal region of the skull has virtually completed its growth by the time the cotton rats are 40 days old.

The growth rate of the lateral expansion of the skull was determined by examining measurements of the breadth of the braincase and the zygomata (see Table 16).

Table 12. Increase of length (in mm.) of the alveolar space for the maxillary tooth-row.

	S.hispidus	S.alleni	S.fulviventer	S.leucotis	S.ochrognathus
1 day	4.2	3.8	4.3	4.2	3.7
increase at 40 days	2.7	2.4	2.2	2.1	2.5
increase at 100 days	0.2	0.1	0.2	0.0	0.1
length at 100 days	7.1	6.3	6.7	6.3	6.3

Table 13. Increase in length (in mm.) of the diastema.

	S.hispidus	S.alleni	S.fulviventer	S.leucotis	S.ochrognathus
1 day	4.0	3.9	3.7	4.2	3.8
increase at 40 days	4.1	2.8	4.3	4.6	3.1
increase at 100 days	0.7	1.9	1.2	0.0	1.4
length at 100 days	9.8	8.6	9.2	8.8	8.3

Table 14. Increase in palatal length.

	S.hispidus	S.alleni	S.fulviventer	S.leucotis	S.ochrognathus
1 day	8.4	6.8	8.7	8.7	8.1
increase at 40 days	8.6	7.1	5.7	6.1	7.0
increase at 100 days	2.6	3.7	3.9	1.5	1.8
length at 100 days	19.6	17.6	18.3	16.3	16.9

Table 15. Increase (expressed in percent) in the length of three dimensions of the palatal region, from 1-40 days (accelerating phase) and from 41-100 days (decelerating phase).

	Palatal length		Alveolar length of maxillary tooth-row		Length of diastema	
	1-40	41-100	1-40	41-100	1-40	41-100
S.hispidus	102%	0.02%	64%	0.03%	102%	0.01%
S.alleni	104	0.03	63	0.02	71	0.03
S.fulviventer	65	0.03	51	0.03	116	0.02
S.leucotis	70	0.01	50	0.00	109	0.00
S.ochrognathus	86	0.01	67	0.02	81	0.02

Table 16. Measurements of the zygomatic breadth (1) and breadth of the braincase (2) for Sigmodon.

Age	S.hispidus		S.alleni		S.fulviventer		S.leucotis		S.ochrognathus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1 day	10.0	10.6	9.7	10.5	10.4	10.2	10.6	10.5	9.9	9.8
10 days	13.5	12.5	12.9	12.1	13.5	11.4	13.0	12.3	10.6	12.0
20 days	15.4	13.4	14.7	12.4	15.5	13.1	14.6	13.0	14.5	12.6
30 days	17.2	13.7	15.6	12.5	17.7	13.7	- -	- -	- -	- -
40 days	18.1	14.8	16.2	12.9	18.2	14.1	16.5	14.0	17.0	13.4
50 days	18.8	14.6	16.9	13.0	18.5	14.2	- -	- -	17.8	13.5
100 days	20.5	15.0	18.1	13.2	19.5	14.5	18.3	14.6	18.6	13.9
200-400 days	23.7	16.4	20.0	14.2	21.7	15.7	19.8	15.3	19.4	14.8

At one day old, the breadth of the braincase is smaller than the zygomatic breadth in all species except S.hispidus and S.alleni. However, in all species the zygomata broadens faster than the braincase. From one day to adulthood the zygomatic breadth increases most in S.hispidus (13.7 mm.) and least in S.leucotis (9.2 mm.). Most growth of the breadth of the braincase is in S.hispidus (5.8 mm.) and the least in S.alleni (3.7 mm.).

The incisive foramen varies considerably in shape (both individually and specifically) between the species of Sigmodon. The shape of this elongate foramen may be oval or sharply pointed. Furthermore, the posterior ends of the incisive foramen in adult vary as to position in relation to the maxillary tooth-row. The posterior ends of the incisive foramina in S.ochrognathus and S.alleni do not reach a line drawn between the anterior margins of the alveoli of this tooth row; in S.leucotis the incisive foramina reaches but does not extend beyond this line; and in S.hispidus and S.fulviventer, the incisive foramina extend posteriorly beyond this line. These findings relate to the relationships between the length of the incisive foramen and the diastema, as shown in Table 17 and Figure 12. Those species with the foramina extending anteriorly in between tooth rows have the largest ratios.

Table 17. Ratio between length of the incisive foramen and the diastema.

Age	S.hispidus	S.alleni	S.fulviventer	S.leucotis	S.ochrognathus
1 day	0.60	0.48	0.67	0.66	0.65
10 days	0.86	0.80	0.84	0.79	0.81
20 days	0.87	0.80	0.90	0.76	0.78
30 days	0.83	0.79	0.86	- -	- -
40 days	0.85	0.80	0.86	0.80	0.81
50 days	0.84	0.78	0.84	- -	0.82
100 days	0.81	0.75	0.83	0.79	0.81
200 days	0.80	0.78	0.81	0.75	0.78

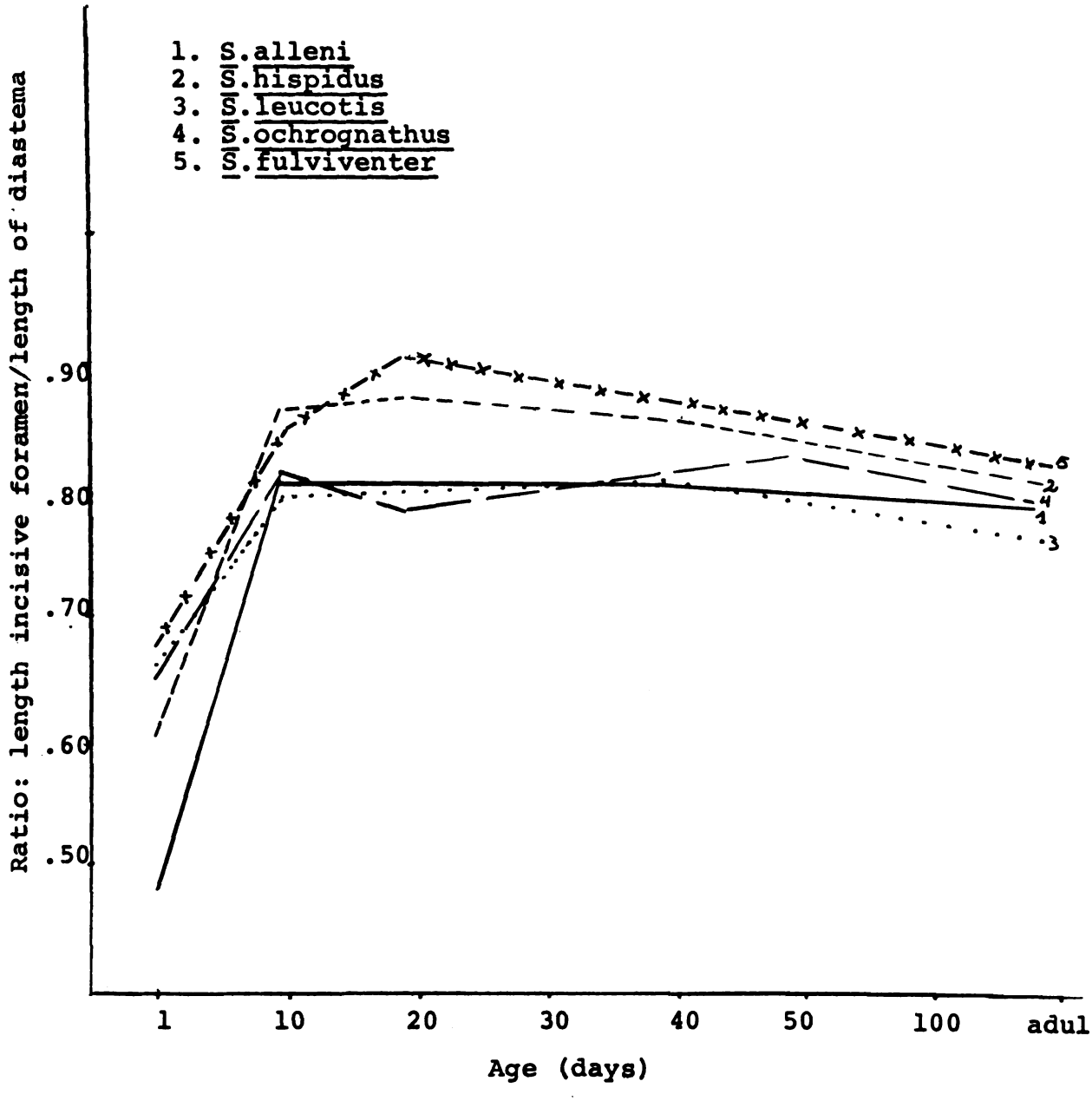


Figure 12. Graph of the curves of the ratio: length of the incisive foramen/length of the diastema for all the species of cotton rats.

Interspecific relationships are demonstrated using the ratio between the length of the incisive foramen and the diastema (Figure 12) for all the species of cotton rats of the genus Sigmodon. The curves indicate that the incisive foramen lengthens rapidly up to 20 days of age, although maximum length is not obtained in S.leucotis until 40 days of age and S.ochrognathus until 50 days. Following 20 days of age, the growth of the incisive foramen is greatly reduced. The ratio as shown in Figure 12 also declines because of the rapid increase of the lengthening of the diastema after 20 days.

