THE SOUTHWESTERN NATURALIST 48(3):427–431 SEPTEMBER 2003

EFFECT OF BODY SIZE ON REPRODUCTIVE CHARACTERISTICS OF THE NORTHERN GRASSHOPPER MOUSE IN NORTH-CENTRAL KANSAS

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ABSTRACT—Northern grasshopper mice (*Onychomys leucogaster*) were sampled periodically from June 1977 to November 1986 in the mixed-grass prairie region of north-central Kansas. Necropsies were performed on 175 mice to assess number of pregnancies and litter size for females and testis size for males. Fourteen of 87 females were pregnant with the earliest and latest dates of captures of pregnant females on 22 March and 18 August, respectively. The proportion of pregnant females peaked during May–June. The average number of fetuses was 4.0 (range: 2 to 5), and number of fetuses was correlated positively with body length of the mother. Testes of large males (≥110 mm) increased in size from January to August, and then rapidly regressed through October, whereas smaller males either exhibited a high degree of variability in testes size or had relatively small testes throughout this period. Temporal patterns for pregnancies and testis size suggested that the reproductive cycle for northern grasshopper mice in north-central Kansas was unimodal, and reproductive activity was greatest in late spring to mid-summer.

RESUMEN—Muestras de ratones saltamontes del norte (*Onychomys leucogaster*) fueron tomadas periódicamente desde junio de 1977 hasta noviembre de 1986 en la pradera de grama mixta de la región centro-norte de Kansas. Necropsias fueron practicadas en 175 ratones para averiguar el número de embarazos y tamaño de la camada para las hembras y el tamaño de los testículos para los machos. Catorce de las 87 hembras estaban preñadas, con las fechas de captura más tempranas y tardías de las hembras preñadas del 22 de marzo y del 18 de agosto, respectivamente. La proporción de hembras preñadas alcanzó su nivel máximo durante mayo y junio. El número promedio de fetos fue 4.0 (rango 2 a 5), y el número de fetos tuvo una correlación positiva con la longitud corporal de la madre. Los testículos de machos grandes (≥110 mm) aumentaron en tamaño desde enero hasta agosto y después disminuyeron rápidamente durante octubre, mientras machos menores o mostraron un nivel de variabilidad alta en el tamaño de los testículos o tuvieron testículos relativamente pequeños durante este período. Patrones temporales de embarazos y tamaño de testículos sugieren que el ciclo reproductivo de ratones saltamontes del norte en la zona centro-norte de Kansas fue unimodal, y la actividad reproductiva fue mayor de fines de la primavera hasta mediados del verano.

The breeding season of the northern grasshopper mouse (*Onychomys leucogaster*) was reported to be from April to September in Kansas (Bee et al., 1981). However, a more recent analysis of museum specimens indicated that pregnancies occurred between March (southwestern Kansas) and October (southwestern and north-central Kansas; Pitts et al., 1988). Herein, we examined reproductive characteristics as related to body size for northern grasshopper mice from field samples taken during a larger study of habitat selection in small mammals in north-central Kansas. First, we examined the length of the breeding season from information collected on pregnant females and trappable juveniles. Second, we assessed litter size and then examined whether it was related to female size. Third, we assessed temporal changes in testis size of males as well as the effect of male size on this pattern. Fourth, we compared the timing and length of the breeding season for grasshopper mice suggested by the occurrence of pregnancies and temporal changes in testis size. We used body length as an index to body size to circumvent difficulties associated with comparing body

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mass among females at different stages of pregnancy. To establish the validity of using body length as an index to body size, we examined the relationships between body length and mass for both male and nonpregnant female northern grasshopper mice.

METHODS—We collected 175 northern grasshopper mice in Lincoln and Russell counties, Kansas, from 1977 through 1986. These mice were collected as part of a larger study that examined habitat selection of small mammals in a variety of habitats, including native mixed-grass prairie, crop fields, old fields, and fencerows. All small mammals were collected by using snap traps baited with peanut butter. Following capture, each small mammal received a tag with date and location of capture. Specimens then were frozen until measurements and necropsies were performed. All laboratory work was done by one of us (GAK). For each grasshopper mouse, we recorded the date and location of capture, sex, body mass, total length, and tail length. For females, we counted the number of fetuses (=litter size) and measured the crown-rump length of a typical fetus. For males, we measured the length and maximum width of the right testis.

