

NATURAL HISTORY OF THE HISPID COTTON RAT

ARTHUR G. CLEVELAND, *Department of Biology, Texas Wesleyan College, and Texas Christian University, Fort Worth, Texas 76105*

Abstract: The geographical and ecological distribution of the hispid cotton rat (*Sigmodon hispidus*) is reviewed. An examination of sexual activity and litter size demonstrates shorter reproductive periods in northern latitudes, but large litters. Animals from southern latitudes reproduce the year around and have small litters. Sex ratio, age classes, home range, population fluctuations, and mortality are considered. Length of skull, upper molar tooth row, and distance between auditory bullae decrease from Kansas south into Mexico. Implications of parasites in this animal are reviewed.

Over the past century it has become increasingly clear that several mammalian species have extended their ranges northward across the south-central United States. Three of these are northern pigmy mouse (*Baiomys taylori*), nine-banded armadillo (*Dasypus novemcinctus*), and hispid cotton rat (*Sigmodon hispidus*). The pigmy mouse continues to expand its range in Texas (Packard 1960; Baccus et al. 1971). The nine-banded armadillo has slowed its northward advance as evidenced by the latest studies of its geographical distribution in the United States (Cleveland 1970, Humphrey 1974). The hispid cotton rat appears to have reached a relatively stable northern distribution, periodically receding from the northern extremes reported by Jones (1960) and Genoways and Schlitter (1966). Of these three species, only the hispid cotton rat appears to have reached the current northern limits of its distribution. Having rapidly invaded the central and eastern United States during the past century, the hispid cotton rat provides an opportunity to learn more about geographic variation. Since the original description of the hispid cotton rat by Say and Ord (1825), its dramatic population fluctuations have fascinated students of mammalogy. Several aspects of the natural history of this wide-ranging rodent are reviewed below.

DISTRIBUTION

Geographical

The hispid cotton rat occurs from northern South America throughout Mexico and into the southern United States (Walker 1964). The geographic range expanded between 1933 and 1947 from southern to northern Kansas (Cochrum 1948). Jones (1960), Genoways and Schlitter (1966), and Choate and Genoways (1967) reported the hispid cotton rat in southern Nebraska. Although Jones' (1960) site was later trapped with negative results (Cleveland 1971), specimens were taken in Webster County, Nebraska (Liesveld and Fiala 1977). A single hispid cotton rat was reported from Missouri (Genoways and Schlitter 1966). Bowles (1975) took hispid cotton rats from southwestern Iowa, although none was obtainable several years earlier (Cleveland 1971). Colorado has populations in the southeastern section of the state (Armstrong 1972, Carey 1978). Hall and Kelson (1959) recorded the hispid cotton rat from southern California to southern Virginia. Pagels (1977) has now taken hispid cotton rats from central Virginia. This rodent appears to have reached its current northernmost limits, with periodic surges and retreats depending upon the severity of winters.

Table 1. Studies on hispid cotton rat habitats in various regions.

Area	Habitat	Source
Southern Nebraska	Mixed grasses along ridge	Jones 1960
Elk County, Kansas	Open grassland	Arnwine, 1966
Kansas	Grass areas, especially weeded areas	Hall 1955
Chase County, Kansas	<i>Andropogon-Rubus-Helianthus</i> along railroad	Cleveland 1971
Piedmont section, Georgia	Greatest numbers along terraces in fields in thickets	Odum 1955
Tennessee	"... dried lake bed amid sedges, rushes, willows ..."	Dunaway and Kaye 1961
Northeastern Oklahoma	Oak-elm association Plum thickets Bluejoint-switchgrass association Clumps of prickly pear cactus	Blair 1938
Southern Oklahoma	<i>Smilax-Rubus</i> oldfield	Cleveland 1971
Southern Louisiana	"... cane fields and truck farms ... on ridges surrounding marshes ... under thick matted grasses ..."	Svihla 1929
South Texas	Railroad right-of-ways and fence rows	Cleveland 1971
Wise County, Texas	Cactus-mesquite association	Cleveland 1971
Brazos Valley, Texas	"... under logs and fallen branches ... in hollow trees ... along cotton fields living inside abandoned railroad cars ..."	Strecker 1929
Bee County, Texas	Ironweed clumps	Cleveland 1971
Central Texas	"... lodged stems of a stand of cattail left by a receding lake ..."	Inglis 1955
Central Texas	"... dense stand of lodged grasses on the edge of an ungrazed field ..."	Halloran 1942
Big Bend Area, Texas	Along the Rio Grande among cane, mesquite, and false willow	Schmidly 1977
South Texas (near Seguin)	"... thickets of thorny chapparrel and bunches of cactus ... edges of cotton fields ..."	Bailey 1905
South Texas	Pricklypear-shortgrass association	Hall 1955
Southern New Mexico	Tamarix stand	Troy Best (personal communication)
Lower Sonoran of Mexico	Chihuahuan desert	Bailey 1913
New Mexico	"... dense stand of grass clumps amid scattered brush ..."	Anderson and Berg 1959
Globe, Arizona	Beargrass, Johnson grass, <i>Agave</i> sp., <i>Yucca</i> sp.	Zimmerman 1970

Table 1. Continued.