Formula for Aging Cotton Rats

The availability of known-age specimens of the five species of cotton rats makes possible the development of an aging formula. To do this, the Multiple Linear Regression Method (Abbreviated Doolittle or Gaus-Doolittle Method) was developed with 9 variables representing a selection of nine (of the 21) measurements for each of the seven age-groups (1-100 days) of each species.

Assuming linear relationships between Y (age) and X (selected parameter), the following formula was applied:

$$Y = a + b_1 X_1 + b_2 X_2 + \ldots\ldots + b_9 X_9$$

with

a : constant (intercept of the line) ≈0

b : constant value obtained from Table 18, specific for appropriate measurements in each species.

X_1 : length of the body.

X_2 : length of the tail.

X_3 : length of the hind-foot.

X_4 : greatest length of the skull.

X_5 : height of the braincase.

X_6 : condylo-basal length.

X_7 : palatal length.

X_8 : length of the rostrum.

X_9 : length of the nasal bone.

Y : age of the specimen measured as determined, after calculations, by consulting Table 19.

The aging-formula was tested with four known-aged cotton rats belonging to each of the five species studied. In 90 percent of the specimens the formula gave the correct age. Consequently, this aging-formula seems useful as another method of aging to add to those now used, including size, wearing of molar teeth, development of skull ridges and condition of pelage.

Table 18. Constant values (b values) for each of the 9 measurements for the five species of Sigmodon.

Species	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9
S.hispidus	0.78	-0.003	1.54	- 0.18	- 0.19	5.10	-13.22	-1.43	- 1.59
S.alleni	-0.20	0.25	-0.24	- 0.27	- 0.23	-0.58	- 0.02	1.64	-1.67
S.fulviventer	0.26	-0.16	0.02	-11.06	13.79	1.15	0.01	-1.81	12.46
S.leucotis	-0.26	-0.03	-0.49	- 0.20	- 0.05	-0.01	0.96	2.20	- 0.84
S.ochrognathus	-0.07	0.03	0.08	0.03	- 5.41	2.47	40.10	-0.22	- 5.98

Table 19. Specific numbers associated with each age-group of cotton rats, when the aging formula is applied.

Species	1 day	10 d	20 d	30 d	40 d	50 d	100 d
S.hispidus	18.80	28.54	37.42	43.97	49.19	52.23	62.06
S.alleni	-20.55	-25.83	-31.42	-34.10	-34.10	-35.70	-40.41
S.fulviventer	1.61	2.02	2.10	2.76	3.64	4.50	4.55
S.leucotis	-11.51	-15.67	-19.52	-21.11	-22.79	-23.37	-26.60
S.ochrognathus	286.97	403.39	434.42	501.81	538.14	556.64	584.34

Growth Rates in Subspecific Crosses in Sigmodon fulviventer

Cotton rats of the species S.fulviventer (see Baker, 1969) range in size (both externally and cranially) from small in northern México (Chihuahua) to large in southcentral México (Jalisco). Since known-age specimens of crosses between parent of S.fulviventer from different localities within this geographic area (see Figure 1) were available for study, measurements were taken to assess the growth rates of the crosses as compared with parent stocks (Table 20).

Three body measurements (lengths of body, tail and hind-foot) and two cranial dimensions (condylo-basal and height of the braincase) were used (see Figures 13-16). The Wilcoxon Rank-Sum Test at 0.05 level was used to determine differences between progeny and parents. No significant differences at 95 percent level were found between the animals studied.

Cotton rats of the cross No. 1 grew more slowly than their parents during the first 20 days of post-natal life in the three body measurements studied (see Figure 13). The growth of the animals of the cross No. 2 is intermediate (Figure 14) in relation to the growth shown by their parents in all the body dimensions used. The cotton rats of cross No. 3 have a growth in the three body dimensions comparable to those of their larger parent (S.f.melanotis) at least

Table 20. Subspecific crosses in *Sigmodon fulviventer*.

Cross No. *	Subspecies involved	Sample size	Localities of parental stocks
1.	*S.f.minimus* x *S.f.fulviventer*	13	
	S.f.minimus	57	vic.Boquilla, Durango
	S.f.fulviventer	60	vic.Coyotes, Durango
2.	*S.f.minimus* x *S.f.fulviventer*	26	
	S.f.minimus	53	vic.Gallego, Chihuahua
	S.f.fulviventer	60	vic.Coyotes, Durango
3.	*S.f.minimus* x *S.f.melanotis*	79	
	S.f.minimus	53	vic.Gallego, Chihuahua
	S.f.melanotis	68	vic.LaBarca, Jalisco

*Number of cross will be referred to in text.

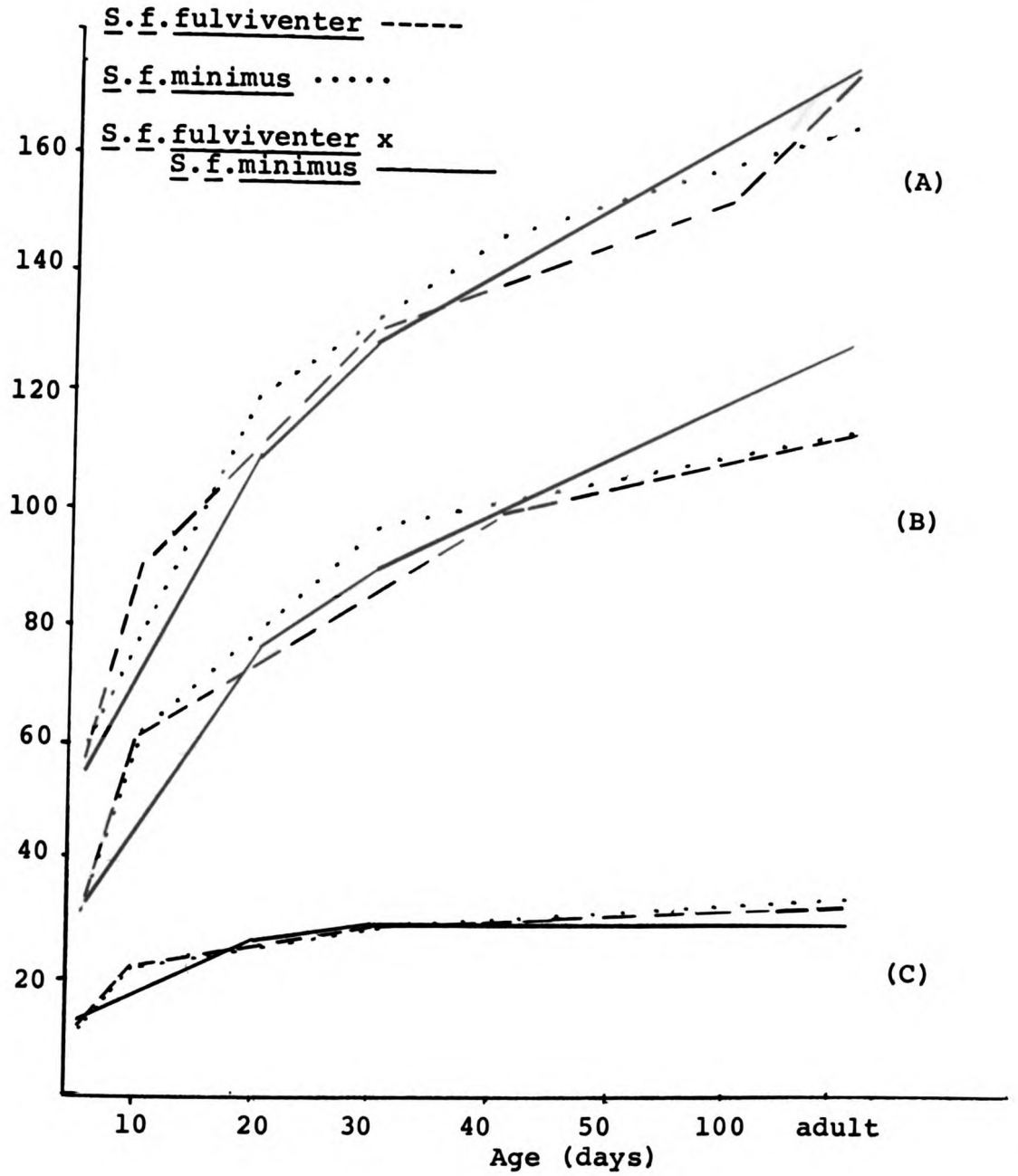


Figure 13. Growth in dimensions of body (A), tail (B), and hind-foot (C) of cotton rats of S.f.fulviventer (Coyotes, Durango), S.f.minimus (Boquilla, Durango), and cross No. 1 (S.f.fulviventer x S.f.minimus).