Body length was calculated as the difference between total length and tail length. Grasshopper mice <80 mm in body length were categorized as juveniles, which is a conservative limit relative to the growth rate of these mice from a laboratory study (Pinter, 1970). We could not use coloration of pelage to assess age (Engstrom and Choate, 1979) because it was not recorded at the time of collection. We divided our data into 6 time periods (January–February, March–April, May–June, July–August, September–October, and November–December) for analyses of the temporal patterns of occurrence of both pregnant adult females and juvenile mice. We used correlation analyses (r) to assess relationships between litter size and maternal body length, and to assess the relationship between body mass and length for both males and nonpregnant females. We used an index to testis volume [testis index = (testis length)*(testis width/2)^2] for analyses of changes in testis size during the year. To assess causes of variation in testis size, we subdivided males into 3 general size classes to determine if seasonal patterns varied with size of males. These groups were small (≤99 mm), intermediate (100 to 109 mm), and large (≥110 mm). We used this latter, more restricted category of male northern grasshopper mice to remove the effect that variation in the proportion of smaller males might have had on the annual pattern of testis size. SAS (SAS Institute, 1989) was used for all statistical analyses.

RESULTS—Body sizes were similar for males (n = 88; range of length: 75 to 122 mm; range of mass: 12.4 to 50.6 g) and nonpregnant females (n = 73; range of length: 77 to 122 mm; range of mass: 12.3 to 57.2 g). The relationship for body mass to body length was significant for males (r = 0.94, df = 86, $P < 0.0001$) and for nonpregnant females (r = 0.90, df = 71, $P < 0.0001$). Body lengths of pregnant females (n = 14) ranged from 100 to 122 mm and were within the range of body lengths observed for males and nonpregnant females. Size distributions of body mass and length of both males and females varied greatly among seasons. Most small grasshopper mice occurred in samples taken during May through September.

The first pregnant female was caught on 22 March and the last on 18 August. The percent of adult females that were pregnant was highest during May–June (33%; Fig. 1a). Consistent with this pattern of reproduction, all 9 juveniles were captured between 31 May and 13 August and the number was highest in May–June (Fig. 1b). The number of fetuses per litter ranged from 2 to 5 and averaged 4.0 (n = 14; 2 SE = 0.5). Litter size was correlated positively with female body length (r = 0.46, df = 12, P = 0.01; Fig. 2).

The testis index varied widely within and among seasons (Fig. 1c). For large males, testis size was smallest during October and November (Fig. 1d). In January, testes began to enlarge and continued to increase in size until late summer. In contrast to this gradual increase during spring, testes decreased from a maximum size in August to a small size by early October. Testis size of large males was highly variable in June–July. Intermediate-sized males exhibited a high degree of variability in testis size from May through August (Fig. 1e). Testis size of these males was never as large as the largest sizes observed for large males. The pattern of increasing size observed for large males was not observed for intermediate-sized males because some of these males had testes that were quite small during June–August. However, testes of intermediate-sized males regressed rapidly at the end of August, which was the same pattern exhibited by large males (Fig. 1d). The only exception to these patterns was the large testis size exhibited by 1 intermediate-sized male (109 mm) that was captured in April. Small males that were caught from late