Area	Habitat	Source
Eastern Durango	Overgrazed Chihuahuan desert	Zimmerman 1970
Chihuahua	Dense Tamarix	Cleveland 1971
Tamaulipas	"... grassy areas, on a beach having sparse grass ..."	Alvarez 1963
Veracruz	"... grasslands, overgrown clearings, weed-grown borders of fields, dense growths of sawgrass or bunchgrass, borders of jungles or forest ..."	Hall and Dalquest 1963

Ecological

Hispid cotton rats have historically been closely linked to tallgrass areas within their geographical range. However, upon closer examination, this animal has been found to occupy extremely varied habitats (Table 1). A well drained soil appears to be required since many investigators noted hispid cotton rats along ditches (Liesveld and Fiala 1977), hummocks of terraces (Odum 1955), ridges surrounding marshes (Svihla 1929), edges of fields (Halloran 1942) and railroad right-of-ways (Cleveland 1971). Hispid cotton rats have adapted to more mesic situations such as sawgrass marshes of south Florida (Bigler and Jenkins 1975). Availability of cover generally is considered essential to support large local populations of cotton rats (Goertz 1964). In contrast, Zimmerman (1970) reports hispid cotton rats from overgrazed Chihuahuan desert in eastern Durango. Hall (1955) records this species from the pricklypear-shortgrass association of south Texas. The best general habitat description would be a well drained area with abundant vegetative cover. Climatically, hispid cotton rats range from xeric to mesic areas, areas of tropical high temperatures to temperate prairie low temperatures, and from near sea level in the coastal plains to the lower altitudes of the

mountains. Hispid cotton rats are present in a majority of the climatic provinces of Thornthwaite (1931).

REPRODUCTION AND DEVELOPMENT

Sexual Activity

Hispid cotton rats are sexually active throughout the year in tropical (Hall and Dalquest 1963) and more temperate areas, but this period decreases to slightly more than 6 months in central North America (Figure 1). Winter weather usually begins in northern areas by November 1. Snow often remains on the ground as late as April 1. Likewise, there is some evidence that breeding and resulting pregnancies are reduced during periods of extreme heat in mid-summer (Goertz 1965).

Litter Size

Litter size in *Sigmodon* has been reviewed by Goertz (1965) and examined for effects of northward dispersal by Kilgore (1970). Unfortunately, Goertz (1964) records no information on litter size above southern Oklahoma or south of the United States-Mexico border. Therefore, he was unable to make comparisons. Likewise, Kilgore (1970) failed to take his southern sample far enough south of his northern sample to fully appreciate the

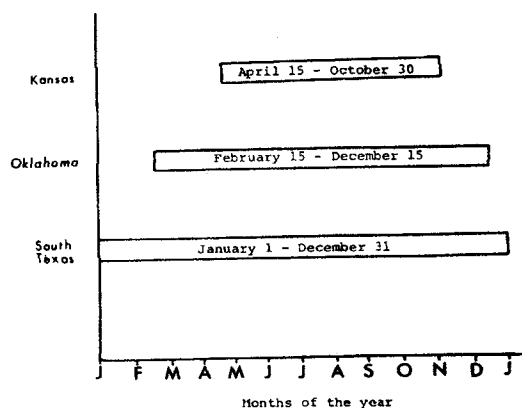


Figure 1. Periods of sexual activity for hispid cotton rats (*Sigmodon hispidus*) (Cleveland 1971).

extent to which litter size may vary in the cotton rat. This paper presents additional data and attempts to substantiate regional differences relative to the theories and examples of Lord's (1960) review and studies by Hoffman (1958), Moore (1961), Barkalow (1962), Jackson (1965), Keith et al. (1966), and Smith and McGinnis (1968).

Variations in litter size (Figure 2) represent a total of 123 records across Mexico and central North America. Regional pooling of data from available sources into three isotherms shows the variation in litter size (Table 2). Those litters from north of the 60°F isotherm are larger, whereas southern litters are noticeably smaller. A clear clinal effect is evident. All of the largest litters (≥ 10) are from the two northern isotherms. Thirty-nine percent of the southern litters are three or less in number. The intermediate isotherms demonstrate only 18% in this category. Only 5% of the litters born in the northern isotherms are three or less in number. This resembles the clinal effect in litter sizes of various North American mammals (Lord 1960, Smith and McGinnis 1968). Barkalow (1962) suggested that latitude apparently is related to re-