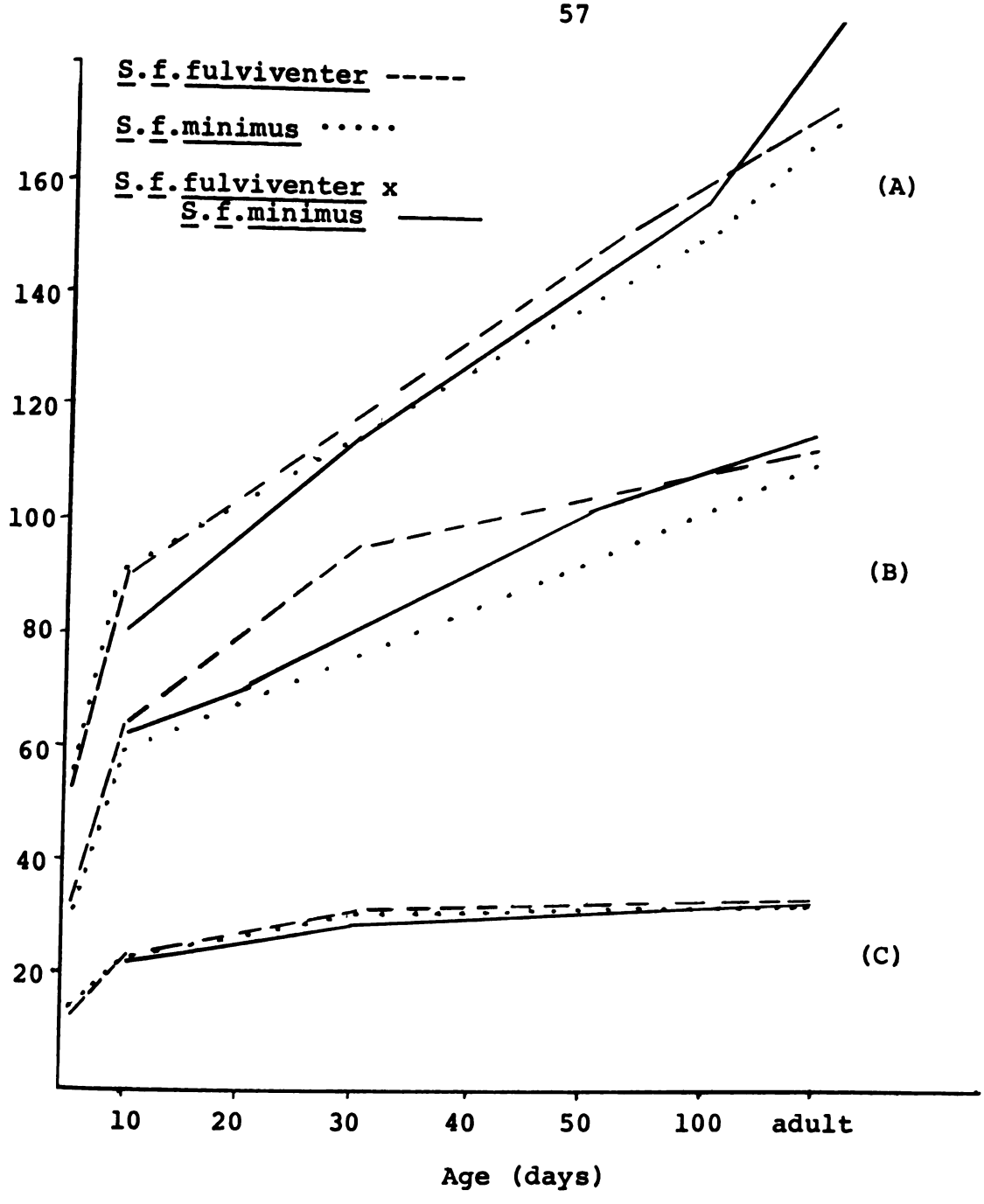


Figure 14. Growth in dimensions of body (A), tail (B), and hind-foot (C) in cotton rats of S.f.fulviventer (Coyotes, Durango), S.f.minimus (Gallego, Chihuahua), and cross No. 2 (S.f.fulviventer x S.f.minimus).

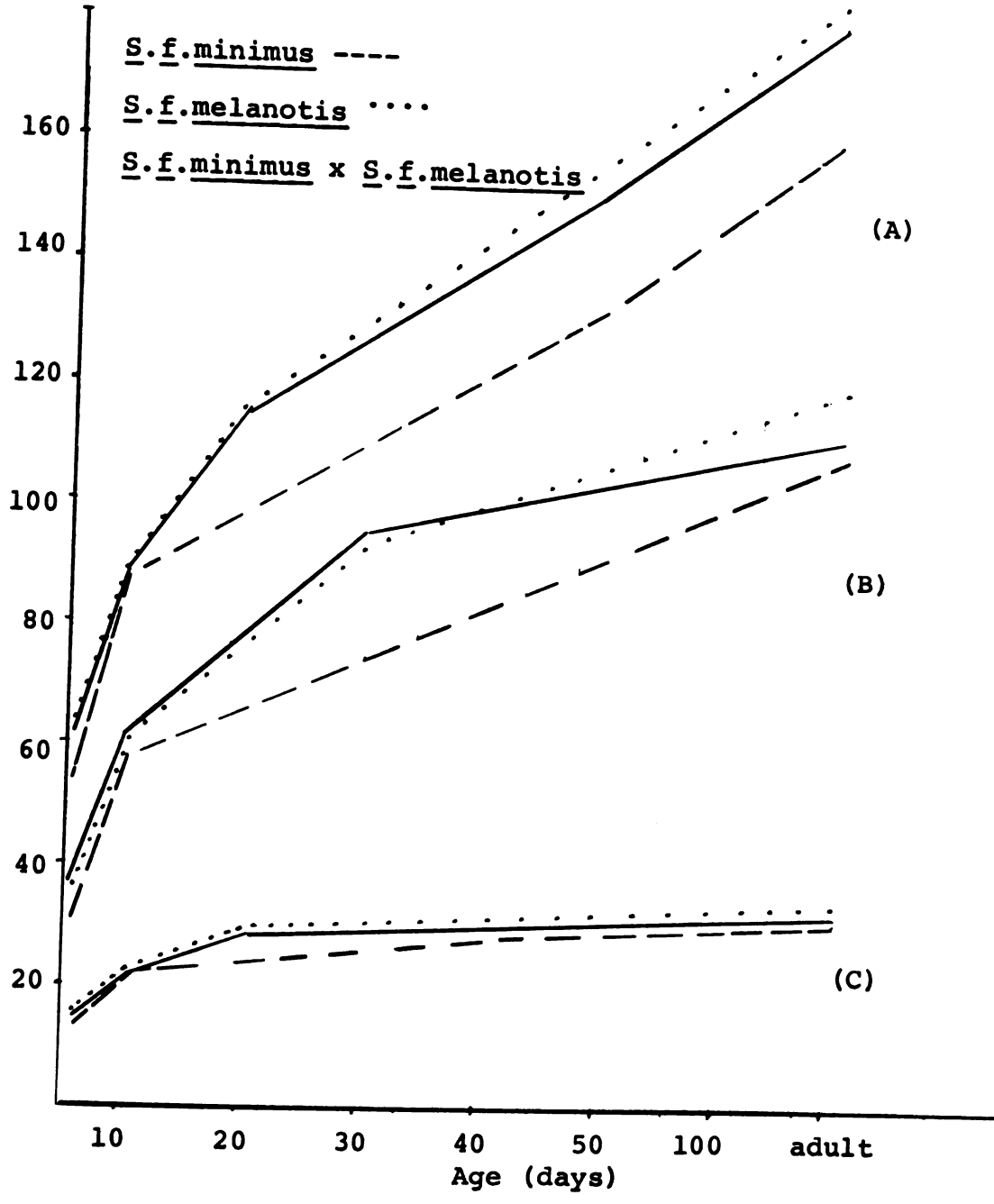


Figure 15. Growth in dimensions of body (A), tail (B), and hind-foot (C) in cotton rats of S.f.minimus (Gallego, Chihuahua), S.f.melanotis (La Barca, Jalisco), and cross No. 3 (S.f.minimus x S.f.melanotis)