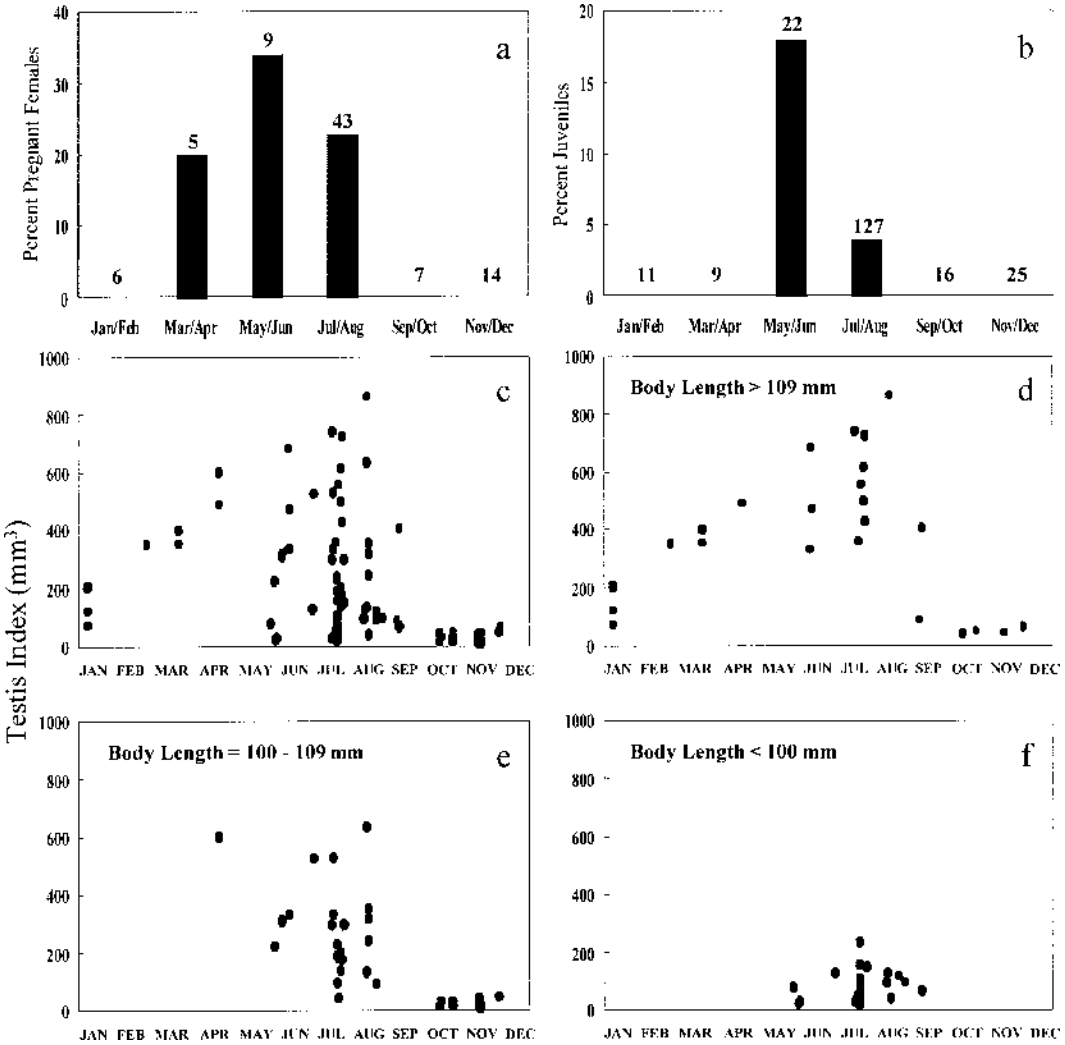

FIG. 1—Reproductive patterns in female (indexed by pregnancy and appearance of juveniles) and male (indexed by testis size) northern grasshopper mice (*Onychomys leucogaster*) from field samples collected in north-central Kansas from 1977 through 1986. Percent of pregnant females (a) relative to adult females (total number in sample given above each bar) and percent of juveniles (b, <80 mm) in total sample (total number of individuals in each sample given above each bar) in each 2-month sample during an annual cycle. Testis index [=(testis length)*(testis width/2)^2] is shown through an annual cycle for all males (c), large males (d), intermediate-sized males (e), and small males (f).

May to early September showed little variation in testis size, and testis size remained small throughout these months (Fig. 1f).

DISCUSSION—The average litter size in our sample (4.0 individuals) was similar but slightly larger than that observed under laboratory conditions for mice from Kansas, Colorado, and Utah (3.4 to 3.7 individuals; Egoscue, 1960; Pinter, 1970; Sikes, 1995). Our range of 2 to 5 individuals per litter was similar to that found in 3 laboratory studies (1 to 6; Egoscue, 1960; Pinter, 1970; Sikes, 1995) but smaller than the ranges reported in studies of free-living grasshopper mice in western Kansas (3 to 8; Pitts et al., 1988) and northeastern Colorado (3 to 7; Flake, 1974). The variation in litter size that we observed for northern grasshopper

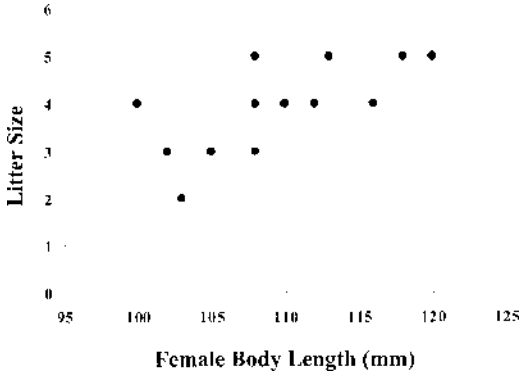

FIG. 2—Relationship between litter size and female size (as indexed by body length) in northern grasshopper mice (*Onychomys leucogaster*) from field samples collected in north-central Kansas from 1977 through 1986.