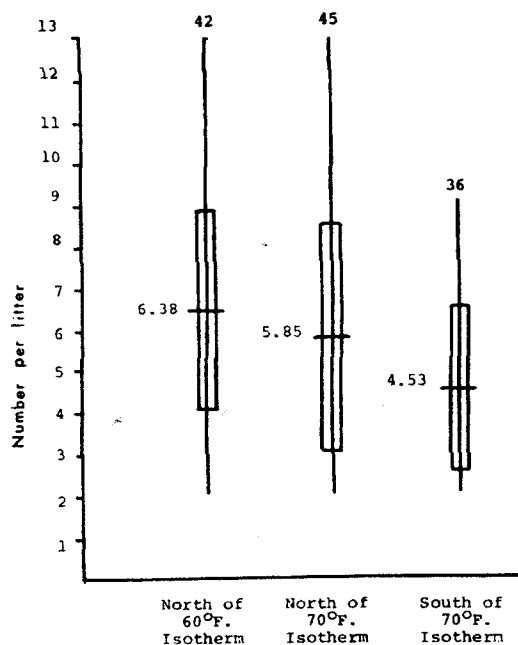


Figure 2. Variation in litter size of hispid cotton rats (*Sigmodon hispidus*) across three temperature isotherms. Vertical lines represent range, horizontal lines the mean, and rectangles twice the standard error. The sample size is shown at the upper extreme of the range (Cleveland 1971).

production, including litter size, in the cottontail rabbit. He failed to indicate any relationship between latitude and change in temperature. However, he did relate this to the fact that reproductive activity commences in southern populations earlier than northern ones. Therefore, to compensate for the decreased days per year for reproduction, Barkalow (1962) suggested a corresponding increase in litter size. This is in agreement with studies of Lord (1960), Smith and McGinnis (1968), and Keith et al. (1966). Figure 1 agrees with the trends suggested by the above authors in relation to litter size.

Growth and Maturity

Growth in hispid cotton rats has been reviewed by Svihla (1929), Meyer and

Table 2. Individual litter sizes of hispid cotton rats from three isotherms.

Location	Litter size records	Source
North of 60°F isotherm	2, 5, 5, 6, 6, 7	Cleveland 1971
	11	Choate and Genoways 1967
	3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 6, 6, 6, 7, 7, 7, 8, 8, 8, 8, 8, 8, 10, 12, 12, 13	Museum notations
North of 70°F isotherm	2, 3, 5, 6, 6, 6, 6, 6, 6, 6, 7, 7, 7, 10, 12, 13, 13	Cleveland 1971
	2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 5, 5, 6, 6, 6, 6, 7, 7, 8, 8, 8, 9, 11	Museum notations
South of 70°F isotherm	4, 5, 6, 9	Cleveland 1971
	3, 4, 4, 5, 5, 5, 5, 6, 6, 6, 7	Museum notations
	2, 3, 4, 4, 4, 5, 8	Alvarez 1963
	2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 7	Hall and Dalquest 1963

Meyer (1944), Chipman (1965), and Kilgore (1970). The gestation period is 27 days. Embryonic and early postnatal development was reported by Keys (1958). Young are born with sparse hair covering. Young hispid cotton rats are vigorously active soon after birth and open their eyes within 36 hours. Males are identified by the presence of a darkly pigmented spot immediately anterior to the anus. Weaning begins at about 1 week, but often is not complete for almost 2 weeks.

Although maximum body size is not reached until the 6th month, sexual maturity in hispid cotton rats is achieved 2 months after birth. Females have been impregnated as early as 38 days after birth by males of the same age. Few reach maximum size, since a majority do not live long enough.

Longevity

Odum (1955) proposed a maximum length of life of less than 5 months.

McCulloch (1959) noted 7 months as his longest record, and Goertz (1964) recorded one individual that survived for 12 months. Complete population turnover in 9 to 10 months was observed in south Texas (Cameron 1977). Goertz (1964) found that habitat quality was the most important factor in survivorship in a local population of cotton rats. The dense vegetation of an Oklahoma old field was suggested as a major factor in the long life of a 16-month-old free-living hispid cotton rat (Cleveland 1971). However, a majority seldom exceed 6 months in age (Goertz 1964). Longevity is most likely related to a combination of factors such as cover thickness, predator density, and parasite load (Cleveland 1971).

POPULATION DYNAMICS

Sex Ratio

Clayton (1952) and Inglis (1955) suggested possible differences from a 1:1 sex ratio in hispid cotton rats. However, an

Table 3. Male-female sex ratios of hispid cotton rats.

	Males	Females	Chi-square
Kansas Plot ¹			
Observed	28	28	0.000
Expected	28	28	
Oklahoma Plot ¹			
Observed	383	366	1.107
Expected	374	374	
Payne County Oklahoma ²			
Observed	166	162	0.048
Expected	164	164	
South Texas Plot ¹			
Observed	48	59	1.355
Expected	53	53	

¹ Cleveland (1971).² Payne County data from J. L. Hepworth, personal communication.

examination of the sex ratio in 1,240 cotton rats (Table 3) by Cleveland (1971) indicated the lack of a significant difference with a 1:1 sex ratio. This has been further substantiated by Haines (1971) in his 3-year study of two cotton rat populations. Similar studies also have shown a 1:1 sex ratio (Abegg 1939, Odum 1955, Arnwine 1966, Haines 1971, Layne 1974, Cameron 1977).