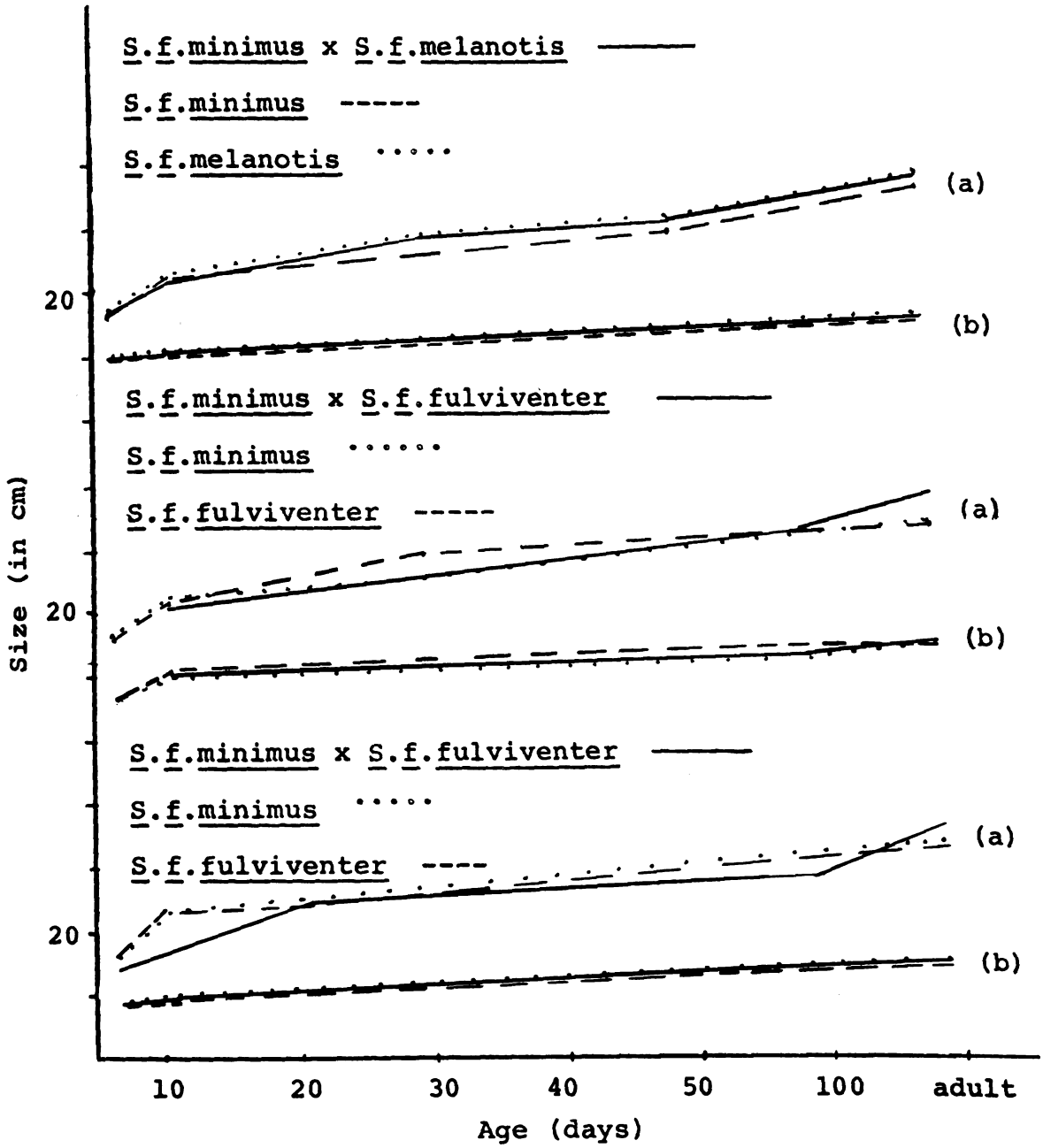


Figure 16. Growth in dimensions of condylo-basal length (a) and height of the skull (b) of the progeny of the crosses Nos. 1, 2, and 3 and their parent subspecies.

until 50 days of age (see Figure 15). Older individuals show that growth in the crosses are somewhat intermediate between the growth of both parents.

The graph curves of the condylo-basal and height of the braincase (see Figure 16) show that there are a somewhat similar growth between the cotton rats of the different crosses and their respective parent subspecies in all the age-groups studied.

DISCUSSION

Massler and Schour (1951) have pointed out that the skull of the albino rat shows two different types of growth. Cotton rats also exhibit two patterns of growth. From one day to 40 days most species of Sigmodon present an accelerated and rapid growth in all the body and cranial dimensions. During this accelerated and generalized phase of growth the increase in body dimensions is almost double (more than 80 percent). The second phase of growth is present during the period of life from 40 days to the adult stage. This period of life may be subdivided into two different growth types. The first one, comprising the period from 40 days to 100 days, results in a more accelerated increase in all the dimensions studied and in most species of cotton rats the adult size is reached in this period of life. The second growth type is considered to be from 100 days to the adult stage. This period is characterized by a gradual cessation of growth. Hoffmeister (1963) demonstrated that there is a little or no further increase in the total length and tail length in S.ochrognathus after 100 days old. Layne (1966) showed

that Peromyscus floridanus reaches 92 percent of the adult size by the eighth week. The same is true for S.hispidus (Meyer and Meyer, 1944) as the growth of individual cotton rats is fairly constant through the first 50 days of life; decreasing somewhat between 50 to 100 days and decreasing markedly after 100 days of age. Dice and Bradley (1942) studied Peromyscus maniculatus and determined that the deer-mice grow rapidly in all body dimensions until they are 6 weeks old. The same authors (1942) have noted that the slowing of growth rate after 4-6 weeks of age is correlated with approaching sexual maturity. Meyer (1942) has demonstrated that female cotton rats have their first estrum between 20 and 30 days of age and that male testes descend to the scrotum at the same time. These ages of attaining sexual maturity correspond well to the age at which the young cotton rats change from a higher rate of growth (1-40 days old) to a much lower growth rate (40-100 days of age). The slopes of the growth curves demonstrated that not all species of Sigmodon grow equally rapidly. The two smallest species S.ochrognathus and S.leucotis (see Figures 7-9) begin to slow their rate of growth at an earlier age (20 days of age) than the largest species, S.hispidus (40-50 days of age). Those species that are intermediate in size, S.alleni and S.fulviventer, begin to reduce their

rate of growth at an age which is somewhat intermediate (30-40 days of life).

Dice and Bradley (1942) stated "... races of deer-mice that are relatively larger or relatively smaller in any dimensions at birth tend to retain these size relationships as they grow to adult size". But cotton rats show a different pattern of growth. The smaller species, S. ochrognathus and S.leucotis, are the largest at one day old. Subsequently with the increase of age, they are exceeded in growth by the other three species of cotton rats (Figures 7-9).

Clark (1936) mentions that ratios between body measurements indicate that the species of the genus Peromyscus differ greatly in body proportions. Likewise, the five species of cotton rats also show marked differences in the comparative growth of different body proportions. The sample of S.hispidus used in this study (S.hispidus major from near Tuxpán, Nayarit), is one of the largest species (Bailey, 1902). The species of the S.fulviventer present interesting patterns of growth. The samples of S.fulviventer show a decline in overall size from north to south (from Chihuahua to Jalisco). The average means for all measurements and the growth rates of S.fulviventer compared favorably with those of S.alleni. The smaller S.leucotis and S.ochrognathus show a somewhat

similar pattern of growth. These relationships between S.alleni and S.fulviventer on one hand and S.leucotis and S.ochrognathus on the other are related in a general sense to environmental adaptations. Sigmodon alleni and S.fulviventer live on deep soils covered with grass and brush. Sigmodon leucotis and S.ochroganthus live on shallow soils on rocky slopes covered with bunch grass and some shrubs.

Fox (1948) in studies with subspecies of Peromyscus maniculatus has demonstrated a direct relationship between tail length and environmental conditions; animals with longer tails live in forested areas while those with shorter tails live in open areas. The hind-feet do not change. Sigmodon hispidus, S.alleni and S.fulviventer have the longest tails and hind-feet of all the species studied and also live on deep soils with grass-shrub cover. Sigmodon leucotis and S.ochrognathus with the shortest tails and hind-feet inhabit shallow soils often covered with sparse bunch grass. Possible, the short tail as well as the small size are of survival value to cotton rats living in sparse overhead cover, especially for avoiding avian predators (hawks and owls) which locate their prey from above by keen eyesight.

The cotton rat skull, with the increase in age, becomes steadily more slender in its proportions. The braincase of Sigmodon becomes progressively deeper but not wider giving

the appearance of increased arching in cross section (Findley and Jones, 1960). The skull of the cotton rat has a pattern of growth different from that shown by external measurements. Its growth is divisible into two well-defined phases: from birth to 100 days and from 100 days to adult stage. Most skull dimensions reach at least minimum adult stage during the first phase of the cranial growth. Changes in the skull length are due to increase in nasal length, or in the length of the braincase, or in both dimensions. This is also emphasized by Hall (1926) who pointed out that most postnatal development of the skull is concerned with muscular development since much of the formation of the brain (and its case) occurred in prenatal time. As is shown in Table 4, the length of the nasals and the condylo-basal length progressively increase during the first 100 days of age, but the breadth of the braincase grows faster than either during the first 20 days of life at which time its size closely approximates that of the adult. The rostral region is small in the newborn, while the braincase in relatively large. With the increase in age, the extension of the nasal bones give the skull of the cotton rats its typical long-snouted appearance. The larger the skull, the narrower it is in relative sense (Findley and Jones, 1960), with the greatest percent of increase in the breadth of the skull being in the

mastoid region which is associated with the increase in growth of the zygomata (see Table 16).

The flattened appearance of old skull of Sigmodon is increased by the developments of crest or ridges (Chipman, 1965). At 20 days to 30 days of life, the frontal bones first show ridging in all species but S.ochrognathus where the ridges do not appear until 30 to 40 days of age.

As was mentioned previously, the one day old rat has small rostrum, a short postpalatal length and a conspicuous, dorsally-expanded braincase (see also Hall, 1926). In subsequent growth, the height of the braincase grows relatively little compared to the lengthening of the rostrum and the postpalatal area. In other words, the basal part of the braincase elongates more rapidly than does the dorsal part increase in size. The dimension of the post-palatal length exceeds that of the height of the braincase in the adults of all species (see Figure 11). But in the growth of the rostrum, its adult dimensions exceeds that of the height of the braincase only in S.hispidus, S.alleni and S.ochrognathus. The growth of the rostrum seems also to be correlated with time of weaning in cotton rats. This event takes place between 10-25 days (Hoffmeister, 1963; Meyer, 1942; Svihla, 1929). As shown in Figure 11 the elongation of the rostrum (as also explained by Hall, 1926) accelerates between 20-100 days of age. This rapid increase

in size appears to be directly correlated with the whole-food-taking function of the rostrum.