mice partly was related to female size, as larger females had a significantly larger numbers of fetuses in utero than smaller females. This positive relationship between litter size and maternal size was consistent with patterns reported for other rodents (deer mice, *Peromyscus maniculatus,* Myers and Master, 1983; old-field mice, *Peromyscus polionotus,* Kaufman and Kaufman, 1987; cotton rats, *Sigmodon hispidus,* Campbell and Slade, 1995; Uinta ground squirrels, *Spermophilus armatus,* Rieger, 1996) Although we made no attempt to assess age of individuals, age and body size likely were correlated.

The proportion of pregnant females was greatest in the May–June sample, and the temporal sequence suggested a unimodal pattern of reproduction. This pattern of reproduction agreed with a study of northern grasshopper mice in northeastern Colorado (Flake, 1974). The northern grasshopper mouse has a gestation period of about 30 days (Egoscue, 1960; Pinter, 1970) and young are weaned around 23 days of age (Horner, 1968). The capture of juvenile grasshopper mice beginning in late May and continuing into late summer was consistent with patterns observed for reproductive activities in adult females.

The change in testis size of large males from February to July suggested a gradual increase in reproductive activity from spring to the peak in summer. In contrast, the rapid regression of testis size at the end of summer, regardless of size of males, indicated an abrupt cessation of the breeding season. This pattern was further supported by the lack of captures of juveniles and pregnant adult females in September and later months. However, other studies have shown that some females can conceive as late as September or early October (Colorado: Flake, 1974; Kansas: Pitts et al., 1988).

The relatively large testis sizes we noted are in contrast to the predicted relationship between testis size and mating system in mammals (Kenagy and Trombulak, 1986). Northern grasshopper mice likely are monogamous (McCarty, 1978), and males are thus expected to have small testes as a result of infrequent copulations (Harcourt et al., 1981). Similarly, southern grasshopper mice (*Onychomys torridus*) are speculated to be monogamous, but have testes nearly 5 times the size of those predicted from allometric relationships (Kenagy and Trombulak, 1986).

Because northern grasshopper mice were collected over a number of years, temporal patterns for occurrence of pregnancies, trappable juveniles, and enlargement of testes should be rather robust and not dependent on the weather conditions of any particular year. Therefore, our results and those of Pitts et al. (1988) suggest that the reproductive period for grasshopper mice in north-central Kansas occurs primarily from March to August and that only a small proportion of litters are born outside this time period. In contrast to grasshopper mice, deer mice in north-central Kansas frequently produce young in autumn and can breed in all months of the year (Brown, 1945; Kaufman, 1990; Kaufman and Kaufman, unpubl. data). As both species are native grassland murids, why do differences occur in reproductive patterns of these 2 species?

Interannual differences in reproduction of deer mice in north-central Kansas (Kaufman, 1990; Kaufman and Kaufman, unpubl. data) suggest that deer mice are opportunistic and reproduce when weather conditions and food resources are suitable. Why then do grasshopper mice at this same latitude and in many of the same habitats cease reproduction in late summer? Perhaps female grasshopper mice are more likely to survive winter and reproduce again during the next year if they do not reproduce in middle to late autumn. Or, perhaps grasshopper mice are more likely to succumb in winter if they are born in middle to late autumn because they are relatively large ro-

dents. Further, differences in reproductive patterns might be related to diet of the 2 species. Grasshopper mice are almost exclusively carnivorous during the spring and summer months (Flake, 1973; McCarty, 1978), whereas deer mice and other grassland murids are primarily granivorous or herbivorous throughout much of the year (Bee et al., 1981). More studies are needed of reproduction in natural populations of small mammals to answer these questions. Regardless, it seems likely that grasshopper mice born in middle to late autumn would have a low overwinter survival rate or females and males would not cease reproduction at a time when other murid rodents in north-central Kansas still are breeding.

Analyses were conducted as part of an undergraduate research project by the senior author. The Kansas Agricultural Experiment Station and the Division of Biology provided support for fieldwork. This is contribution 03-59-J, Kansas Agricultural Experiment Station, Kansas State University, Manhattan.

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Submitted 12 March 2001. Accepted 8 October 2002.
Associate Editor was Loren K. Ammerman.