Age Classes

Hispid cotton rats have been placed in age classes by weight (Odum 1955) as either juvenile (0–59.5 g), young adult or subadult (60–109.9 g), or adult (over 110 g). Although body weights are admittedly a poor indicator of age (Chipman 1965), researchers have found this method convenient (Cameron 1977). Plotting of distribution of age classes by month over a 3-year period has demonstrated seasonal differences within and between years (Cameron 1977). Chipman (1965) expressed doubt that growth curves and age determination obtained in the laboratory or at a specific geographic locality could

be applied to other regions. Additional study in this area should be encouraged.

Home Range

Abegg (1939) concluded that the hispid cotton rat had a home range of "less than 30 yards." Such use of a linear measurement to depict "home range" was not uncommon in earlier studies. Home range studies by Inglis (1955) showed that a definite measurement was difficult to obtain since it changed according to population density. This was supported by Goertz (1964) who reviewed various estimates of home range size. Habitat cover also affects distances traveled by individual cotton rats (Cleveland 1971). Accurate determination of home range would require locality qualification (type of habitat, latitude, season, and population density). Further studies into such a scheme would prove challenging but within the realm of possibility utilizing computer technology.

Population Fluctuations

Populations of the hispid cotton rat are subject to extreme fluctuations in density, somewhat comparable to population cycles of certain rabbits and rodents of more northern regions. Except for the possible regulatory factors discussed by Goertz (1964) and Haines (1971), causes for these dramatic fluctuations remain unknown. Largely because of these unexplained fluctuations, the population dynamics of cotton rats have been widely studied over the past 30 to 40 years. Results of many of these studies remain unpublished—being parts of manuscripts submitted in partial fulfillment of requirements for academic degrees.

More recent accounts of massive population increases in cotton rats were reported by Haines (1963) for Texas. Ro-

dent pop
United S
(numeros
Along w
habitats,
ately lar
across th
numbers
most are
ulation
1957, G
have also
(Raun and
small pop
of individ
vironment
cimation
tion of th
survive a
doubtedly
resulting
parentage
massive
comitant
"near-ext
lation nu
tion press
suited for
The fac
to be res
and hence
are rainfa
ism (Cle
1972), and
ature ext
Flehart
swer, if it
involve a

Mortality

Hispid
origin, an
to environ
rodents (G
Guess 19

dent populations across the southwestern United States often drop to low numbers (numerous personal communications). Along well drained, heavily covered habitats, isolated populations of moderately large numbers remain scattered across the range. As a general rule, small numbers of hispid cotton rats remain in most areas despite severe drops in population numbers (Gier and Bradshaw 1957, Gier 1968b). Drastic reductions have also been recorded in south Texas (Raun and Wilks 1964). These extremely small population remnants are made up of individuals who have survived the environmental factors that caused the decimation of their relatives. Natural selection of the cotton rats most likely to survive and produce offspring is undoubtedly strong. Genetic composition of resulting litters originates from a small parentage of survivors. The alternating of massive population explosions and concomitant range expansion coupled with "near-extinctions" in years of low population numbers and strong natural selection pressures, produces a species ideally suited for the creation of a cline.

The factors thought by mammalogists to be responsible for these fluctuations, and hence deserving additional study, are rainfall cycles (Haines 1963), parasitism (Cleveland 1971, Fleharty et al. 1972), and protracted periods of temperature extremes (Cleveland 1968, 1971, Fleharty et al. 1972). The ultimate answer, if it is ever realized, probably will involve a combination of these factors.

Mortality and Predators

Hispid cotton rats, being of Sonoran origin, apparently are more susceptible to environmental stress than many other rodents (Chipman 1966, Selander and Guess 1970). Further evidence suggests

that extremes of temperature are the most important of these environmental stresses (Cockrum 1948, Goertz 1964, Cleveland 1968, Selander and Guess 1970, Kilgore 1970, Dunaway and Kaye 1961, Cleveland 1971, Fleharty et al. 1972). Prolonged, low ambient temperatures, as well as unseasonal sudden changes in temperature, increase mortality (Dunaway and Kaye 1961, Cleveland 1968).

With temperature having such a role, nest availability could be a critical insulative factor in mortality during winter. Normally, hispid cotton rats construct spherical nests of grass in shallow depressions or under a variety of natural or man-made objects. Northern populations are now known to use deep burrows and nests 76.2 cm below the surface (Baar et al. 1975). This deep burrow is well below the maximum depth of the frost line for that location near Hays, Kansas. Utilization of such burrows is most likely a major factor for survival of pioneer cotton rats in marginal northern populations.

Hispid cotton rats are a basic food for many carnivores including coyotes (Gier 1968a), barn owls (Raun 1960), and marsh hawks (Odum 1947). The effects of natural predation on experimental cotton rat populations have been demonstrated by Schnell (1968).