Comparison of the growth data obtained from S.hispidus from Tuxpán, Nayarit, with the growth data given by other authors that studied the same species but from different localities, shows that the Tuxpán sample is one of the largest of the species. It is also much larger than any of the samples of other species of cotton rats studied herein.

In viewing the growth data of the S.fulviventer group it may be possible to separate the four species composing this group into two categories: (1) S.alleni and S.fulviventer and (2) S.leucotis and S.ochrognathus. The former group show the larger dimensions at the adult stage and the latter group the smaller. As Baker (1969) has pointed out, S.leucotis and S.ochrognathus may have separated earlier from the ancestral stock of S.hispidus than S.alleni and S.fulviventer. This earlier separation from the S.hispidus stock may account for the great amount of distinctive variation in body and cranial features common to both species. The distinction showed by S.alleni and S.fulviventer, however, show their closer relationship to S.hispidus.

SUMMARY

Laboratory-raised cotton rats of the five recognized species in the genus Sigmodon were killed at predetermined intervals (1, 10, 20, 30, 40, 50, 100, and 200-400 days after birth) and prepared as museum study specimens. These known-age animals were then used to study differences and similarities between the population samples of these rodents. Postpalatal growth was determined by making a series of 21 external and cranial measurements of these known-age samples (a total of 610 specimens). Some sexual dimorphism was found in S.hispidus and S.alleni but was discounted because of the small sample being used.

In external features, body length increased rapidly from one day to 40 days. From 40 days to 100 days this growth rate was slower and from 100 days to adulthood (200-400 days)growth practically ceased. The population sample of S.hispidus was the largest while those of S.alleni and S.fulviventer showed an intermediate size and those of S.leucotis and S.ochrognathus were smallest. The tail and hind-foot in all species lengthened to adult size in the first 40 days with S.hispidus having the longest appendages and S.leucotis the shortest.

At birth the skull is oval in shape as the result of the large expansion of the well-developed braincase and the lack of growth of the rostrum. In all species, the braincase continues to expand in the first 20 days of post-natal life to near the adult size. Subsequently, the skull begins to lengthen rapidly with the development of the rostral area and the extension of the bones at the base of the braincase. This growth transforms the rounded form into the long-snouted condition typical of the adult cotton rat. The adult size is attained in the first 100 days.

Skull measurements made show the correlation between the initial rapid expansion of the braincase and the subsequent extension of the rostrum and basal part of the braincase. Measurements which reflect the development of the braincase are taken of the breadth and the height of this feature. Those which reflect the elongation of the skull are taken of the length of the rostrum and the postpalatal length.

Normally the height of the braincase has a greater dimension than the postpalatal length in the first days after birth. However, at the 20-30 days period, the growth of the postpalatal area increases to surpass in size the former feature. In three species, S.hispidus, S.alleni and S.ochrognathus, the rostral length exceeds in size the height

of the braincase only after the animals are older than 100 days.

By the time the animals are 40 days old the palatal length and the length of the maxillary tooth-row are near the adult size, while the diastema is 50-67 percent (depending on species) of the adult size. At birth the zygomatic arches are small but expand rapidly laterally compared with the slower-growing braincase. This development along with the lengthening in the rostral region have to do with the time of the weaning and development of the masticatory and facial muscles. Also, the change of the growth from an accelerated phase (1-40 days) to a much slower rate (40-100 days) seems correlated with the time of sexual maturity in these species.

The smallest species, S.leucotis and S.ochrognathus, are actually the largest at birth; however, the other species exceed them in size shortly thereafter. The population sample representing the wide-spread S.hispidus reaches the largest dimensions, with S.alleni and S.fulviventer in slightly smaller position. Ecologically, these three larger species are usually associated with deep soils covered with heavy grass and brush. The two smaller species seemingly prefer shallow soils on rocky slopes covered with scattered bunch grass and some shrubs. The short tails and small body size of S.leucotis and

S.ochrognathus may be of survival value to them on rocky hillsides having sparse overhead cover.

Sigmodon leucotis and S.ochrognathus show patterns of growth sufficiently different to set them apart from the other species. If all modern species of cotton rats were descended from a single hispid-like ancestoral stock, these morphological findings indicate that S.leucotis and S.ochrognathus may have evolved at a different time, perhaps more remotely, than S.alleni and S.fulviventer, which have developmental characteristics more closely resembling S.hispidus.

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APPENDICES

APPENDIX A

Average and Extreme Measurements of the Five Species of *Sigmodon* in Eight Age Classes

Appendix A - Table 1. Sigmodon hispidus major

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-7	10-6	20-6	30-4	40-8	50-6	100-6	Adult-27
Length of body	55.6 48-61	86.7 83-91	110.0 89-118	129.8 122-135	143.8 132-157	150.3 140-161	176.8 165-207	203.7 173-217
Length of tail	37.3 30-43	66.5 62-75	86.6 73-97	112.8 100-120	116.6 108-128	122.0 110-129	129.0 100-150	130.3 100-139
Length of hind-foot	14.6 13-16	23.8 23-25	29.8 27-31	34.3 31-36	36.4 34-39	37.0 36-39	39.2 38-42	40.9 37-43
Greatest leng. skull	17.1 16.9-17.2	24.0 23.2-25	27.5 25.8-28.5	30.3 29.3-31.5	31.8 29.9-33.4	32.7 32-34	36.0 31.2-40.3	42.2 40.5-44.6
Height of braincase	8.5 8.1-8.6	10.8 10.5-10.9	11.6 11-12.2	12.1 11.7-12.5	12.6 12.2-13	12.9 12.7-13.1	13.0 11.8-14.8	15.8 14.8-17.3
Condylo-basal leng.	16.1 15.9-16.3	21.7 20.9-22.8	25.1 23.5-26.2	28.4 27.2-29.6	30 28-32	31.3 30.3-32.3	34.6 29.9-38.8	40.9 39.1-42.5
Basal length	14.7 14-16	19.5 18.8-20.2	22.9 21.6-23.9	26.4 25.7-27.2	27.6 25.6-29.1	29.8 27.7-29.7	32.1 27.5-36.2	35.7 31.7-40.8
Basilar length	13.4 13-15	18.3 17.4-19.2	21.7 20.5-22.6	24.9 24.4-25.4	25.7 23.6-27.1	26.8 25.9-27.7	29.9 25.4-33.9	33.8 30.8-38.2
Palatal length	8.4 8-8.6	10.8 10-12.2	14.0 12.9-14.6	16.0 15.2-16.7	17.0 15.6-18.2	17.7 17-18.4	19.6 16.3-22.5	23.5 21.7-24.9
Palatilar length	7.4 7.3-7.5	10.5 9.9-10.9	12.7 11.6-13.2	14.4 13.7-15	15.1 13.7-16	15.4 15-16.2	17.1 13.5-19.8	20.3 18.6-21.2

"Appendix A - Table 1 (cont'd.)"

Palatal bridge	4.2 4.1-4.3	5.0 4.8-5.2	5.7 5-6.2	6.4 6.1-6.5	6.6 6.2-6.8	6.7 6.5-7.2	7.1 6-7.9	8.1 6.9-9.1
Length of rostrum	5.1 5-5.3	7.8 7.3-8.3	9.3 8.4-9.7	10.9 10.3-11.5	11.6 10.7-12.3	11.9 11.1-12.7	13.6 11.9-15.6	16.6 15.6-17.8
Width of rostrum	4.4 4.3-4.5	5.1 4.9-5.3	5.4 5.1-5.6	5.8 5.3-6.5	6.3 6.1-6.6	6.7 6.4-7.1	7.3 6.6-8.2	8.9 8-9.9
Least interorbital breadth	4.6 4.5-4.7	4.6 4.5-4.8	4.6 4.4-4.8	4.8 4.5-5.1	4.8 4.6-5	4.8 4.6-5	5.0 4.6-5.4	5.6 5.2-6.2
Interparietal breadth	8.0 7.8-8.4	9.4 8.7-10.2	10.4 10.2-10.8	10.3 9.9-11	10.4 9.8-10.5	10.9 10.5-11.2	11.3 10.8-11.5	12.1 11.2-13.3
Breadth braincase	10.6 10.3-10.8	12.5 12.4-12.7	13.4 13.1-13.7	13.7 13.2-14.4	14.6 14.3-15.2	14.8 14.5-15.2	15.0 14.8-15.5	16.4 15.5-17.6
Zygomatic breadth	10.0 9.8-10.2	13.5 13.3-13.8	15.4 14.3-16.1	17.2 16.1-18	18.1 17.3-19.3	18.8 18.3-19.2	20.5 18.2-22.9	23.7 22.1-25.4
Alveolar length of molar tooth row	4.2 4-4.3	5.7 5.5-5.8	5.9 5.6-6.3	6.9 6.2-7.1	6.9 6.6-7.3	7.1 6.7-7.5	7.1 6.2-8	7.6 7.1-8.2
Length of diastema	4.0 3.9-4.2	5.0 4.5-5.2	6.4 5.6-7	7.7 7.1-8.4	8.1 7.3-8.6	8.4 8-9	9.8 7.7-11.6	12.3 11.1-13.1
Length incisive foramen	2.4 2.2-2.5	4.3 4.1-4.6	5.6 5.3-5.9	6.4 5.9-7	6.9 6.3-7.5	7.1 6.8-7.4	8.0 6.5-9.4	9.9 9.5-10.5
Length of nasal	4.9 4.8-5.2	7.7 7.5-8.2	9.3 8.3-9.8	10.5 10-10.9	11.4 10.4-12.2	11.7 10.7-12.5	13.3 11.7-15.3	16.5 15.3-18