GEOGRAPHIC VARIATION

During the past 25 years, classical rules for recording climatic variation have undergone extensive discussion and evaluation. Particularly, Bergmann's and Allen's Rules (Mayr 1956) have caught the attention of evolutionists. These rules revolve around the concept that a species or group of related species undergo morphological and physiological changes with latitude and altitude. Not that altitude nor latitude alone has any direct in-

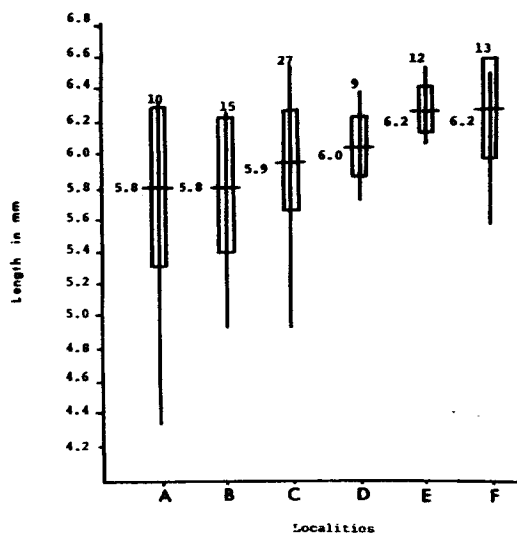


Figure 7. Variation in upper molar tooth row in hispid cotton rats (*Sigmodon hispidus*) along a south to north line. Vertical lines represent range, horizontal lines the mean, and rectangles twice the standard error. The sample size is shown at the upper extreme of the range. Localities shown are: A—Faumare, Mexico, B—San Patricio County, Texas, C—Maverick County, Texas, D—Vila Acuna, Mexico, E—Adair County, Oklahoma, F—McPherson County, Kansas (Cleveland 1971).

ectoparasites, encysted cestodes, and visceral trematodes, cestodes, and nematodes. These parasites, however, were not considered to be causative factors in the population reduction since they had also been observed when "stable" population numbers were present. Unfortunately, neither quantitative data nor species identification were presented (Goertz 1964). Helminths were reported from the cotton rat by Melvin and Chandler (1950). Subsequently, endoparasite surveys of cotton rats have been made in Brazos (Hughhins 1951), Haskell (Kimbrough 1970), and Hays (Martin 1976) counties in Texas. Other parasitological examinations of cotton rats have been concerned with ectoparasites (Whitaker and Wilson 1974), applications of cotton

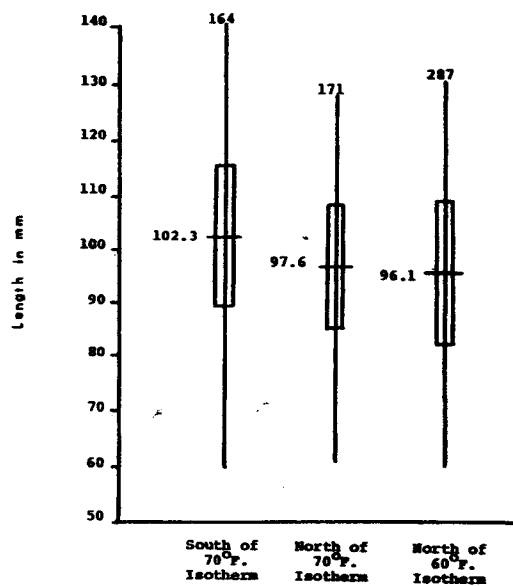


Figure 8. Variation in tail length in hispid cotton rats (*Sigmodon hispidus*). Vertical lines represent range, horizontal lines the mean, and rectangles twice the standard error. The sample size is shown at the upper extreme of the range (Cleveland 1971).

rat filarial infections to medical research (Bertram 1966), and presentations of new species of endoparasites (Schell 1952, Melvin 1952, Smith 1954). A study of blood parasites of southwest Texas rodents included examination of 400 cotton rats (Eads and Hightower 1952). The filarial worm (*Litomosoides carinii*) has been reported from cotton rats in Florida (Williams 1948), "southern states" (Bertram 1966), south Texas (Westbrook and Scott 1955) and southwestern Texas (Eads and Hightower 1952). Hughhins (1951) noted his inability to recover a single filarid in his study in east-central Texas. Although filarids were not specifically mentioned in the north Texas study of Kimbrough (1970), he indicated their complete absence from the 397 specimens examined (personal communication). Cleveland (1971) found filarid in-

fecti
Okla

The
vide
want
aspe
mal
and
ed i
easte
show
racr
to b
nific
sex
span
mon
prob
hom
hisp
the
tigat
in th
this
temp
mar
diti
gle
tuat
supp
Ack
for m
rat h
Bess
them
in m
G. R
ence
work
eral
sista
J. C.
Hall

fection in south Texas, but none in Oklahoma or Kansas.

CONCLUSIONS

The hispid cotton rat continues to provide students of field biology with a rewarding subject for their research. Many aspects of the natural history of this animal still remain in doubt. Bergmann's and Allen's Rules have been demonstrated in the hispid cotton rat from north-eastern Mexico to Kansas. Litter size was shown to increase along a line from Veracruz to Kansas. An inverse relationship to breeding season was shown. No significant differences from the expected 1:1 sex ratio can be supported. Maximum life span in the wild has been shown to be 16 months, although the normal life span is probably less than 6 months. The idea of home range should be re-examined in the hispid cotton rat. Parasitic infection or the lack of it, should be carefully investigated to ascertain if this is a major factor in the periodic population fluctuations this animal exhibits. The effect that cold temperatures play in the northward march by this species still warrants additional study and quantification. No single explanation for the population fluctuations of the hispid cotton rat has been supported.

Acknowledgments: Financial support for much of my work on the hispid cotton rat has been provided by the Rob and Bessie Welder Wildlife Foundation. To them I am grateful. For encouragement in my work I am appreciative to Gerald G. Raun, E. Raymond Hall, the late Clarence Cottam, and W. C. Glazener. My work would have all come to an end several times without the patience and assistance of my close friend and colleague, J. C. Streett. I am grateful to E. Raymond Hall for critically reading the manuscript.

LITERATURE CITED

- ABEGG, R. 1939. A preliminary study of the home range and territory of the cotton rat, *Sigmodon h. hispidus*. M.S. Thesis. La. State Univ. 62p.
- ALVAREZ, T. 1963. The recent mammals of Tamaulipas, Mexico. Univ. Ks. Mus. Nat. Hist. Publ. 14(15):363-473.
- ANDERSON, S., AND W. N. BERG. 1959. Extension of the known range of the cotton rat, *Sigmodon hispidus*, in New Mexico. Southwestern Nat. 4:40-42.
- ARMSTRONG, D. M. 1972. Distribution of mammals in Colorado. Monogr. Mus. Nat. Hist. Univ. Ks. No. 3. Lawrence. 415p.
- ARNWINE, J. E. 1966. A population of cotton rats (*Sigmodon hispidus*) at the University of Oklahoma Biological Station, Marshall County, Oklahoma. Unpubl. Res. Rep. Independence Community Coll., Ks. 13p.
- BAAR, S. L., E. D. FLEHARTY, AND M. A. ARTMAN. 1975. Utilization of deep burrows and nests by cotton rats in west-central Kansas. Southwestern Nat. 19:440-444.
- BACCUS, J., R. GREER, AND G. RAUN. 1971. Additional records of *Baiomys taylori* in north central Texas. Tx. J. Sci. 23:148-149.
- BAILEY, V. 1905. Biological survey of Texas. N. Am. Fauna 35:145.
- . 1913. Life zones and crop zones of New Mexico. N. Am. Fauna 35:1-100.
- BARKALOW, R. S. 1962. Latitude related to reproduction in the cottontail rabbit. J. Wildl. Manage. 26:32-37.
- BERTRAM, D. S. 1966. Dynamics of parasitic equilibrium in cotton rat filariasis. P. 255-319 In: B. Dawes. Advances in Parasitology, Vol. 4, Academic Press, New York.
- BIGLER, W. J., AND J. H. JENKINS. 1975. Population characteristics of *Peromyscus gossypinus* and *Sigmodon hispidus* in tropical hammocks of south Florida. J. Mammal. 56:633-644.
- BLAIR, W. F. 1938. Ecological relationships of mammals of the Bird Creek region, northeast Oklahoma. Am. Midl. Nat. 20:473-526.
- BOWLES, J. B. 1975. Distribution and biogeography of mammals of Iowa. Spec. Publ. Mus. Tx. Tech Univ. No. 9. 184p. Lubbock, Tx.
- BROWN, J. H., AND A. K. LEE. 1969. Bergmann's rule and climatic adaptation in woodrats (*Neotoma*). Evolution 23:329-338.
- CAMERON, G. N. 1977. Experimental species removal: Demographic responses by *Sigmodon hispidus* and *Reithrodontomys fulvescens*. J. Mammal. 58:488-506.
- CAREY, A. B. 1978. Distributional records for the prairie vole and the hispid cotton rat in Colorado. J. Mammal. 59:624.
- CHIPMAN, R. K. 1965. Age determination of the cotton rat (*Sigmodon hispidus*). Tulane Stud. in Zool. 12:19-38.