Appendix A - Table 2. Sigmodon alleni

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-9	20-6	30-4	40-5	50-9	100-6	Adult-33
Length of body	55.2 48-63	78.8 65-91	103.7 99-107	117.5 104-132	122.3 116-135	126.4 123-138	153.8 143-160	161.7 143-183
Length of tail	32.0 29-36	61.9 52-70	81.8 78-86	92.8 81-102	96.8 89-109	99.4 98-117	117.5 113-121	119.6 88-122
Length of hind-foot	12.5 12-13	22.1 20-25	26.5 23-28	28.5 26-30	30.0 28-32	30.7 30-33	32.3 31-33	32.3 30-35
Greatest leng. skull	17.9 17.8-18	23.2 22.3-24.6	26.6 26-27.8	28.6 27.5-29.1	29.0 28-30.7	30.9 29.7-32.1	33.3 32.1-34.4	36.0 33.4-37.8
Height of braincase	8.5 8.3-8.6	9.6 9-10	10.6 10.3-11.4	11.3 10.5-12.2	11.5 11-12.1	11.5 11.1-12	12.3 11.9-12.9	13.2 12.2-13.9
Condylo-basal leng.	15.0 13.9-17.1	21.1 19.9-21.5	24.6 24.2-25.5	26.6 25.8-27.3	26.9 26.3-28.9	28.4 27.2-30.3	31.4 30.4-32.4	34.3 31.9-35.8
Basal length	15.2 15-15.6	19.4 18.4-20	22.7 22.4-23.4	24.4 23.4-25.3	24.4 23.4-26.6	26.1 25.1-27.8	29.3 28.5-30	31.9 29.4-33.4
Basilar length	14.8 13.3-15.4	18.1 17.2-19.1	21.0 20.6-21.7	22.3 21.4-23.2	22.5 21.5-24.5	23.9 23-25.2	26.6 25.4-27.4	29.3 26.8-30.5
Palatal length	6.8 6.3-8.4	11.4 10.8-11.9	13.4 12.8-14.1	14.8 14.5-15.1	14.9 14.4-15.7	15.7 15.3-16.4	17.6 17.3-18.1	19.1 17.4-19.9
Palatilar length	5.8 5.3-7.6	10.0 9.3-10.7	11.7 11.1-12.2	12.6 12.3-13	12.8 12.2-13.7	13.5 13.4-14.2	14.9 14.4-15.5	16.1 15.1-17.1

"Appendix A - Table 2 (cont'd.)"

Palatal bridge	4.2 3-5.1	5.1 4.8-5.7	5.7 5.2-6	6.2 6.1-6.2	6.2 5.6-6.7	6.4 6.3-7.1	7.1 6.8-7.7	7.4 6.6-7.7
Length of rostrum	5.5 5.2-5.8	8.2 8-9	9.5 9.2-9.9	10.2 9.8-10.7	10.7 10.5-11.7	11.5 10.5-12	12.8 12.2-13.7	14.1 12.1-15.2
Width of rostrum	4.5 4.4-4.6	4.6 4.1-4.9	5.4 5.2-5.6	5.7 5.3-6.2	5.8 5.4-6.2	6.0 5.8-6.4	6.7 6.5-7	7.5 6.6-8.3
Least interorbital breadth	4.4 4.3-4.7	4.5 4.3-4.8	4.6 4.5-4.9	4.6 4.3-4.8	4.8 4.6-5	4.9 4.8-5.2	5.1 4.9-5.5	5.4 4.9-5.5
Interparietal breadth	8.5 8.4-8.7	9.9 9.8-10.2	10.1 9.8-10.8	10.6 10.5-10.8	10.3 9.9-11.3	10.9 10.7-11.2	11.2 10.9-11.6	11.3 10.3-13.1
Breadth braincase	10.5 10.3-10.8	12.1 11.9-12.4	12.4 11.9-13	12.5 12-13.2	12.9 12.8-13.5	13.0 12.7-13.6	13.2 12.9-13.7	14.2 13.2-14.9
Zygomatic breadth	9.7 9.1-10.6	12.9 12.6-13.2	14.7 14.2-15.1	15.6 14.8-16.4	16.2 15.7-17.2	16.9 15.9-18	18.1 17.6-19	20.0 18.1-20.7
Alveolar length of molar tooth row	3.8 3.5-4.2	5.4 4.7-5.5	5.7 5.4-6.1	6.2 5.9-6.4	6.2 5.9-6.3	6.2 6.1-6.3	6.3 6.1-6.5	6.3 5-6.9
Length of diastema	3.9 3.5-4.2	4.7 4.4-5.1	5.7 5.2-6.2	6.4 5.9-6.9	6.7 6.6-7.6	7.3 6.8-8.1	8.6 8.2-9.3	9.7 8.8-10.4
Length incisive foramen	1.9 1.4-2.2	3.8 3.4-4.3	4.6 4.3-5.1	5.1 4.5-5.6	5.4 4.9-6.1	5.7 5.5-6.3	6.5 6-6.6	7.6 6.1-8.4
Length of nasal	4.4 3.9-5	7.6 6.9-8.7	8.1 7.6-10.1	10.6 10.2-11.3	10.8 10.7-11.7	11.9 10.4-12.7	13.1 12.3-14.5	14.6 12.9-15.9

Appendix A - Table 3. Sigmodon fulviventer

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-31	10-27	20-24	30-36	40-25	50-27	100-23	Adult-166
Length of body	53.5 48-64	88.4 78-97	110.9 98-122	128.0 114-154	137.4 117-157	141.4 122-156	159.0 138-188	165.8 140-186
Length of tail	33.6 27-40	60.7 56-68	77.8 66-84	91.6 72-105	96.0 76-113	99.0 79-107	106.3 82-126	109.7 86-133
Length of hind-foot	13.3 11-15	22.4 20-25	27.1 26-30	30.2 28-35	31.4 29-34	32.3 27-34	32.7 28-36	33.3 27-35
Greatest leng. skull	17.9 16.3-19.8	23.4 22.2-26	26.4 26.6-28.7	29.7 27.6-31.6	30.5 28.8-33.1	31.4 27.7-32.7	32.6 29.4-36.9	36.6 32.2-40.1
Height of braincase	9.0 8.5-9.8	10.7 9.7-11	11.3 11-12.7	12.2 11.8-13.4	12.5 11.9-13.3	12.8 11.6-13.7	13.3 12.3-14.4	14.6 13-15.8
Condylo-basal leng.	16.2 15.3-17.5	21.5 20-24.4	24.7 23-27.4	28.3 26-32.9	29.1 27.2-30.7	30.2 26.4-31.8	32.4 28.2-36.7	35.6 30.9-39.7
Basal length	14.3 13.9-15.7	19.3 18.8-22.4	21.5 20.8-24.2	26.1 23.8-30.3	26.6 24.6-28.4	27.7 24.2-28.8	28.9 26.2-33.4	31.5 28.6-37.2
Basilar length	13.2 13-14.8	17.9 17.5-20.9	20.0 19.4-22.8	24.3 22.4-27.9	24.6 23-26.8	26.1 22.8-26.9	26.9 24.3-31	30.1 26.5-33.7
Palatal length	8.7 8.2-9.6	11.9 11.1-13.6	13.8 13-14.9	15.7 14.9-17.8	16.4 14.5-17.3	17.1 14.6-18.2	18.3 16-20.2	20.3 17-22.2
Palatilar length	6.8 6.5-8.4	10.2 9.8-12.4	11.5 11-13.3	13.8 13.3-15.7	14.2 13-15.6	15.5 13-15.9	16.1 13.9-18.1	18.1 14.9-20.3

"Appendix A - Table 3 (cont'd.)"

Palatal bridge	4.0 3.4-4.7	4.9 4-6	5.3 4.7-5.8	5.9 5-6.9	5.9 5-6.4	6.2 5.1-6.8	6.4 4.7-7.1	7.1 5.4-8
Length of rostrum	5.3 4.6-6.1	7.7 7.1-9	9.2 8.5-10	10.7 9.5-14.3	11.6 10.5-11.8	11.6 9.8-12.3	12.7 11.8-13.7	14.3 12.7-15.7
Width of rostrum	3.8 3.2-4.7	4.9 4.4-5.3	5.4 5-6.1	6.0 5.2-7.4	6.2 5.8-7	6.3 5.3-6.9	6.6 5.6-7.7	7.3 6.1-8.6
Least interorbital breadth	3.9 3.5-4.7	4.4 4.1-5	4.4 4.2-5	4.6 4.2-5	4.6 4.2-4.9	4.6 4.1-5	4.8 4.3-5.4	5.2 4.5-6
Interparietal breadth	8.5 7.7-9.4	10.0 9-11.3	10.5 9.8-11.3	11.0 10.3-11.9	11.2 10.5-11.8	11.5 10.9-12.4	11.5 10.5-12.5	12.7 11.6-14.6
Breadth braincase	10.2 9.7-10.8	11.4 10.8-12.9	13.1 12.6-13.5	13.7 13.1-14.3	14.1 13.5-15.1	14.2 12.8-15.8	14.5 13.6-15.2	15.7 14.4-17.5
Zygomatic breadth	10.4 9.6-11.1	13.5 12.7-15.1	15.5 15.1-16.3	17.7 16.8-19.6	18.2 17.2-19.1	18.5 16.4-20	19.5 17.3-20.9	20.9 17.9-23.4
Alveolar length of molar tooth row	4.3 3.5-5	5.6 5.2-6.4	6.0 5.5-6.7	6.5 6-6.9	6.5 6.1-7	6.6 5.7-6.9	6.7 6.3-7.5	6.7 6.2-7.3
Length of diastema	3.7 3.3-4.2	5.2 4.4-6.9	6.2 5.8-6.9	7.5 6.7-9	8.0 7-8.8	8.4 7.2-9	9.2 7.9-10.8	10.7 9-12.2
Length incisive foramen	2.5 2-3.2	4.4 3.5-5.5	5.6 4.8-6.1	6.5 5.8-8	6.9 5.7-8.1	7.1 6.5-7.8	7.7 5.7-9.4	8.7 7-10.3
Length of nasal	4.6 3.9-4.9	7.1 6.6-8.8	8.8 8.2-9.8	9.9 9.1-14.3	10.8 9.6-11.3	11.3 9.4-12.1	12.2 10.6-13.9	13.9 12-15.7