- . 1966. Cotton rat age classes during a population decline. *J. Mammal.* 47:138-141.
- CHOATE, J. R., AND H. H. GENOWAYS. 1967. Notes on some mammals from Nebraska. *Trans. Ks. Acad. Sci.* 69:238-241.
- CLAYTON, K. 1952. Some phases of the winter ecology of some small mammals in a blue-stem, blue-grass meadow of Lyon County, Kansas. M.S. Thesis. Ks. State Teacher's Coll. 32p.
- CLEVELAND, A. G. 1968. Rectal temperatures of the cotton rat, *Sigmodon hispidus*. M.S. Thesis. N. Tx. State Univ.
- . 1970. The current geographic distribution of the armadillo in the United States. *Tx. J. Sci.* 22:90-92.
- . 1971. Studies on morphology and biology of cotton rats from northern Mexico to southern Nebraska. Ph.D. Dissertation. N. Tx. State Univ. 83p.
- COCKRUM, E. L. 1948. The distribution of the hispid cotton rat in Kansas. *Trans. Ks. Acad. Sci.* 51:306-312.
- DUNAWAY, P. B., AND S. V. KAYE. 1961. Cotton rat mortality during severe winter. *J. Mammal.* 42:265-268.
- EADS, R. B., AND B. G. HIGHTOWER. 1952. Blood parasites of southwest Texas rodents. *J. Parasitol.* 38:89-90.
- FLEHARTY, E. D., J. R. CHOATE, AND M. A. MARES. 1972. Fluctuations in population density of the hispid cotton rat: factors influencing a "crash." *Bull. Southern Ca. Acad. Sci.* 71:132-138.
- GENOWAYS, H. H., AND D. A. SCHLITTER. 1966. Northward dispersal of the hispid cotton rat in Nebraska and Missouri. *Trans. Ks. Acad. Sci.* 69:356-357.
- GIER, H. T. 1968a. Coyotes in Kansas. *Ks. Agric. Exp. Stn. Contrib. No. 994*. Manhattan, Ks. 118p.
- . 1968b. The Kansas small mammals census: terminal report. *Trans. Ks. Acad. Sci.* 70:505-518.
- , AND G. V. R. BRADSHAW. 1957. Five-year report on the Kansas small mammal census. *Trans. Ks. Acad. Sci.* 60:259-272.
- GOERTZ, J. W. 1964. The influence of habitat quality upon density of cotton rat populations. *Ecol. Monogr.* 34:359-381.
- . 1965. Reproductive variation in cotton rats. *Am. Midl. Nat.* 74:329-340.
- HAINES, H. 1963. Geographical extent and duration of the cotton rat, *Sigmodon hispidus*, 1958-1960 fluctuation in Texas. *Ecology* 44:771-772.
- . 1971. Characteristics of a cotton rat (*Sigmodon hispidus*) population cycle. *Tx. J. Sci.* 23:3-27.
- HALL, E. R. 1955. Handbook of Mammals of Kansas. Univ. Ks. Mus. Nat. Hist. Publ. 7:1-303.
- , AND W. W. DALQUEST. 1963. Mammals of Veracruz. Univ. Ks. Mus. Nat. Hist. Publ. 14:165-362.
- , AND K. R. KELSON. 1959. The mammals of North America. Roland Press, New York. Vol. II:547-1083.
- HALLORAN, A. F. 1942. A surface nest and the young of *Sigmodon* in Texas. *J. Mammal.* 23:91.
- HOFFMAN, R. S. 1958. The role of reproduction and mortality in population fluctuations of Voles (*Microtus*). *Ecol. Monogr.* 28(1):79-109.
- HOFFMEISTER, D. R. 1951. A taxonomic and evolutionary study of the pinion mouse, *Peromyscus truei*. II. Biol. Monogr., Univ. Ill. 21:4-104.
- HUGHINS, E. J. 1951. A survey of the helminths and ectoparasites of roof and cotton rats in Brazos County, Texas. *Am. Midl. Nat.* 46:230-244.
- HUMPHREY, S. R. 1974. Zoogeography of the nine-banded armadillo (*Dasypus novemcinctus*) in the United States. *Bioscience* 24:457-462.
- INGLIS, J. M. 1955. Population dynamics of the cotton rat (genus *Sigmodon*). M.S. Thesis. Tx. A & M Univ.
- JACKSON, W. B. 1965. Litter size in relation to latitude in two murid rodents. *Am. Midl. Nat.* 73:245-247.
- JONES, J. K. 1960. The hispid cotton rat in Nebraska. *J. Mammal.* 41:132.
- JUDD, F. W. 1970. Geographic variation in the deer mouse, *Peromyscus maniculatus*, on the Llano Estacado. *Southwestern Nat.* 14:261-282.
- KEITH, L. B., O. J. RONGSTAD, AND E. C. MESLOW. 1966. Regional differences in reproductive traits of the snowshoe hare. *Can. J. Zool.* 44:953-961.
- KEYS, C. E. 1958. The rate of development of *Sigmodon hispidus* as compared with some other rodents. *Trans. Ks. Acad. Sci.* 19:25-27.
- KILCORE, D. L. 1970. The effects of northward dispersal on growth rate of young, size of young at birth, and litter size in *Sigmodon hispidus*. *Am. Midl. Nat.* 84:510-520.
- KIMBROUGH, J. D. 1970. A survey of endohelminths of the cotton rat, *Sigmodon hispidus* in Haskell County, Texas. M.S. Thesis. Southern Methodist Univ. 38p.
- LAYNE, J. N. 1974. Ecology of small mammals in a flatwoods habitat in north-central Florida, with emphasis on the cotton rat (*Sigmodon hispidus*). *Am. Mus. Novit.* 2544:1-48.
- LIESVELD, D., AND K. FIALA. 1977. The cotton rat in Nebraska. *Southwestern Nat.* 21:559.
- LORD, D., JR. 1960. Litter size and latitude in North American mammals. *Am. Midl. Nat.* 64(2):488-499.
- MARTIN, J. L. 1976. An ecological survey of the helminths of *Sigmodon hispidus* from the area of San Marcos, Texas. M.S. Thesis. S.W. Tx. State Univ. 112p.
- MAYR, E. 1956. Geographic character gradients and climatic adaptation. *Evolution* 10:105-108.

- MCCULLOCH, C. Y. 1959. Populations and range effects of rodents on the sand sagebrush grasslands of western Oklahoma. Ph.D. Dissertation. Ok. State Univ. 159p.
- MELVIN, D. M. 1952. Studies on the life cycle and biology of *Monoecocestus sigmodontis* (Cestodae: Anoplocephalidae). J. Parasitol. 38:346-354.
- , AND A. C. CHANDLER. 1950. New helminth records from the cotton rat, *Sigmodon hispidus*, including a new species, *Strongyloides sigmodontis*. J. Parasitol. 36(6):505-510.
- MEYER, B. J., AND R. K. MEYER. 1944. Growth and reproduction of the cotton rat, *Sigmodon hispidus hispidus*, under laboratory conditions. J. Mammal. 25:107-129.
- MOORE, J. C. 1961. Geographic variation in some reproductive characteristics of diurnal squirrels. Bull. Am. Mus. Nat. Hist. 122:1-32.
- ODUM, E. P. 1947. Marsh hawks responding to peak abundance of cotton rats. Oriole 12:48-49.
- . 1955. An eleven year history of a *Sigmodon* population. J. Mammal. 36:368-378.
- PACKARD, R. L. 1960. Speciation and evolution of the pygmy mice, genus *Baiomys*. Univ. Ks. Publ., Mus. Nat. Hist. 9:579-670.
- PAGELS, J. F. 1977. Distribution and habitat of cotton rats (*Sigmodon hispidus*) in central Virginia. Va. J. Sci. 28:133-135.
- RAUN, G. G. 1960. Barn owl pellets and small mammal populations near Mathis, Texas, in 1956 and 1959. Southwestern Nat. 5:194-200.
- , AND B. J. WILKS. 1964. Natural history of *Baiomys taylori* in southern Texas and competition with *Sigmodon hispidus* in a mixed population. Tx. J. Sci. 16:28-49.
- SAY, T., AND G. ORD. 1825. Description of a new species of Mammalia, whereon a genus is proposed to be founded. J. Acad. Sci. Philadelphia. 4:353.
- SHELL, S. C. 1952. Studies on the life cycle of *Physaloptera hispida* Schell (Nematoda: Spiruroidea), a parasite of the cotton rat. J. Parasitol. 38:462-472.
- SCHENDEL, R. H. 1940. Life history notes on *Sigmodon hispidus texianus* with special emphasis on populations and nesting habits. M.S. Thesis. Ok. A & M Coll. 40p.
- SCHMIDLY, D. J. 1977. The mammals of trans-pecos Texas. Tx. A & M Press. College Station, Tx.
- SCHNELL, J. H. 1968. The limiting of natural predation on experimental cotton rat populations. J. Wildl. Manage. 32:698-711.
- SCHREIDER, E. 1964. Ecological rules, body-heat regulation, and human evolution. Evolution 18:1-9.
- SEALANDER, J. A., AND C. E. GUESS. 1970. Effect of forced swimming on body temperature and eosinophil levels in cotton rats (*Sigmodon hispidus*). J. Mammal. 51:348-357.
- SMITH, C. F. 1954. Four new species of cestodes of rodents from the high plains, central and southern Rockies and notes on *Catenotaenia dendritica*. J. Parasitol. 40:245-254.
- SMITH, M. H., AND J. T. MCGINNIS. 1968. Relationships of latitude, altitude, and body size to litter size and mean annual production of offspring in *Peromyscus*. Res. Popul. Ecol. 10:115-126.
- STRECKER, J. K. 1929. Notes on the Texas cotton and Attwater wood rats in Texas. J. Mammal. 10:216-220.
- SVIHLA, A. 1929. Life history notes on *Sigmodon hispidus hispidus*. J. Mammal. 10:352-353.
- THORNTHWAITE, C. W. 1931. The climates of North America according to a new classification. Geogr. Rev. 21(4):633-656.
- WALKER, E. P. 1964. Mammals of the world. Johns Hopkins Press, Baltimore. Vol. II:647-1500.
- WESTBROOK, M. G., AND J. A. SCOTT. 1955. A statistical analysis of the growth in length of the filarial worms in the cotton rat. Tx. Rep. Biol. Med. 13:537-558.
- WHITAKER, J. O., AND A. WILSON. 1974. Host and distribution lists of mites (Acari), parasitic and phoretic, in the hair of wild mammals of North America, north of Mexico. Am. Midl. Nat. 91:1-67.
- WILLIAMS, R. W. 1948. Studies on the life cycle of *Litomosoides carinii*, filarid parasite of the cotton rat, *Sigmodon hispidus latoralis*. J. Parasitol. 34:24-42.
- ZIMMERMAN, E. G. 1970. Karyology, systematics and chromosomal evolution in the rodent genus, *Sigmodon*. Mi. State Univ., Publ. Mus., Biol. Ser. 4(9):389-454.