Appendix A - Table 4. Sigmodon leucotis

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-4	10-5	20-2	30-0	40-2	50-0	100-3	Adult-31
Length of body	57.8	79.0	93.0	-	112.0	-	141.0	153.9
	55-62	76-80	88-98	-	111-113	-	132-149	140-169
Length of tail	32.0	47.5	64.0	-	80.0	-	86.0	101.1
	30-36	47-48	60-68	-	80	-	69-96	87-117
Length of hind-foot	14.0	20.0	23.0	-	25.5	-	27.3	30.2
	13-15	19-21	23	-	25-26	-	27-28	28-31
Greatest leng. skull	18.7	22.9	24.7	-	28.0	-	31.2	35.4
	17.4-19.8	22-23.1	24.2-25.2	-	25.9-30.1	-	30-31.3	33.4-37
Height of braincase	9.4	10.5	10.9	-	11.9	-	13.3	14.1
	9.3-9.8	10.2-10.7	10.8-11	-	11.2-12.6	-	13.1-13.5	13.6-14.6
Condylo-basal leng.	16.9	21.0	23.1	-	26.3	-	30.2	33.7
	15.8-17.9	20.1-21.4	22.5-23.7	-	24.3-28.3	-	30-30.5	32.4-35.4
Basal length	15.6	19.3	21.2	-	24.2	-	28.0	31.4
	14.4-16.3	18.7-19.9	20.5-21.9	-	22.3-26.1	-	27.6-28.5	30.5-33.4
Basilar length	14.7	18.7	20.2	-	22.7	-	26.0	29.2
	13.4-15.9	18-19.2	19.5-20.9	-	21-24.4	-	25.8-26.3	28-31.4
Palatal length	8.2	11.3	12.9	-	14.8	-	16.3	19.1
	8-9	10.8-11.7	12.5-13.3	-	13.6-16	-	15.6-17.8	18.2-20.1
Palatilar length	8.0	10.4	11.9	-	13.3	-	15.0	16.6
	7.5-8.5	10-10.8	11.4-12.4	-	12.2-14.4	-	14.4-16.3	15.9-17.7

"Appendix A _ Table 4 (cont'd.)"

Palatal bridge	3.9 3.8-4	4.5 4.4-4.6	5.2 5.1-5.3	- -	5.9 5.6-6.2	- -	6.5 6.3-6.9	6.7 6.1-7.3
Length of rostrum	5.2 4.9-5.7	7.1 6.7-7.5	8.1 8-8.2	- -	9.6 8.8-10.4	- -	10.8 10.6-10.9	13.8 12.8-14.7
Width of rostrum	4.3 4.2-4.5	4.7 4.4-4.9	5.0 4.9-5.1	- -	5.7 5.3-6.1	- -	6.7 6.5-7	7.7 6.9-8.3
Least interorbital breadth	4.5 4.4-4.6	4.5 4.4-4.7	4.6 4.6	- -	4.6 4.5-4.7	- -	5.0 4.9-5.2	5.1 4.9-5.4
Interparietal breadth	8.3 8.1-8.4	9.3 9.2-9.5	10.8 10.8	- -	10.5 9.8-11.2	- -	11.8 11.7-11.9	12.2 11.5-12.9
Breadth braincase	10.5 10.2-11.1	12.3 12.2-12.5	13.0 12.9-13.1	- -	14.0 13.3-14.7	- -	14.6 14.6	15.3 14.8-16
Zygomatic breadth	10.6 10.4-11	13.0 12.6-13.4	14.6 14.3-14.9	- -	16.5 15.1-17.9	- -	18.3 18.1-18.5	19.8 19.3-20.8
Alveolar length of molar tooth row	4.2 3.7-4.4	5.3 5-5.6	5.5 5.3-5.7	- -	6.3 6-6.6	- -	6.3 6.1-6.5	6.6 6-7.2
Length of diastema	4.2 4.1-4.6	5.4 5.1-5.7	6.0 5.7-6.3	- -	7.1 6.5-7.7	- -	8.8 8.4-9.5	9.8 9.4-10.5
Length incisive foramen	2.8 2.4-3.3	4.3 4-4.6	4.6 4.4-4.8	- -	5.7 5.2-6.2	- -	7.0 6.6-7.4	7.4 7-8.5
Length of nasal	4.6 4.2-5.3	6.5 5.9-6.8	7.9 7.7-8	- -	9.1 8.6-9.6	- -	11.2 10.3-12.5	12.8 11.8-13.4

Appendix A - Table 5. Sigmodon ochrognathus

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-5	20-6	30-0	40-5	50-6	100-6	Adult-31
Length of body	52.0	75.2	96.3	-	128.4	131.7	138.8	150.0
	49-55	73-80	84-104	-	123-131	116-137	130-149	141-175
Length of tail	32.8	59.2	65.3	-	102.0	102.3	102.5	103.8
	31-34	56-61.2	45-73	-	99-109	94-105	83-120	64-113
Length of hind-foot	12.8	19.6	24.8	-	28.0	28.8	29.0	30.7
	12-13	18-20	23-26	-	27-31	28-29	29-30	26-30
Greatest leng. skull	17.2	23.1	24.5	-	29.2	29.9	32.0	33.8
	16.6-17.5	21.5-27	23.2-25.5	-	28.1-30	28.3-30.1	30.8-36	32.6-34.9
Height of braincase	8.7	10.2	10.5	-	11.5	11.6	12.4	12.8
	8.3-9	9.7-11.2	10.2-10.8	-	11.3-11.8	11.3-11.7	11.9-14	12-13.9
Condylo-basal leng.	15.3	21.2	22.5	-	26.3	27.8	30.2	32.1
	15.1-15.7	19.1-25.7	21.1-23.7	-	25.3-27.8	26.4-27.6	28.6-34.9	31-33.4
Basal length	13.9	19.3	20.5	-	25.0	25.7	27.9	29.9
	13.7-14.1	17.2-23.6	19.2-21.7	-	24-25.4	25.1-27	26-32.3	28.5-31.7
Basilar length	12.8	17.8	19.0	-	23.1	23.7	25.8	27.8
	12.2-13.3	15.9-21.5	17.7-19.8	-	22.4-23.4	23-25.1	23.7-29.9	26.6-29.7
Palatal length	8.1	11.3	12.2	-	15.1	15.0	16.9	17.9
	7.8-8.5	10.2-14.6	11.4-13	-	14.8-15.2	14.5-15.5	16.1-19.6	17-18.7
Palatilar length	7.0	9.8	10.6	-	12.9	13.2	14.6	15.6
	6.5-7.8	8.9-12.3	10-11.3	-	12.7-13.3	12.4-13.3	13.7-17.1	14.4-16.9

"Appendix A - Table 5 (cont'd.)"

Palatal bridge	3.6	4.7	4.9	-	5.8	5.9	6.3	6.6
	3.4-3.8	4.3-5.9	4.3-5.4	-	5.5-6.3	5.6-6.1	5.9-6.8	5.7-7
Length of rostrum	4.8	7.6	8.5	-	10.8	10.9	12.3	13.1
	4.7-5.1	6.7-9.9	7.8-9	-	10-11.3	10.6-11.7	11.4-14	12.3-13.9
Width of rostrum	4.1	4.9	5.1	-	6.1	6.3	6.7	7.1
	3.9-4.3	4.5-5.7	4.7-5.4	-	5.7-6.3	6-6.7	6.2-7.5	6.5-8.1
Least interorbital breadth	4.2	4.4	4.3	-	4.7	4.6	4.9	5.0
	4-4.3	4.3-4.5	4.2-4.5	-	4.6-4.8	4.5-4.8	4.7-5.1	4.6-5.3
Interparietal breadth	7.7	9.7	9.6	-	10.4	10.7	10.2	11.7
	7.5-8	9.3-11	9.2-10.1	-	10.2-10.9	10.2-10.9	9.6-11.4	11-12.6
Breadth braincase	9.8	12.0	12.6	-	13.4	13.5	13.9	14.8
	9.6-10.2	11.4-13.1	12.1-13.2	-	13.2-13.7	13.3-13.8	13.5-14.9	14-15.9
Zygomatic breadth	9.9	10.6	14.5	-	17.0	16.9	18.6	19.3
	9.6-10.3	10.3-12.3	13.4-15.5	-	16.5-17.5	16.3-17.6	17.7-21.2	18.4-20.5
Alveolar length of molar tooth row	3.7	5.2	5.3	-	6.2	6.3	6.3	6.3
	3.4-3.9	4.8-6	5.2-5.6	-	6-6.3	6.2-6.4	6.1-7.3	5.7-6.5
Length of diastema	3.8	4.8	5.5	-	6.9	6.9	8.3	9.1
	3.4-4.1	3.9-6.7	5.1-6.1	-	6.8-7	6.7-7.1	7.5-10	8.2-9.7
Length incisive foramen	2.5	3.9	4.3	-	5.6	5.7	6.8	7.1
	2.3-2.8	3.5-5	4.1-4.6	-	5.1-5.8	5.4-5.9	6.2-8.6	6.6-7.6
Length of nasal	4.4	7.3	8.3	-	9.1	10.2	12.2	13.0
	4.1-4.6	6.2-10.1	7.8-9	-	8.5-11.2	9.9-10.8	11.1-13.8	11.9-13.9

APPENDIX B

Average and Extreme Measurements of the Progeny of Crosses and Their Parent Subspecies

Appendix B - Table 1. *Sigmodon fulviventer minimus* x *S. fulviventer melanotis*
(Gallego, Chihuahua) (La Barca, Jalisco)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-6	20-6	30-6	40-6	50-6	100-12	Adult-31
Length of body	62.8 61-64	91.2 88-97	118.3 114-124	134.0 131-136	145.0 145-148	155.5 130-139	158.6 150-172	184.4 156-200
Length of tail	37.7 34-41	63.2 55-67	81.2 76-90	97.8 92-110	101.0 95-109	102.3 94-102	109.1 105-125	113.7 88-129
Length of hind-foot	14.8 14-15	22.5 22-24	29.3 29-30	31.7 31-33	31.8 31-33	32.3 32-33	32.6 31-35	32.9 30-35
Height of braincase	9.3 9-9.7	10.5 10.3-10.6	11.4 11.2-11.8	12.1 11.9-12.4	12.7 12.6-12.8	12.8 12.7-13.1	13.7 13.4-14.5	14.7 14.1-15.9
Condylo-basal leng.	17.0 16.1-18	21.6 20.8-22.4	25.4 25-25.9	28.1 27.3-28.9	29.5 29.2-29.7	29.9 29.1-30.7	33.6 32.2-34.4	36.6 34.6-38.3

Appendix B - Table 2. *Sigmodon fulviventer minimus* x *S.f.fulviventer*

(Gallego, Chihuahua) (Coyotes, Durango)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-0	10-6	20-2	30-1	40-0	50-6	100-6	Adult-5
Length of body	-	79.8	99.0	114.0	-	135.8	155.3	183.7
	-	73-88	98-100	114	-	131-144	146-158	177-189
Length of tail	-	62.3	70.0	82.0	-	101.2	104.8	116.2
	-	56-63	67-73	82	-	94-110	69-122	114-119
Length of hind-foot	-	21.0	25.0	28.0	-	30.5	31.8	32.0
	-	20-22	25	28	-	29-32	30-33	30.2-33.8
Height of braincase	-	10.6	11.0	11.6	-	12.6	13.3	15.2
	-	10.4-10.8	11	11.6	-	12.2-12.8	13.1-14.1	14.6-15.8
Condylo-basal leng.	-	20.4	23.3	-	-	29.3	32.3	38.4
	-	19.7-21.5	23.1-23.5	-	-	27.8-30.8	31.2-33.7	36.4-40

Appendix B - Table 3. *Sigmodon fulviventer minimus* x *S.f.fulviventer*

(Boquilla, Durango) (Coyotes, Durango)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-0	20-2	30-4	40-0	50-0	100-0	Adult-1
Length of body	55.0	-	108.5	128.5	-	-	-	180.0
	50-61	-	108-109	124-136	-	-	-	180
Length of tail	32.5	-	76.0	89.5	-	-	-	128.0
	31-34	-	73-79	83-97	-	-	-	128
Length of hind-foot	12.8	-	26.5	29.8	-	-	-	30.0
	12-13	-	26-27	29-31	-	-	-	30
Height of braincase	9.0	-	11.3	12.0	-	-	-	15.3
	8.9-9.3	-	11.3	11.8-12.1	-	-	-	15.3
Condylo-basal leng.	15.4	-	24.4	27.4	-	-	-	36.4
	15-15.9	-	23.9-24.9	26.9-28.2	-	-	-	36.4

Appendix B - Table 4. *Sigmodon fulviventer minimus*
(Gallego, Chihuahua)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-3	10-3	20-2	30-0	40-4	50-6	100-5	Adult-30
Length of body	55.3	90.7	102.0	-	120.0	135.2	143.2	164.7
	51-59	88-93	102	-	117-122	122-144	138-155	142-177
Length of tail	31.3	59.3	87.2	-	77.8	92.2	92.4	109.7
	28-35	57-61	86.6-87.8	-	76-79	79-101	83-101	85-133
Length of hind-foot	12.7	23.0	26.0	-	29.3	30.0	30.6	30.9
	12-13	22-24	26	-	29-30	27-32	30-32	27-35
Height of braincase	8.5	10.7	11.5	-	10.8	12.4	13.2	14.7
	8.5-8.6	10.5-10.8	11-12	-	10.5-11.9	11.6-12.9	12.4-14.4	13.2-16
Condylo-basal leng.	15.8	21.7	25.5	-	23.4	28.6	30.1	34.7
	15.3-16.4	21.5-21.9	25-26	-	22.2-24.2	26.4-29.6	29.3-30.4	33.1-38.1

Appendix B - Table 5. *Sigmodon fulviventer minimus*
(Boquilla, Durango)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-10	10-3	20-1	30-5	40-2	50-5	100-1	Adult-30
Length of body	56.3	83.3	118.0	123.5	145.5	139.4	160.0	163.3
	49-63	79-86	118	122-125	139-147	135-140	160	141-172
Length of tail	32.8	61.0	87.0	89.0	97.0	98.4	111.0	113.1
	27-36	56-65	87	88-90	92-101	94-106	111	93-120
Length of hind-foot	12.7	21.3	26.0	28.5	30.0	31.0	32.0	33.5
	11-14	20-22	26	28-29	29.4-31.2	30-32	32	31-35
Height of braincase	-	10.7	11.8	12.1	12.8	12.8	12.9	14.3
	-	10.5-10.8	11.8	11.9-12.3	12.5-13.5	12.5-12.9	12.9	13.1-15.2
Condylo-basal leng.	16.2	20.6	26.5	28.4	30.1	30.4	31.2	35.4
	14.2-17.9	20-21.1	26.5	26.6-30.2	29-30.3	26.9-31.2	31.2	32.9-37.1

Appendix B - Table 6. *Sigmodon fulviventer fulviventer*
(Coyotes, Durango)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-6	20-3	30-3	40-2	50-5	100-6	Adult-29
Length of body	51.7 48-54	90.0 82-90	101.5 100-103	130.0 123-135	144.0 143-145	149.0 134-177	153.2 129-160	172.7 155-193
Length of tail	30.3 27-32	61.3 57-67	72.5 71-74	96.3 88-102	95.0 95	101.3 97-105	106.3 82-113	111.4 84-123
Length of hind-foot	11.8 11-13	22.5 21-24	26.0 26	30.3 29-31	29.5 29-30	29.3 29-30	31.3 28-33	31.8 29-33
Height of braincase	8.9 8.5-9.5	10.7 10.5-10.9	11.2 11-11.4	12.4 11.9-13.4	12.5 12-13	13.2 12.8-14.2	13.7 12.3-13.9	13.9 13.5-15.4
Condylo-basal leng.	15.7 15.3-16.3	21.3 20.5-22.1	24.0 23.5-25.5	29.0 26.8-32.9	29.4 29.3-29.5	31.0 29.5-33.8	31.8 28.2-33.6	33.0 32.7-39.7

Appendix B - Table 7. *Sigmodon fulviventer melanotis*
(La Barca, Jalisco)

Measurements taken	Age-Classes (in days) and Number of Specimens							
	1-6	10-6	20-6	30-7	40-7	50-6	100-5	Adult-25
Length of body	61.8	96.3	117.8	133.6	144.1	145.2	176.4	178.8
	57-65	85-97	114-122	124-154	134-157	137-156	138-188	142-196
Length of tail	37.8	62.2	79.0	94.6	104.6	103.3	119.4	121.5
	36-40	60-66	74-84	90-105	93-113	96-107	83-126	104-130
Length of hind-foot	14.8	23.0	29.0	32.1	33.0	33.0	35.2	35.9
	14-15	21-25	28-30	30-35	32-34	32-34	30-36	29-38
Height of braincase	9.2	10.7	11.8	12.1	12.6	12.9	13.8	14.7
	8.8-9.5	10.4-11	11-12.7	11.9-12.5	12-13.3	12.2-13.2	12.4-14.4	13.2-16.2
Condylo-basal leng.	17.1	21.7	25.6	28.3	29.5	31.0	34.7	37.1
	16.4-17.5	20.8-22.5	24.5-26.4	27.4-30.4	28.1-30.7	30.7-31.7	29.3-35.9	35.3-38.5